Routing mechanisms for IP over OBS-WDM optical networks

Ioannis Karamitsos
Evagelos Varthis
Routing mechanisms for IP over OBS-WDM optical networks

Ioannis P. Karamitsos* and Evagelos Varthis*

*University of The Aegean, Department of Information and Communication Systems, Karlovasi, Samos, Greece
gkaram@aegean.gr

Abstract—In this paper, we combine Optical Burst Switching (OBS) for managing congestions and Multiprotocol Label Switching (MPLS) for handling routing and Quality of Service (QoS). The performance of two control plane mechanisms such as MPLS explicit routing and Interior Gateway Protocol (IGP) shortest path are examined and numerical results are presented on the throughput and the round trip time (RTT). Using MPLS explicit routing the throughput is 42 percent higher than that for the IGP protocol and the RTT demonstrates an improvement of 57 percent compared IGP shortest path. In addition, the average RTT time for IGP is six times higher with the explicit routing MPLS. Therefore, it is proven that improved QoS for IP over OBS-WDM networks is achieved using MPLS explicit routing.

I. INTRODUCTION

With recent technologies advances WDM optical networks are used to support the continuously growing IP traffic as they offer huge capacity. Currently switching is not performed at the optical layer but requires numerous O/E/O conversions. An alternative switching technique that can be used to support optical transparent networks is the Optical Burst Switching (OBS). OBS transfers transparently the data burst while the control packet is processed in the electronic domain. OBS will need no buffering of the data at intermediate nodes as opposed to Optical Packet Switching (OPS) and achieves efficient bandwidth use appropriate for bursty traffic as in OPS. OBS is seen as a transport technology for the next generation optical backbone [1]. In IP over OBS-WDM networks, the Internet traffic needs to support different types of services, to provide QoS and traffic engineering abilities and to assign the network resources to optimize the overall routing and performance of the networks. Commonly, the routing needs to be addressed using minimum resources introducing routing problems. One of the main reasons causing these problems is the use of traditional IP routing in the networks. To achieve this we use the MPLS technique that supports constrained-based routing. The main difference between conventional IP routing and constrained-based routing is the following. The conventional IP routing search to find a path that optimizes a certain scalar metric, while constrained-based routing optimizes a certain scalar metric and at the same time does not violate a set of constraints. In this paper, we examine two routing protocols the Interior Gateway Protocol (IGP) shortest path and MPLS explicit routing. The IGP routing protocol use destination-based forwarding algorithm without considering other network features, such as the available bandwidth, while the MPLS explicit routing supports constrained-based routing in the IP over OBS-WDM networks. The reason for using MPLS explicit routing is twofold. First of all, MPLS explicit routing allows decoupling of the information used for forwarding (a label) from the information carried in the control packet. Second, it is responsible for establishing the forwarding information along an explicit route.

This paper is organized as follows: In Section II a general description of IP over OBS-WDM networks is introduced. The forwarding part in section III is discussed. In Section IV, we describe the simulation setup. The performance results from the simulations are presented in the Section V.

II. IP OVER OBS WDM NETWORKS

Optical Burst Switching (OBS) [2] allows switching of data channels in the optical domain, where all the electronic processing is performed at the ingress/egress nodes. The main characteristic of the OBS is that it sets-up dynamically a wavelength path across the network. A separate control packet precedes each burst, which is offset in time with respect to the data packet, carrying forwarding information. The OBS network does not need a two-way reservation and end-to-end signaling like circuit switching and therefore the data is transferred through the network without waiting the set-up of the entire connection. IP over OBS WDM networks use two types of nodes: Edge nodes and Core nodes.

Figure 1. Edge and Core node components

Edge nodes are electronic devices, which comprise an assembly and a reservation mechanism. The reservation
The mechanism is responsible to separate the data information from the control packet. The control packet contains routing information, burst, and offset value. The edge nodes are connected to the core nodes, which provide the first management of IP packets and the routing. The routing can be partitioned into two basic parts control and forwarding. Core nodes comprise a switch fabric and a control plane with forwarding engine parts. The switch fabric performs burst switching, as an incoming data packet on a given wavelength is switched to a wavelength of an outgoing fiber. The control plane utilizes more routing protocols such as IGP, and MPLS explicit routing that provide exchange of routing to update the information and the forwarding table. However, the control part is responsible for construction and maintenance of the forwarding table. The forwarding component consists of a set of procedures that a core node uses to make a forwarding decision on a packet, and it is responsible for the forwarding of control packets from input to output across a switch.

The forwarding mechanisms available in an OBS network are Multiprotocol Lambda Switching (MPLS) [4] or Label Optical Burst Switching (LOBS) [5].

III. DESCRIPTION OF FORWARDING MECHANISM

In this section, the forwarding mechanism is presented using a variant MPLS [6] technique. The forwarding mechanism uses two sources of information. The first one is a forwarding table presented in the control plane, and the second is a shim label carried in the control packet itself. The forwarding algorithm used by the forwarding mechanism is based on label swapping and the algorithm works as follows. When a core node receives a control packet, it extracts the label from the control packet and uses it as an index in its forwarding table. The forwarding table consists of a sequence of entries such as incoming label, outgoing label, incoming interface, and outgoing interface. The core node uses as entry the forwarding table in contrast to the conventional destination based hop-by-hop. Each of the intermediate core nodes uses the label of incoming packet to decide its next node and replaces the incoming label in the control packet with the outgoing label and sends the control packet over the outgoing interface in the next node, as depicted in the Fig.2.

![Figure 2. Forwarding Mechanism](image)

IP over OBS-WDM networks use a small “shim” label [8] header, which follows the header of the IP packet and the format is the following. The shim label itself is 20 bits wide, with 3 extra bits for EXP field (also called CoS). The encapsulation specification also includes a 1-bit bottom of stack (S) field. The S bit is set to 1 to mark the bottom of stack entry before the original control packet, and set to 0 for all other entries. In addition, an 8-bit Time to Live (TTL) field is included in the shim header to relieve in detecting and discarding looping MPLS packets in Labeled Switched Paths (LSPs).

Each OBS core node contains routing information in its label information base (LIB) that stores the characteristics of the label. The core node that has the control packet can simply carry label as well as the offset and burst length information. When the control packet arrives in the first intermediate node, the following actions are performed:

- The label in the control packet can point to the information about the route of the connection thus specifying the incoming fiber or wavelength to outgoing fiber or wavelength, and any priority or QoS information about the connection.
- Then the control packet is led to the next intermediate core node by outgoing fiber or wavelength.

Another additional function of the forwarding components is the partition in subsets of all possible data bursts. From a forwarding point of view, the node treats bursts within each subset in the same way. We refer to such subset as Forwarding Equivalence Classes (FECs). The reason a node forward all bursts with a given FEC the same way is that the mapping between the information carried in the IP header of the packets and the entries in the forwarding table, where the entry describes a particular FEC.

IV. SIMULATION SETUP

We simulate performing TCP and UDP streams in an OBS-WDM network. The simulation program used was Ns-2 [9] running under the Linux. In the performance, use the network topology as shows in the following figure.

![Figure 3. Simulation Network](image)

Nodes 1 and 3 represent IP routers whereas node 2 is an OBS-WDM core node. Each core node supports thirteen OC-12 wavelengths (622Mbit/s by wavelength) by output interface and the transmission rate is 80 Gbs. We simulate twenty (20) such optical Label Switching Paths (LSPs) each carrying traffic supported on TCP and UDP. There are five TCP sessions in each of these optical
LSP’s. The basic idea is how the control packet information is best mapped into an explicit LSP to improve performance of IP over OBS-WDM networks.

V. SIMULATIONS RESULTS

In this section, the simulation results are presented. The scope of the tests is to verify how to optimize the routing of the control packets and minimize the effects of the network congestion with OBS-WDM network. Using explicit routing, each OBS core node does not choose the next node with separate LSP for the control packet, but instead uses only a single LSP. The role of the MPLS explicit routing is to minimize the effects of routing problems on the network performance using constrained-labeled routing technique. This section involves measurement of TCP data transfer between two IP nodes. We set up one explicit path (LSP) between Node1 and Node3. Fig.4 shows the measurements of TCP flow between the IP nodes as a variation of message sizes, for the cases of MPLS explicit path and IGP shortest path respectively. The bottom line shows the throughput when the traffic flow traverses the IGP shortest path and the top line when the same traffic flow traverses an MPLS explicit path. When the traffic traverses the two IP nodes with IGP shortest path, the result is that the throughput for the TCP traffic is low. However, using the MPLS explicit routing, we note a significant improvement 42% over the IGP shortest path.

![Figure 4. Throughput TCP streams](image)

We also measure the average round trip time (RTT) for both TCP and UDP streams. The performance metric is the total number of request/response packets pairs by second. That means the case gives the transactions exchanged by second, where one transaction is the exchange of a single request and a single response. Therefore, we can calculate the average round trip time incurred by each message. Fig. 5 and Fig. 6, shows the TCP and UDP average round trip times respectively.

![Figure 5. RTT for TCP messages](image)

It is proven that the round trip time dramatically increases for the congested IGP path. On the other hand the MPLS explicit LSPs offers significantly shorter RTT and improves the RTT by 57% for message size of 8192 Mbit/s.

![Figure 6. RTT for UDP messages](image)

From the figures, we notice significant performance improvements for routing that follows the non-congested explicit LSPs. However, without MPLS constrained-based routing all unlabeled control packets take the shortest path, while other links remain unutilized. In addition, if the traffic traverses the congested IGP route it incurs long delays, and degradation. This shows how MPLS study offers superior performance compared to IGP and supports improved resource utilization in the network. This simulation shows that routing has an important impact on network performance and can be solved using MPLS explicit routing as the control plane under the constrained-based technique.
VI. CONCLUSION

In this paper, we have described two routing protocols the MPLS explicit routing and the IGP shortest path for the control plane of OBS core node. For both MPLS explicit routing and IGP shortest path simulation results have been given on the throughput and round trip time as a function of the message size. We have shown the MPLS explicit routing achieve a good performance for TCP and UDP flows because of the use of constrained-based routing instead of the IGP which is based on traditional IP routing. In summary, the use of the MPLS constrained-based routing for the control plane in OBS core node can efficiently support the routing of the control packets in IP over OBS-WDM networks.

REFERENCES