Architecture and Design Issues of an Optical Burst Switched Network Testbed

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Abstract

In this paper, we report a testbed employing optical burst switching technology. The network model and node architecture are introduced. The key design issues, including burst format, burst assembly and channel scheduling, are discussed.

1. Introduction

In the future network, optical technology will play a stronger role not only for transmission but also for switching. Optical burst switching (OBS) emerged as a promising switching paradigm. It brings together the complementary strengths of optics and electronics.

In OBS networks, a data burst (DB) and its control signal (CS) are transmitted separately on different channels and switched respectively in optical and electronic domains. The setup CS reserves resource for the associated DB, it is followed by the DB after a short delay called “offset time.” This physical separation simplifies the electronic processing of the CS and provides end-to-end transparent optical path for the DB, facilitating greater use of optical switching technologies.

To implement the OBS networks, a lot of challenging issues must be solved. The related studies can be found, for instance, in [1]-[2]. In this paper, we report an OBS network testbed comprising self-developed OBS nodes. The node architecture, burst format, burst assembly and channel scheduling are discussed in details.

2. Network Model and Node Architecture

2.1 Network Model

The OBS network testbed is composed of one core node (CN) and three edge nodes (ENs). It is a mesh network working in overlay mode. The legacy client networks are connected to OBS network through ENs. A CN contains an electronic control unit (ECU) and an optical switching unit (OSU) without wavelength conversion and optical buffer. It forwards transit bursts in optical domain with contention resolution [3]. An EN consists of a burst transceiver unit (BTU) and an OSU. It performs client signal-burst conversion, as well as burst forwarding. The electronic data processing and buffering are performed by the EN while the CN concentrates on all-optical switching. This brings a better synergy of mature electronic technologies and state-of-the-art optical technologies.

At the ingress EN, packets are assembled into bursts. Then the bursts are routed through the OBS network and disassembled back into packets at the egress EN to be forwarded to client networks. This network employs optical bursts with variable length and runs in an asynchronous mode. One link (or fiber) carries five WDM channels (or wavelengths), four dedicated data channels and one shared control channel.

2.2. Core Node Architecture

The main function of the CN is to realize burst switching. As shown in Fig. 1, it supports 4 links. The ECU consists of two parts: control signal processing part (CSPP) and system management part (SMP). The CSPP performs route searching with contention resolution, CS updating and forwarding, resource reserving and channel scheduling; while the SMP conducts supervision and control of optical devices.

The OSU consists of splitters, MUX/DEMUXs, optical switch matrix, power equalizers and optical amplifiers (AMP). More specifically, the splitter separates the control channel from the data channels; the MUX/DEMUX is used to multiplex and de-multiplex four data channels; the optical switch matrix consists of four non-blocking thermo-optic switches with the switching speed of less than 3ms; the power equalizer and AMP are used to equalize and amplify the power of data channels respectively. A burst cuts through the CN, so its format and bit rate can be arbitrary.

2.3 Edge Node Architecture

In addition to having the same functions as the CN, the EN is mainly used to connect to legacy client networks, which is realized by a BTU with Gigabit Ethernet (GE) interfaces, as shown in Fig. 2. An EN supports two remote links connected to other OBS nodes and one local link (or four local channels) connected to client networks through BTU. Both the bursts from other OBS nodes (remote bursts) and those generated within the BTU (local bursts) are routed and scheduled by the BTU.

The BTU mainly consists of a transmitter and a receiver. Its main functions include generating, receiving, forwarding and scheduling of DB and CS. At ingress EN, the BTU transmitter assembles multiple GE frames into bursts according to their egress EN addresses and QoS requirements, and generates the associated CS simultaneously. At egress EN, the BTU receiver disassembles the received bursts back into GE frames.
3. Key Issues in Design of BTU

3.1 Burst and CS Format

To simplify the implementation, the burst is designed to be a simple aggregation of multiple GE frames with the same egress EN address and QoS requirement. The GE preamble is also included so as to delineate the burst, as shown in Fig.3. In addition, an inter-burst gap is inserted between consecutive bursts to allow rate adaptation, which helps to overcome the delay variation in different channels, the uncertainty of burst arrival, and the offset time variation due to clock drifts between nodes.

The CS is used to reserve network resources for the associated bursts. It includes the following fields: CS type, wavelength ID, egress EN address, ingress EN address, offset time, burst length, QoS and option for various applications. In our testbed, the Fast Ethernet frame and a special control channel are adopted to deliver the CS.

3.2 BTU Architecture

The BTU transmitter generates the optical bursts with variable length running in the asynchronous mode, which matches the natural form of packets and simplifies implementation by avoiding synchronization and burst alignment. It works as follows:

1. The GE frames buffered in the 1st level FIFOs are switched to the 2nd level FIFOs according to their egress EN addresses and QoS requirements. The egress EN address is determined based on the destination address of the GE frame.
2. Multiple frames buffered in the same 2nd FIFO are assembled into one burst according to a time-size-based assembly mechanism, which means a burst is created when either the assembly time or the length of burst reaches its threshold.
3. After the data channel being assigned by the wavelength assignment algorithm, e.g. PWA [3], and the transmission time being decided by the scheduler, the bursts are buffered in the 3rd level FIFOs and transmitted at the scheduled time.

For bursts with variable length working in the asynchronous mode, the channel scheduling is indispensable. Suppose an EN has \( M \) output links and every link carries \( N \) channels, the output channel is denoted as \( CH(m, n) \) and its scheduling table is denoted as \( CST(m, n) \), where \( 1 \leq m \leq M \) and \( 1 \leq n \leq N \). As shown in Fig. 5, the \( CST(m, n) \) contains scheduling information of \( CH(m, n) \) in a period of time \( T_s \). The scheduler maintains \( CST(m, n) \) and keeps track of the unscheduled time of each \( CH(m, n) \). Let \( K, L, D, T \) and \( T_t \) denote the output link, output channel, duration time, arrival time and offset time of the burst, respectively.

As indicated before, both the remote bursts and the local bursts are scheduled by the BTU. We discuss these two cases respectively.

For a local burst, the scheduling steps are as follows:

1. If the burst is created at time \( T_a \), its \( K, L, D, T \) and \( T_t \) are then obtained. The earliest possible arrival time to the local optical switch is \( T_a + T_t \).
2. The scheduler looks up \( CST(K, L) \) \((1 \leq n \leq N)\) and finds all the available outgoing channels within the time period of \( T_a + T_t \). If there is at least one such channel, as shown in Fig.5, it goes to step 4; otherwise it goes to step 3.
3. The scheduler looks for the outgoing channels in a further future. The \( T \) is increased by a step of \( T_d \). If the \( T_a + T_d \) lies in the \( T_s \), it goes to step 2; otherwise the scheduling fails and the burst is dropped.
4. The output channel \( L \) is assigned by the wavelength assignment algorithm. The burst and its CS will be buffered and transmitted at time \( T_a + T_t \) respectively.

For a remote burst, when the associated CS arrives, the \( K, L, D, T \) and \( T_t \) can be obtained by interpreting the CS. The scheduler looks up \( CST(K, L) \) and finds whether the time period of \( T_a + T_t \) is available. If it fails, the burst will be deflected [3] or dropped.

As discussed above, this scheduling algorithm acts on both bursts and CS. In our testbed, \( M=3 \) and \( N=4 \).

4. Summary

In conclusion, we construct a software-based ECU, a general-purpose OSU and a programmable BTU in the OBS nodes. Various protocols can be adopted and the related parameters can be flexibly modified or reconfigured.

Up to now, we have implemented one CN and three ENs. Currently, the contention resolution algorithms and system management software are being developed. Evaluation of the network performance, e.g. dropping probability, throughput, delay and jitter, will be addressed in future works.

References