# Optical switching using IP protocol

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## ABSTRACT

To understand and evaluate the Optical Layer, and how it will affect the IP protocols over WDM (Switching), the present analyse is proposed. Optical communications have attractive proprieties, but also have some disadvantages, so the challenge is to combine the best of both branches. In this paper, general concepts for different options of switching are reviewed as: optical burst switching (OBS) and automatically switching optical network (ASON). Specific details such as their architectures are also discussed. In addition, the relevant characteristics of each variation for switching are reviewed.

**Keywords:** optical switch, optical circuit switching, optical packet switching, optical burst switching

## 1. INTRODUCTION

The principal building blocks of communications networks are communication terminals, transmission links, and switching centers. This entire paper is about switching. Indeed, it is about a group of switching technologies and systems that have the potential to change the future of networking. Switching is a cornerstone of communication systems and networks and has evolved, since the inception of telegraphy and telephony in the nineteenth century until today, from one form to another while encompassing numerous enabling technologies and embracing several communication methods. In this paper switching technologies will be relieved and compared, to have a better understanding about switching at optical layer.

The optical switching technologies use the basic concepts of circuit switching and packet switching. Optical switches process all the information at an optical level and this enables to optimize the response times for delivery of information. Therefore, optical switching will provide higher transmission speeds but at a higher cost because better technical features for the equipment are required.

## 2. OPTICAL SWITCHING

Today, the terms optical networks and optical switching are used to denote systems and networks that are not optical in the full meaning of the word. For example, SDH/SONET systems are widely regarded in the telecommunications industry as the optical transport networks of today, although there is nothing optical in them beyond single-wavelength point-topoint transmission links. All other functional ingredients of SDH/SONET based networks, including multiplexing, cross-connection, add/drop and control, are performed by electronics. Also, some equipment vendors developed cross-connects based on electronic switching matrices with optical interfaces (OEO systems) and labeled this equipment as optical cross-connects and/or optical switching systems. By comparison, switching systems which would be based on optical switching fabrics are referred to as OOO systems. While OOO systems are called transparent, and sometimes all-optical, their OEO counterparts are often called opaque.

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An optical switch enables switching of a spatial optical signal without electronic conversion. A common application includes protection devices and optical cross-connect. The main technologies for constructing these types of switches are: optical couplers, Mach-Zander interferometer, MEMS, Bubble, etc. Although these technologies have been developed for a long time, they are still dependent of an electronic control, this control couldn´t also be optical by the time[1]. Properties of all-optical bistable fibre switch using two fibre Bragg gratings and rare earth elements doped optical fiber are also proposed[2, 3]. In the electro-optic EO effect, an electric field causes electron or crystal-lattice displacements, which result in refractive index change. Very fast response is expected in devices based on this effect. LiNb03 is a unique EO crystal in that large wafer substrates can be grown and can exhibit small dielectric constant, fast device responses, and low power consumption. The dependence of the refractive index n on the electric field E is expressed by:

$$1/n2 = l/n0\ 2 + rE + hE2 + \ldots\ldots \quad (1)$$

where n0 is the refractive index without electric field, r is the electro-optic coefficient, and h is a higher order electro-optic coefficient.

## 3. OPTICAL CIRCUIT SWITCHING

Like switching in the electrical domain, there are two main methods of optical switching, namely, Optical Circuit Switching (OCS) and Optical Packet Switching (OPS)[1,4].

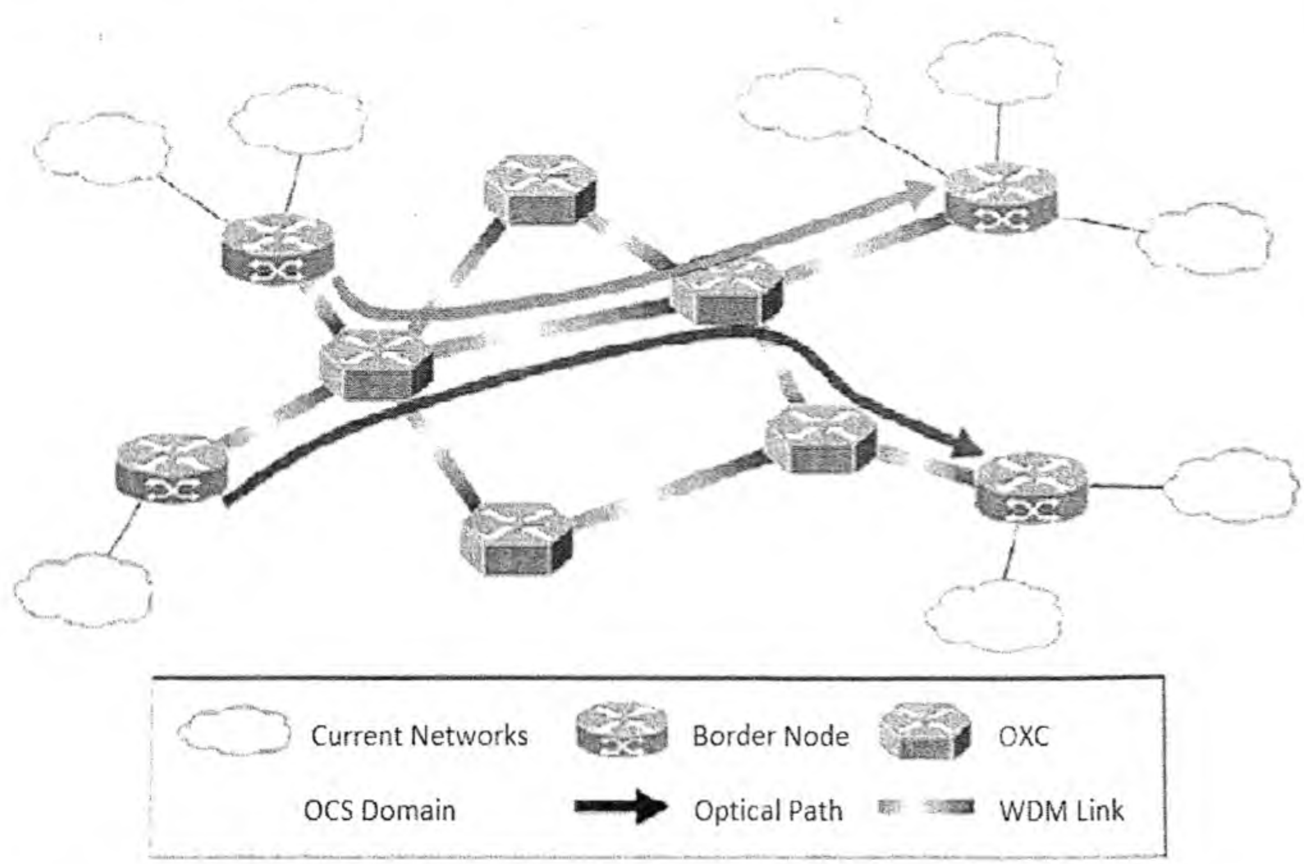


Figure 1. Optical Circuit Switching. It establishes optical paths between two nodes not necessarily adjacent, as a basic communication mechanism, which can carry multiple links.

This technique is based on wavelength routing (WR). Wavelength routers are interconnected by WDM links, thus optical paths established between two nodes are established, which may have multiple links. Network nodes or optical cross-connectors (OXCs) link the ports entry and exit ports based on a wavelength. When a node wishes to establish an optical path for a certain traffic flow, it sends a signaling request along the route; if the request is successful each OXC reserves configuration resources for the path.

This switching is efficient for large volumes of traffic. Also statistical multiplexing is not performed and therefore has small bandwidth flexibility. It has a limited number of wavelengths per fiber and has low adaptability because of their static nature[5-8].

## 4. OPTICAL PACKET SWITCHING

Optical packet switch optimizes the bandwidth available, has a variety of functions in terms of routing and flexibility. It is ideal for New Generation Metropolitan Networks and provides connectivity with high performance and simplicity to end-to-end users.

Is based on WDM since this technology has allowed greatly increase of transmission speeds through fiber optics, becoming the best alternative for the implementation of all-optical networks.

OPS networks employ detailed commutations, and require much faster optical switches (switching times in the order of nanoseconds)[9]. Each border node collects the incoming data and places them in optical packages, depending on the format adopted by the network. Both information and control data travel in the same channel; each intermediate node extracts the control headers to find the correct path within the OPS network.

When a packet enters the domain OPS, it is transparently switched by the nodes with statistical multiplexing techniques. When the packet reaches the correct border node, volume data is returned to the original format and delivered to the belonging network[7, 10, 11].

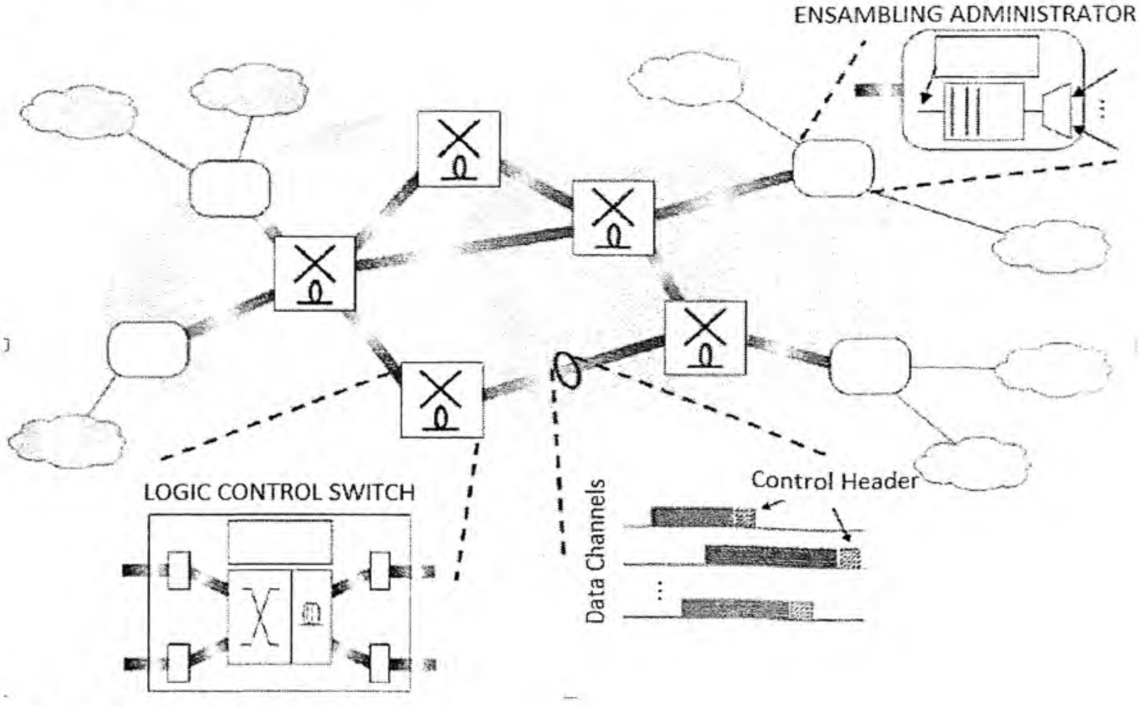


Figure 2. OPS network with mesh topology.

OPS can be either synchronous or asynchronous[12]:

- In synchronous OPS the time domain is divided into slots during where packets are sent and received, and the duration of a packet is no longer than the time slot. The duration of a time slot depends on the technology used in the equipment. The existing optical gates can be switched on and off in about two nanoseconds, which corresponds to the guard time between packets.

- In asynchronous OPS the time domain is slotted, and so packets can arrive at any time. This technology received less attention than the synchronous technology, even though it is easier to build, because no synchronization is needed. It has probably been so, because the asynchronous OPS suffer of larger contention probabilities in comparison with the synchronous technology. The other reason might be the low network utilization needed, so that the network delivers packets with low probability of packet loss.

## 5. OPTICAL BURST SWITCHING (OBS)

Optical Burst Switching (OBS) was introduced as a compromise between OCS and OPS, and has since then received considerable research interest. OBS is packet based, which makes it potentially more bandwidth efficient than OCS. Meanwhile, the technological requirements to implement OBS are relaxed in comparison to those of OPS. In an OBS network, packets are assembled into larger data bursts (DB). For every burst, a Burst Header Packet (BHP) is created. DB assembly and BHP generation take place in ingress OBS edge nodes. Each DB/BHP pair is routed to their destination (an egress OBS edge node) through OBS core nodes. The burst is transmitted over a data channel to the following node while its BHP is sent over a dedicated control channel to the same node. Depending on the protocol deployed BHPs may be transmitted ahead of their DBs thereby introducing an offset time to account for BHP processing delays in subsequent nodes. While data bursts are switched optically and remain in the optical domain, BHPs are converted to the electrical domain at every node for processing and recreation with new control information. Then, they are converted back to the optical domain before transmission to next node. Each BHP contains the necessary information to configure downstream optical switching fabrics for the incoming DB. At the other end, an egress OBS edge node disassembles DBs into their original packets and the latter are forwarded to their destinations outside the OBS network.

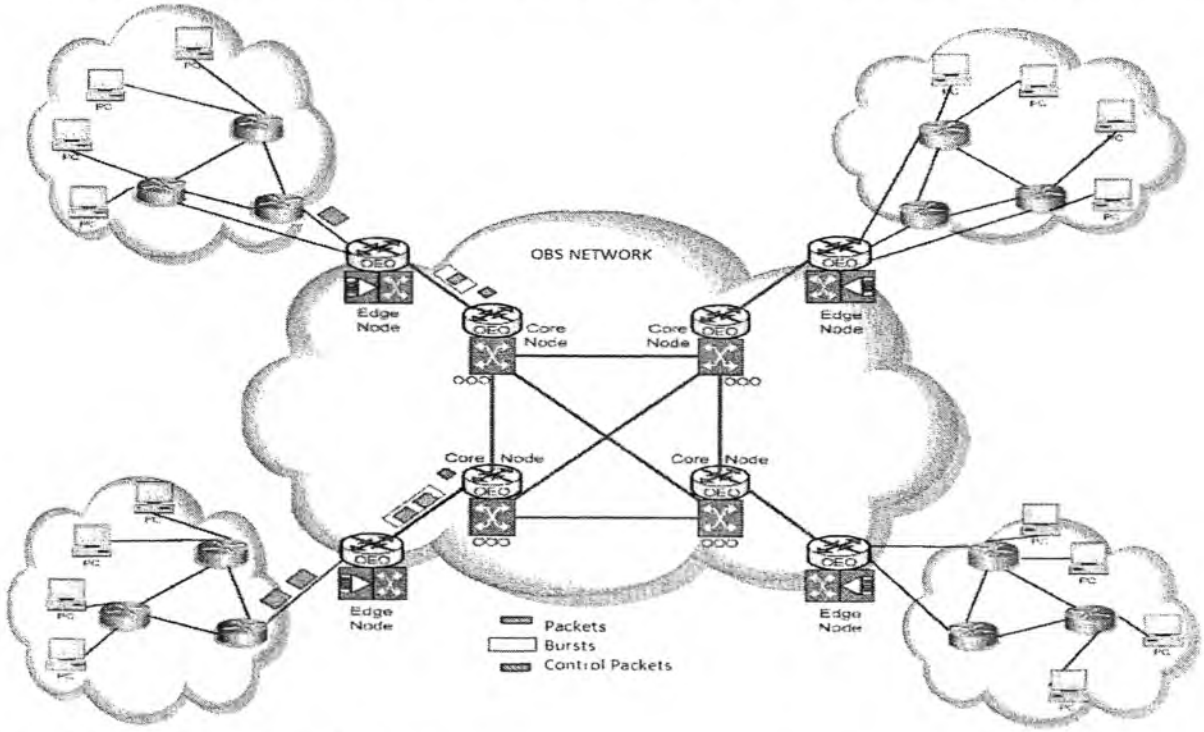


Figure 3. Basic structure of the OBS network.

Customer data are assembled / disassembled at the border nodes of the OBS network, creating bursts of varying length. The burst carries data and is associated with a control packet containing the header information.

The control data is sent over a channel or wavelength, different from those used to transport the data burst, and are processed at an electronic level on all nodes of the network. The information is transmitted in the optical domain transparently through the network on the path created by the control packet.

The nodes on OBS network can be nodes of ingress border, egress border or core. Border nodes generate and receive bursts; also they generate a control packet, which informs the intermediate nodes the path status for burst transmission.

Ingress nodes receive user data units coming from the networks connected to the OBS network and grouped in bursts of varying length. This is known as assembly bursts, where the user units are grouped according to the destination node. These nodes also generate and transmit control packets to reserve the necessary resources.

Egress nodes receive the transmitted bursts to recover the original data for end users.

The inner nodes or core nodes process and manage the control information they receive from other interior nodes or directly from the border nodes. They also check that the required resources are available for transmission, if not the case burst is discarded when it reaches the node, if not contention mechanism are available[7, 13].

## 6. AUTOMATICALLY SWITCHED OPTICAL NETWORK

The control unit of an optical-switching system, such as an OXC or a Reconfigurable Optical Add and Drop Multiplexer (R-OADM), generates the necessary commands to configure the switch fabric in such a way as to connect certain inputs to certain outputs at any given moment. This is done in accordance with the topology of the network. The control unit also works with its peers in the optical layer and in client layers to establish end-to-end lightpaths. These two tasks are obviously interrelated. We'll discuss switch-fabric control in latter papers. We now briefly highlight some technologies which have been developed to control optical networks and set-up/tear-down lightpaths.

This architecture provides three layers: transport, control and management. The management and control channels can be "in-band" or "out-of-band".

There are different types of connections: permanent, semi-permanent and switched. Protection techniques are providing at an optical level.

In the control layer admission control procedures calls of "policing" dynamic routing are managed[8].

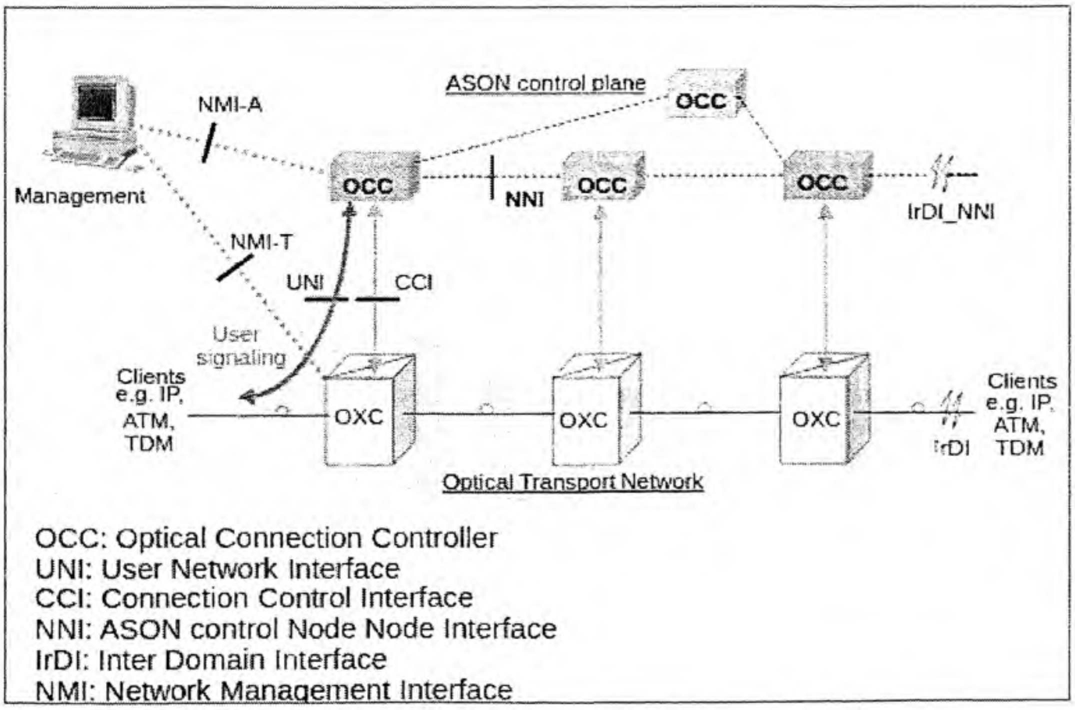


Figure 4. Automatically Switched Optical Network.

## 7. MPLS/MPλS (MULTIPROTOCOL LABEL SWITCHING / MULTIPROTOCOL LAMBDA SWITCHING)

These techniques are derived from the experience of ATM and IP over ATM, introducing a generation of virtual circuits. The basic switching operation, instead of using the "longest prefix match", uses a label switching.

Input and output tags are stored in a table when creating the virtual circuit.

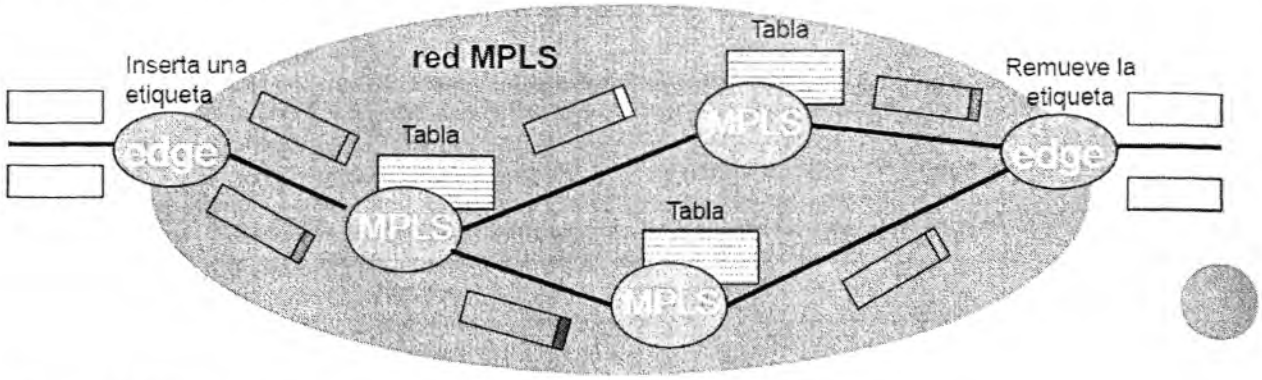


Figure 5. MPLS Network Diagram.

Paths (LSP: Label Switched Path) are decided at the source. There is a signalling protocol (LDP: Label Distribution Protocol) which coordinates label placement. This implies a paradigm shift: "soft-state" paradigm to a "hard-state".

It enables traffic engineering and building virtual private networks (VPN: Virtual Private Network). It forces a separation between the control plane and the user plane.

Tag aggregation functionalities (grooming) and labels hierarchies are provided. For MPλS labels are wavelengths[8, 14].

## 8. GENERALIZED MULTI-PROTOCOL LABEL SWITCHING (GMPLS)

GMPLS, on the other hand, is a generalization of the concept of MultiProtocol Label Switching (MPLS)[15]. The latter works with IP routing to provide high-speed packet forwarding with Quality of Service (QoS). MPLS uses a technique known as label swapping to forward data through the network. A label is added to each data packet when it enters the IP/MPLS network and the packet is routed based on this label and on the input interface through which it enters the router. The packet is forwarded to an output interface with a new label that identifies the next hop for the packet, and so on. Therefore, a router in an MPLS-based IP network is referred to as a Label-Switched Router (LSR) and the path of the packet across the network is termed a Label Switched Path (LSP).

The work of the Internet Engineering Task Force - IETF in distributed control planes for the optical layer started at the end of the 1990s with the development of the concept of MPA.S based on extensions of MPLS Traffic Engineering (TE). MPA.S evolved to Generalized MPLS (GMPLS) which is largely considered as an acceptable basis for optical-layer control. GMPLS is a suite of IP-centric protocols which extend MPLS-TE from supporting only Packet Switching Capable interfaces, for which MPLS was designed, to other classes of interfaces. Four classes with different interface/switching capabilities have been defined: Layer-2 switching capable, Time-Division Multiplex (TDM) capable, Lambda (k) switching capable, and fiber switching capable. As such, GMPLS should enable a variety of electronic and optical switching systems to interoperate. GMPLS also extends the MPLS definition of an LSP from being a path that merely connects LSRs to one that may connect pairs of layer-2 switches, SDH/SONET network elements, or a lightpath that interconnects optical network elements[16], using the same framework of MPLS-TE, G-MPLS.

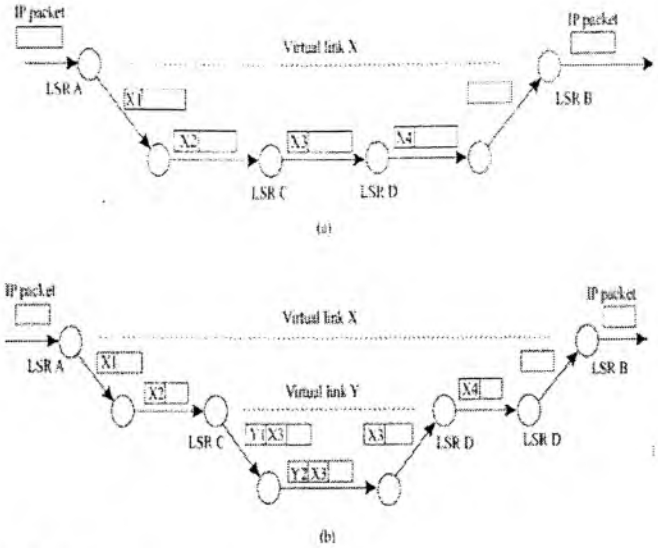


Figure 6. Label Switched Path Tunnels.

G-MPLS is an IETF proposal to extend MPLS so that the control plane is capable of supporting different switching technologies: time, space, packets. The architecture consists of three layers: transport, control and management[14, 15].

Link Management Protocol (LMP) is also considered:

- Maintenance Control Channel,
- Link Property Correlation,
- Link Connectivity Verification,
- Fault Management.

## 9. CONCLUSIONS

Optical Switching was described, in such a way that give us a particular interest about the structures of these switches, and special when the OOO doesn't exist on them. OCS and OPS were compared, as was described: OPS had better characteristics in low packet loss probability. A third option also was present like OBS, where its advantage over OCS for example is to have more bandwidth efficient, in this option occurs that while data bursts are switched optically and remain in the optical domain, BHPs are converted to the electrical domain at every node for processing and recreation with new control information. Automatically Switched Optical Network as the part of control in the switch equipment was investigated and finally a comparison between GMPLS and MPLS were performed.

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