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All Optical Burst Switching by Strict Sense Nonblocking Switch using AOTF

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Abstract

In this paper we review the concept of all optical burst switched network and proposed the unique design of a strict sense non blocking switch using a Acosto-Optic Tunable Filter. This design will avoid the requirement of memory or delay lines at the switching unit.
Keywords: Optical burst switching, Optical Cross Connect, Acosto optic tunable filter.

1. Introduction

With the increase of demand of high data rates we have moved towards several generation of wireless communication but the back bone of every wired or wireless network relies on the high speed long distance trunk lines. Initially a bunch of wires were used as a truck lines, But now a day's optical fiber cables are being used as backbone of every network.

Optical Communication fulfils all the requirements to be a backbone of a network because of having large bandwidth, low loss, low power consumption, high data rate and capability to carry the signal up to a very large distance without using repeaters/Amplifiers. In spite of all the above capability of optical communication we are not able to get more then 40 Gb/s speed due to bottleneck of electronic equipments used at end nodes.

As we know that the efficiency of a network can be increase by switching from circuit switching to packet switching because in most cases connection establishment time is more than payload time period. So packet switching is preferred for a variety of applications now a day. There are several approaches have been given [1]-[3] for optical packet switching, Still there is a viability problem with the all optical packet switching because of limited buffering, optical header processing units, optical error detection and correction units and many more. So we have shifted our attention towards optical burst switching. Optical burst switching is a kind of connection less service in which different kind of client data are aggregated at the ingress node and transmitted as a data burst while the header is transmitted separately in the network. Different Protocols have been proposed in this regard as per the availability of existing infrastructure.

In this paper we have proposed a switch using acosto-optic tunable filter (AOTF) which works as an optical cross connect and as a basic element of the switch. This switch can filter out/Switch a particular wavelength to desired output port as per the Header information and a connection can be maintained between input and output port. A clos architecture of strict sense nonblocking switch having three stages is also demonstrated with MXN AOTF switch

2. Optical Burst Switching

In a conventional IP packet transmission whole packet is received, Stored, Processed and forwarded as per the header information. Since all these processes are done electronically so the maximum speed of IP packet transmission is limited up to the maximum speed of electronic circuits even if we are using optical fiber cables for transmitting the signals. So we started thinking about all optical packet switching (OPS) [4] but due to unavailability of buffering units this technique is not viable. Many researches in OPS have been published by using Fiber Delay lines (FDLs), which can introduce the delay to optical packet so that header can be processed in this duration. However about 500Km of optical fiber is required to introduce a delay of about 2.5 ms. So we can say that use of FDL is not a practical Solution. To overcome the disadvantage of conventional IP packet switching and all optical packet switching a new and very promising technique has been proposed [1-3] called as optical burst switching. Optical Burst switching is a technique of sending an optical burst through a switch which does not need E/O/E conversion. A burst is formed by combining a variety of data in a single packet. Size of this burst may be much larger than an IP packet length. Sometimes a burst may be 4000 times larger than an IP packet so the delay introduced in transmitting a burst is quite greater than the conventional IP packet. AS per the traffic and burst size different burst switching protocols have been proposed as follows. In optical burst switching the control signaling is carried out by burst header cell or control packet. The data burst and control packets are transmitted separately in the network as shown in figure.

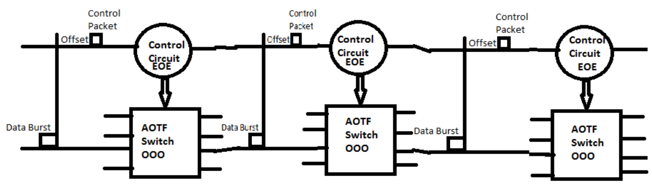

Figure 1: Transmission Mechanism Of Optical Burst Switching

2.1 Tell and wait (TAW) Protocol

When an engress node wants to transfer a burst it sends a control packet to the control circuit while the burst is stored electronically (RAM). Control packet carries the information of switching, burst length and other signaling information. This optical control packet is converted in to electronic domain and controlling information is extracted at switching node. On receiving the control packet if the switching node is a virtual path is established between engress node and switching node along with a confirmation message to engress node given by control packet. On receiving the confirmation message engress start sending the burst from electronic memory. If the switching node is not free control packet will send a message to engress node to wait either a random amount of time or as per the sequence list prepared on the basis of priority.

2.2 Tell and Go (TAG) Protocol

In this protocol engress node sends a burst and control packet without any virtual path created. The data burst and control packet is send with difference of an offset time which is equal to the sum of time required to extract the information from control packet(T1) and the time required to setup the virtual path in between engress node and Switch (T2). To create this offset time optical delay lines (FDL) are used. If the switch node is free a success message is given to the engress node and if switch node is busy the data burst will be discarded and a failure message will be given to engress node. On receiving the success message memory erase the data bust and if a failure message is received engress node sends the data burst again.

For Shorter distance where propagation delay is very low Tell and Wait (TAW) protocol gives higher throughput while for longer distance and higher propagation delay Tell and Go (TAG) is better.

2.3 Just In Time (JIT)

This protocol can be considered as an extension of Tell and wait (TAW) Protocol. It requires a central scheduler which can inform all the switching nodes about exact time of transmission of data burst. So that as a data burst arrives a switch it is already configured as per the control packet header information. If all the switching nodes of the rout are configured in advance a reliable data burst transmission can achieved. It has a problem that a centralized protocol is not scalable. So a to avoid this a reservation just in time protocol has been proposed [4, 5].

2.4 Just Enough Time (JET)

Just Enough Time (JET) Protocol is analogous to Tell and wait (TAW) Protocol with the difference is that it does not require any buffering instead an offset time is kept in between the data burst and control packet. Each control packet carries the information of actual arrival time of data burst. In this offset time switching node is configured as per the information received by the control packet.

3. Acosto-Optic Tunable Filter

The acousto-optic tunable filter is a versatile device. It is probably the only known tunable filter that is capable of selecting several wavelengths simultaneously. This capability can be used to construct a wavelength crossconnect. The acousto-optic tunable filter (AOTF) is one example of several optical devices whose construction is based on the interaction of sound and light. Basically, an acoustic wave is used to create a Bragg grating in a waveguide, which is then used to perform the wavelength selection[6].

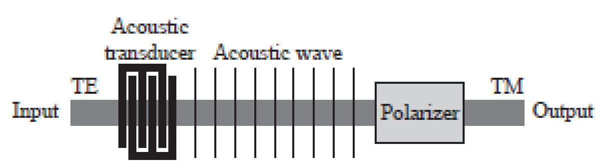

Figure 2: A simple AOTF

Figure 2 shows a simple version of the AOTF. We will see that the operation of this AOTF is dependent on the state of polarization of the input signal.

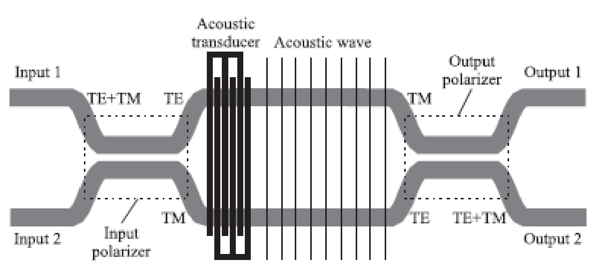

Figure 3: A Polarization Independent AOTF

Figure 3 shows a more realistic polarization-independent implementation in integrated optics

3.1 Principle of Operation

Consider the device shown in Figure 2. It consists of awaveguide constructed from a birefringent material and supporting only the lowest-order TE and TM modes. We assume that the input light energy is entirely in the TE mode. A polarizer, which selects only the light energy in the TM mode, is placed at the other end of the channel waveguide. If, somehow, the light energy in a narrow spectral range around the wavelength to be selected is converted to the TM mode, while the rest of the light energy remains in the TE mode, we have a wavelength-selective filter. This conversion is effected in an AOTF by launching an acoustic wave along, or opposite to, the direction of propagation of the light wave. As a result of the propagation of the acoustic wave, the density of the medium varies in a periodic manner. The period of this density variation is equal to the wavelength of the acoustic wave. This periodic density variation acts as a Bragg grating. From the discussion of such gratings in Section 3.3.3, it follows that if the refractive indices n_{TE} and n_{TM} of the TE and TM modes satisfy the Bragg condition

$$\frac{n_{TM}}{\lambda} = \frac{n_{TE}}{\lambda} \pm \frac{1}{\Lambda} \quad (1)$$

then light couples from one mode to the other. Thus light energy in a narrow spectral range around the wavelength λ that satisfies (1) undergoes TE to TM mode conversion. Thus the device acts as a narrow bandwidth filter when only light energy in the TE mode is input and only the light energy in the TM mode is selected at the output, as shown in Figure 2. Here ʌ is period of grating. In LiNbO3, the TE and TM modes have refractive indices n_{TE} and n_{TM} that differ by about 0.07. If we denote this refractive index difference by (Δn), the Bragg condition (1) can be written as

$$\lambda = \Lambda(\Delta n) \quad (2)$$

The wavelength that undergoes mode conversion and thus lies in the passband of the AOTF can be selected, or tuned, by suitably choosing the acoustic wavelength. In order to select a wavelength of 1.55 µm, for (Δn) = 0.07, using (2), the acoustic wavelength is about 22 µm. Since the velocity of sound in LiNbO3 is about 3.75 km/s, the corresponding RF frequency is about 170 MHz. Since the RF Frequency is easily tuned; the wavelength selected by the filter can also be easily Tuned. The typical insertion loss is about 4 dB.

The AOTF considered here is a polarization-dependent device since the input Light energy is assumed to be entirely in the TE mode. A polarization-independent AOTF, shown in Figure 3, can be realized in exactly the same manner as a Polarization-independent isolator by decomposing the input light signal into its TE and TM constituents and sending each constituent separately through the AOTF and recombining them at the output.

3.2Transfer Function

Whereas the Bragg condition determines the wavelength that is selected, the width of the filter passband is determined by the length of the acousto-optic interaction. The longer this interaction, and hence the device, the narrower the passband. It can be shown that the wavelength dependence of the fraction of the power transmitted by the AOTF is given by

$$T(\lambda) = \frac{\sin^2\left((\pi/2)\sqrt{1 + (2\Delta\lambda/\Delta)^2}\right)}{1 + (2\Delta\lambda/\Delta)^2}.$$

This is plotted in Figure 4.

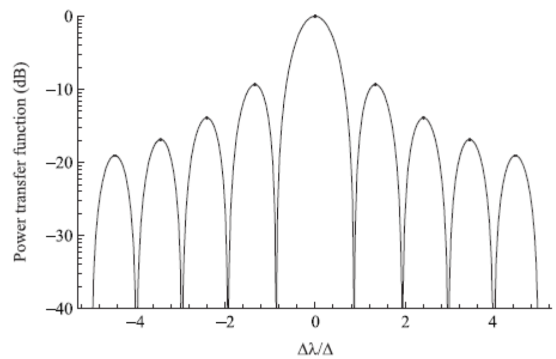

Figure 4: Power transfer function of acosto optic tunable filter

Here Δλ = λ −λ0, where λ0 is the optical wavelength that satisfies the Bragg condition, and $\Delta = \lambda_0^2$ /ln is a measure of the filter passband width. Here, l is the length of the device (or, more correctly, the length of the acousto-optic interaction). This equation clearly shows that the longer the device, the narrower the passband. However, there is a trade-off here: the tuning speed is inversely proportional to l. This is because the tuning speed is essentially determined by the time it takes for a sound wave to travel the length of the filter.

By launching multiple acoustic waves simultaneously, the Bragg condition (2) can be satisfied for multiple optical wavelengths simultaneously. Thus multiple wavelength exchanges can be accomplished simultaneously between two ports with a single device of the form shown in Figure 3.

4. Proposed AOTF switch

We have proposed a switched using acosto optic tunable filter as shown in figure 5, It works as an optical cross connect and switches a particular wavelength of input to desired output just by selecting the corresponding RF signal.

We have proposed here a strict sense non blocking switch with individual unit is constructed using Acosto-Optic Tunable Filter as Shown in figure 5. Here first and third stage has two 2X8 switches and middle one is an AOTF switch with 2X2. Since there is a condition for strict sense non blocking switch is that the middle stage should have at least [2(no. of first stage switch)-1]. This switch is satisfying this condition so we can call it as a strict sense non blocking switch.

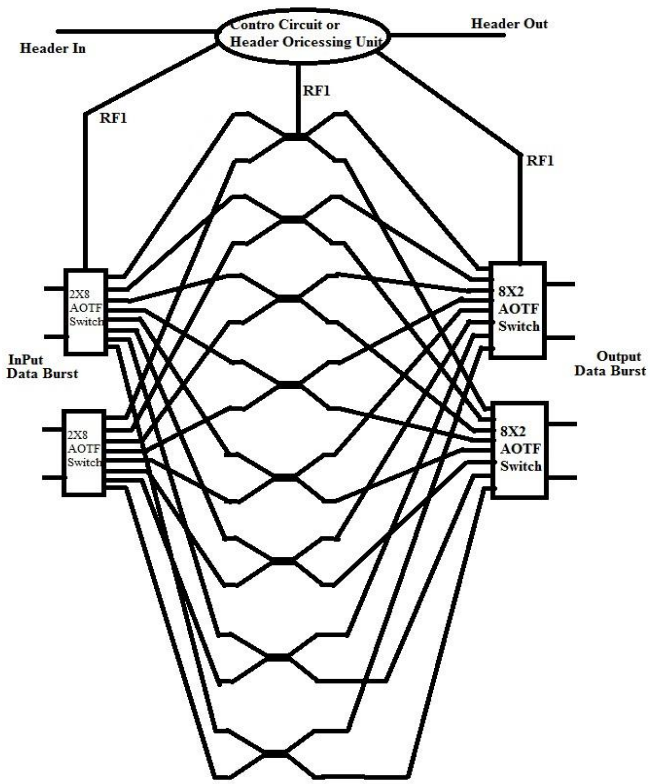

Figure5: Strict Sense non blocking switch for OBS networks

A block of 2X8 switch has been given at input and output stage having internal structure as shown in figure 6

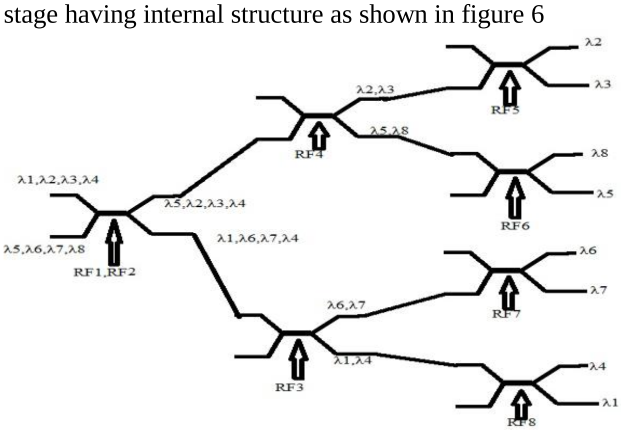

Figure 6: A 2X8 optical switch having different input wavelength and different output for every wavelength

As we know that in an optical burst switched network control packet/ Header and data burst are transmitted separately and with an offset time in between the control packet and data burst. This switch is very much suitable for JIT protocol. In Which an Optical control packet is received by Header processing Unit/Control Circuit and then it is converted in to electronic domain, this control unit extracts the information like source address, destination address, burst length etc and decides the preferred output port for incoming burst as per the routing algorithm used. Once the output port is decided by control unit an RF signal is generated and provided the to the LiNbO3 optical fiber, which creates a grating of period equal to the wavelength of RF signal. These gratings created within the fiber filter out/cross connect the particular wavelength at different output ports.

The wavelength to be filtered out is given by

$$\lambda = \Lambda(\Delta n)$$

Since the incoming optical burst would be on a anyone wavelength out of four incoming ports, the single RF signal will configure all three stages of strict sense non blocking switch and hence there will be zero probability of blocking the incoming data burst.

5. Conclusion:

This switch can solve all the problems of optical burst switched networks.

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