

# Analisis of the Methods of Preventing of Contention Resolution in Optical Packet Switching Networks

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**Abstract**— Optical networks evolve fast. Nowadays many technologies of optical networks are using. But there are some restrictions which make limited of the possibilities of the optical networks. Contention Resolution is one of them. There are several technologies of reducing of Contention Resolution. They will be analyzed in this paper. The advantages and disadvantages of these technologies will be described and discussed at the end of the paper.

**Keywords**— Optical packet switching networks, contention resolution, optical buffering, fiber delay lines, wavelength conversion, deflection routing.

## I. INTRODUCTION

Packet switching has some advantages in compared with circuit switching the main which is an efficient usage of existing links. Data is transported from one node to another in the form of packets in optical packet switching (OPS) networks. These packets contain two distinct portions – header and payload (information). Header is processed electronically, while data (payload) remains in the optical form at the intermediate nodes. Transmitting data is packetized and these packets consist of a header and payload (information). These processes are carried out with opto-electronic conversion or without one in the nodes. SDH/SONET networks are example for the first case and DWDM for the second [1], [2], [3].

Optical packet-switched networks are divided to slotted (synchronous) and unslotted (asynchronous) categories. All packets have the same size in slotted networks. They are placed together with the header inside a fixed time slot, which has a longer duration than the packet and header to provide guard time. The packets may have the same size or not in unslotted networks. Packets arrive and enter the switch without being aligned. Therefore, the packet-by-packet switch action can take place at any point in time. Obviously, the chance of contention is larger in unslotted networks because the behavior of the packets is more unpredictable and less regulated. On the other hand, unslotted networks are easier and cheaper to build, more robust, and more flexible than slotted networks [4].

The main device for the optical packet switching is optical packet switch. Optical packet switches are one of the potential candidates to improve switching capacity to be comparable with optical transmission capacity. They analyze the header information of packets and determine the destination point. Central element of switch is a switching fabric. And they can be classified into the following classes depend on the types of the optical packet switch architectures: a space switch, broadcast-and-select, and wavelength routing, based on the used switching fabrics.

The basic structure of the optical packet switch contains an input interface, a switching fabric, an output interface, and a control unit. The input interface receives packets, aligned them, extract header information and remove it. The switch fabric performs optical switching. The output interface regenerates optical signals and put header back to the packet. The control unit controls whole process. Optical packet switches are typically designed for fixed-size packets [5].

There are two main difficulties in OPS [1]:

- 1) A bit-level processing is impossible in the optical domain to date;
- 2) There is not an efficient way to store information in the optical domain indefinitely.

The first problem consists in the following: it is necessary to extract the headers in the process of the handling of the packets and then to rewritten the headers again in the switches. In this process it is possible the damages of erasure and insertion of the headers. There are several solutions for this problem. These are following: usage of the subcarrier multiplexing, transmitting of the headers and payloads on the different wavelengths.

The second problem concerns to the term called as a *Contention Resolution*. Contentions occur in the network switches when two or more packets have to exploit the same resource, for example, when two packets must be forwarded to the same output channel at the same time. There are several ways for the solution these problems

which are following: Optical Buffering, Deflection Routing, and Wavelength Conversion [6].

Several technologies of reducing of Contention Resolution are analysed in this paper. The basic properties, key elements and the system architecture are presented in introduction section I. Optical Buffering is described in the section II. Section III is devoted to Deflection Routing. Wavelength Conversion technologies are considered in section IV. Section V is devoted to comparison of three technologies. Section V concludes the paper.

## II. OPTICAL BUFFERING

*Buffering* is the technique of resolving contention by storing packets when more than one wishes to go to the same output at once, due to the unscheduled nature of their arrival. To preserve an all-optical data path, it would be desirable to implement the buffer memory in the OPS optically. However, optical memory is in a relatively primitive state; there is no such thing as optical random access memory (RAM), and for memory it is necessary to use the fiber delay lines (FDL) which are fixed-length fibers [7]. An FDL can delay a packet for a specified amount of time, which is related to the length of the delay line and the speed of light. A buffer for  $D$  packets with a FIFO discipline can be implemented using  $D$  fiber delay lines whose lengths are equivalent to multiple of slots. A slot,  $T$ , is the time required for a packet to be transmitted and propagated from an input port to an output port [8]. Optical buffering technique consists of two classes: traveling and recirculating type. First buffer type consists of several FDLs whose length is equal to the integral multiples of a packet duration  $T$ . Packet's storage time is determined by the delay line through which the packet propagates. Second type buffer is constructed on a basis of a single FDL forming a loop with a circulation time equal to the one packet duration. Packet's storage time is determined by the number of times the packet circulates in the delay line in such buffer type. It is possible to store of the multiple packets in both buffer types and one packet enters and leaves the buffer at any moment. The recirculating buffer is more flexible than the traveling one. But a signal should be amplified after some circulation due to its power losses. And the storage time of the traveling buffer depends on the length of FDL. Four most common configurations of optical buffering exist: output buffering, shared buffering, recirculation buffering, and input buffering [9]. All these configurations were analyzed in [10], [11], [12], [13], [14], [15] and [16]. The structural scheme of the single-stage shared-FDL optical switch was showed in Fig.1.

## III. DEFLECTION ROUTING

*Deflection Routing* uses the space domain for the solution of the problem of the contentions. The essence of a deflection routing is: when a contention resolution occurs between two or more packets, one will be routed

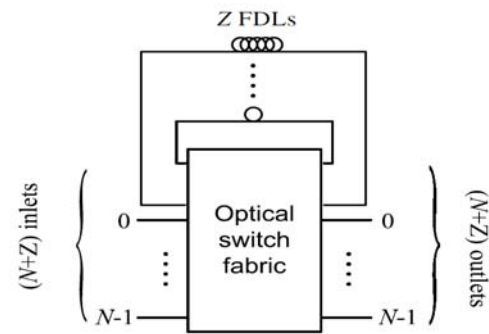


Fig.1. A single-stage shared-FDL optical switch

to the correct output port, the others to any free output port. Routing decisions for deflection of packets are based on destination address and packet priorities. In this case the network has to be multi-path or re-circulatory due to the deflected packets can be routed to the destination on an alternate path [17]. The priority of deflected packet is increased for reducing the end-to-end latency and avoiding deflecting a packet indefinitely. The number of input links should be equal to the number of output links in a switching node. Performance of this technique decreases monotonically as the number of nodes increases [18]. This impairment is compensated by increasing the link speed or by reducing the deflection's probability.

## IV. WAVELENGTH CONVERSION

*Wavelength Conversion* is very important technology not only for avoiding a contention resolution. It has some properties that will have been considered just below. There are several wavelength conversion techniques which are applied in the optical converters such as nonlinear polarization rotation (NPR), cross-gain modulation (XGM), cross-phase modulation (XPM), four-wave mixing (FWM) and so on [19].

Wavelength converters (WC) transform one wavelength ( $\lambda_i$ ) to another one ( $\lambda_j$ ). A tunable wavelength converter (TWC), which can be a compact tunable transceiver - e.g., a type of commercially available tunable multirate XFP transceiver, may be applied for optical input signal [20]. TWC is used at the input and Fixed wavelength converters (FWC) at the output of the switching fabric.

Next types of wavelength converters exist:

- 1) Opto-electronic converters;
- 2) Laser converters;
- 3) Coherent converters (FWM and difference frequency generation);
- 4) Converters based on optically controlled optical gates.

One of switches has dedicated wavelength converter at each output port (Fig.2). This type of switches has individual wavelength converter for each output ports.

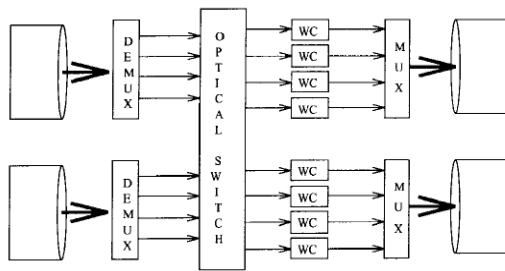


Fig.2. Switch with dedicated wavelength converter at each output port

Dedicated wavelength-convertible switch, however, is not very cost efficient since all of the wavelength converters may not be required all the time. Therefore the other types of switches with shared converters were developed. They are divided to: a) Share-per-node wavelength-convertible switches, where OSW is Optical Switch (Fig.3); b) Share-per-link wavelength- convertible switches (Fig.4) [21].

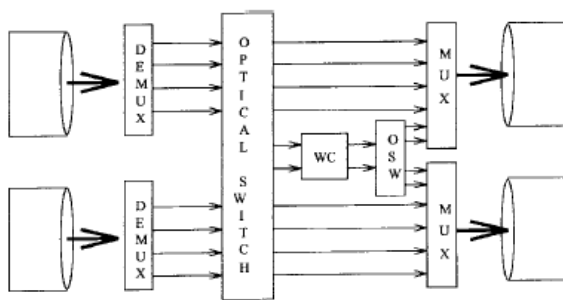


Fig.3. Share-per-node wavelength-convertible switches

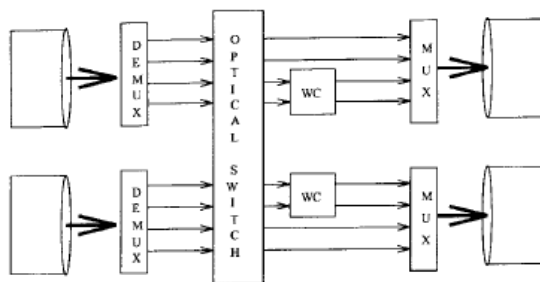


Fig.4. Share-per-link wavelength- convertible switches

## V. COMPARISON OF THE TREE TECHNOLOGIES

All three described technologies of preventing of contention resolution have advantages and disadvantages.

Advantages of Optical Buffering: conceptually simple; mature technology; has larger network throughput.

Disadvantages of Optical Buffering: requires more hardware and control; more voids; bulky FDLs; extra delay.

Advantages of Deflection Routing: good for implementation; no extra hardware requirement.

Disadvantages of Deflection Routing: does not provide good network performance; possible instability; out of order arrivals.

Advantages of Wavelength Conversion: small amount of optical buffers; lower packet loss probability.

Disadvantages of Wavelength Conversion: noise suppression; immature and expensive technology; signal reshaping.

Sharing of these technologies allows to overcome or minimize some disadvantages, that each technology has separately.

## VI. CONCLUSIONS

Optical packet switches are one of the potential candidates to improve the switching capacity of all-optical networks. It will contribute to the use of potential enormous optical transmission capacity of these networks. The effort of all scientists of the world is directed on improving the characteristics of existing optical packet switching technologies. Despite many research have been carried out, still there are many problems which require some solutions. For instant, the effective wavelength conversion has not researched enough. In the paper several possible technologies of reducing of contention resolution for optical packet switches were analyzed.

There are three most famous methods of preventing of Contention Resolution – Optical Buffering, Deflection Routing and Wavelength Conversion.

Optical Buffering technique is used for very short delays of optical packets. It is possible to use single-stage Optical Buffering, which is easier for controlling, but using of multiple stage of Optical Buffering allows economize of hardware's amount. It is derived due to limited amount of delay-lines, used to inside of switching nodes. This technique requires some compensation devices or methods for decreasing of packet delays in switching nodes.

Deflection Routing technique is ideally suited for the switches with little buffer space. It suffers the penalty of increased delay in the wide-area networks, where it may be highly significant for delay-sensitive traffic such as that serving real-time broadband application.

Wavelength Conversion technique is more applicable in the optical networks for enhancing routing options and network properties, such as reconfigurability, wavelength reuse and nonblocking capability are required besides of contention resolution.

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## BIOGRAPHIES



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