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Efficient IP Traffic over Optical Network Based on Wavelength Translation Switching

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Abstract

With the advent of TCP/IP protocol suite the overall era of communication technologies had been redefined. Now, we can't ignore the presence of huge amount of IP traffic; data, voice or video increasing day by day creating more pressure on existing communicating media and supporting back bone. With the humongous popularity of Internet the overall traffic on Internet has the same story. Focusing on transmission of IP traffic in an optical network with signals remaining in their optical nature generated at particular wavelength, proposed is the switching of optically generated IP packets through optical cross connects based on translation of wavelength when an IP packet is crossing the optical cross connect. Adding the concepts of layer 3 routing protocols along with the wavelength translation scheme, will help in spanning the overall optical network for a larger area.

***Keywords**: Optical WAN, Wavelength translation switching, Optical encapsulated IP packet, Optical intelligent Router*

1. Introduction

SONET (Synchronous Optical Network) [1] is one of the finest technologies for the purpose of having optical-fibre based networks. The team of Bellcore (Bell Communication Research) had developed a protocol for fiber-optic transmission providing synchronous transport. Scope of SONET are respectively; synchronous fiber-optic networking, efficient multiplexing, compatibility of manufacturers equipment, robust fiber rings, supporting services, enhanced network operations and managements. Electrical signals after certain modifications are undergone through electric-to-optic conversion for the purpose of transmission through optical media. When we are speaking about IP traffic and its transmission, we generally believe that digitals signals of IP packets are to be transported through electrical channel but when we are to incorporate optical media electrical to optical conversion of electrical signal is to be performed first and then transmission of optical signals is done. Further switching technologies which are used commonly for the switching of IP packets among several nodes of the inter-network are generally MEMS (Micro Electro Mechanical Systems) [2,14-15] based or OXC (Optical Cross Connects) based. MPLS (Multi protocol label switching) [10-11] is yet again an important and interesting concept used by the ISP (Internet Service Provider's) providing telecommunication services to end users of the Network. With MPLS entire traffic of the Network user is to be transported through various nodes of the MPLS backbone based on either IP or ATM. MPLS nodes of the service provider have presence

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for a larger area so that they are capable of behaving like a network cloud for any of their customer having offices at distant locations (*e.g.*, Hub and Spoke locations of a company). Route optimization is done based on certain protocols as per the selection of best suited routes. However IP is the layer-3 protocol of the OSI model, which is responsible for the encapsulation of layer-4 segment (transport layer PDU) into certain number of layer-3 packets with proper logical addressing to individual IP packets based on that IP routing takes place. Routing is the key phenomena which determines based on the information the IP packet has to cross one node (select one route) or to not cross a node (reject one route). There are various routing protocols (layer-3 protocols) which are in use like static/default routing, RIP, OSPF, IGRP, EIGRP, IS-IS, BGP *etc.* Routing information of the IP network is distributed into the network at certain duration of time as is set by the network admin, so that the layer 3 devices will know how many live connections they have, how many routes are learning. Hello packets are being sent and received among the layer-3 devices for live connections as well as routing table is maintained by the router adding new routes learned and removing old routes for which hello packets are not received from long, the same routing table is distributed by the router in the inter-network so that other routers or layer-3 devices will know the routes or the destinations being reachable from that device.

2. Optical Networking

Considering an optical network so that an internetwork has been established by connecting various layer-3 devices with optical fiber channel based on lambda switching [3-9,12,16]. There are many optical communication and FPGA based work is also going in [17-20]. Multi-party communication can take place with such a network. The network we are representing is an all fiber network. Logical addressing of the layer-3 devices is done based on the IP address so that it will help in IP routing within a WAN formed from above stated optical network. The IP traffic to be passing through certain links of the network will be in the form of optical signals. Let's consider an optical network as shown in the figure below.

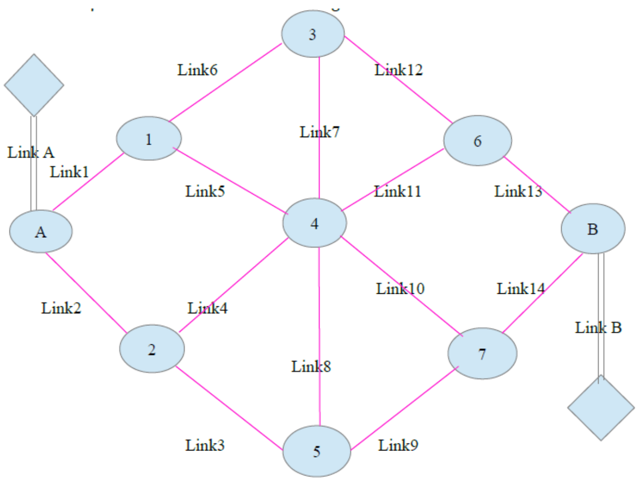
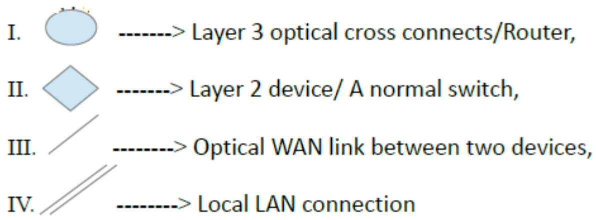


Figure 1. Diagram of Optical Network with Wavelength Segregation Property

Considering Figure (1), the symbol represents respectively;



As per the figure shown above representing all fiber optical network, our scope is of developing of routing feature within an all fiber optical WAN. Considering above diagram two different LAN connections A & B, remote to each other wants to communicate through optical WAN. IP traffic from source of LAN A wants to send and receive data from LAN B, but the IP traffic will have to pass through an all fiber WAN network. All of the layer 3 devices respectively A, B, 1, 2, ---7 are provided logical addressing (IP addressing) to form the WAN network according to the diagram. To make feasibility of above network we consider fixed wavelength for each of the optical link, so that links respectively Link 1, Link 2,....Link 13, Link 14 are given fixed wavelengths as λ_1, λ_2 ,.... λ_{13} , λ_{14}. So that, if the devices A and 1 wants to communicate with each other then they will have to use the signal for transmission as well as for reception to be at wavelength λ_1, similarly device A and 2 will have to communicate at λ_2 and so on. Therefore, it is indeed needed to distribute the link wavelength along with IP address in the routing table being distributed by individual routing devices. Also, each of the routers in the network is supposed to keep respective link wavelength entries for each of the destination IP address in the routing database as well as in the route-forwarding database.

3. Procedure

As per the diagram and the explanation given above for the optical network, we are now explaining the procedure for the communication between device A and device B. Considering that logical addressing and respective link wavelength assignment is already been done of the devices. We can use any of the routing protocol like RIP v1/v2, OSPF, IGRP, EIGRP (IGRP & EIGRP being Cisco proprietary routing protocols only working on Cisco devices), IS-IS, PIM *etc*. Only the thing to be modified is that we have to add the mechanism of wavelength assignment along with routing so that wavelength will become an enhanced feature of routing in our supposed network.

Step 1: Consider the segment of network as shown below;

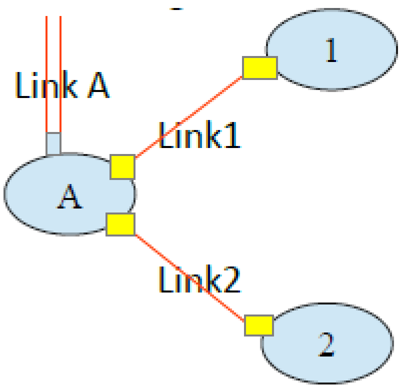


Figure 2. Device a Connected with Device 1 and Device 2

As per shown in the diagram Figure 2, we are finding device A connected with device 1 and device 2. "Link A" is the LAN or Ethernet connection there with the "Router A" at its interface (Gigabit Ethernet/ Fast Ethernet/or Simple Ethernet port if considering the LAN to be purely electrical). Thus IP packet generated from any of the host from Ethernet link of LAN A is encapsulated into data link frame and the same is received by the Router A at its Ethernet port.

Step 2: FCS is checked from the received frame's FCS field in the data link trailer, also checking the destination MAC address of the frame's header. If all is found ok then "Router A" has to process the received frame, it will de-encapsulate the received frame.

Step 3: Router has to check for the destination IP address and match it from the routing table entries the subnet address & subnet mask and corresponding next hope IP address, the outgoing port as well as the link wavelength after de-encapsulating the data-link frame.

Step 4: Concept is that the routing algorithm has to calculate the least cost route/path for the destination IP address from the routing table of "Router A". Assuming that based on the routes received by the router only least cost entries for different IP subnet along with next hope IP address and corresponding link wavelength are to be maintained by the router in the RIB (Routing Information database) and FIB (Forwarding Information database) of the router.

Step 5: Assuming that the destination subnet is matched in the routing table of "router A" for the IP packet,

Table 1. Routing Table of Router "A"

Destination Subnet Address	**Destination Subnet Mask**	**Next Hope IP Address**	**Link Wavelength**
-.-.-.-	-.-.-.-	-.-.-.- (device"1"/ "2")	"λ_1"or "λ_2"
-.-.-.-	-.-.-.-	-.-.-.- (device"1"/ "2")	"λ_1"or "λ_2"
-.-.-.-	-.-.-.-	-.-.-.- (device"1"/ "2")	"λ_1"or "λ_2"
-.-.-.-	-.-.-.-	-.-.-.- (device"1"/ "2")	"λ_1"or "λ_2"
-.-.-.-	-.-.-.-	-.-.-.- (device"1"/ "2")	"λ_1"or "λ_2"

Now the next hope IP address and the link wavelength has been matched as per the routing table of router "A" as shown in Table 1. Router "A" will identify its port to which the encapsulated packet in the optical form generated at wavelength either "λ_1" or "λ_2" is to be forwarded. Considering Figure 2; we have shown the optical ports of the router in yellow.

Step 6: Next step is to transform the IP packet from electrical to optical form at link wavelength as per the previous steps and send through the corresponding optical port of router "A" to the next hope router "1" or "2" after encapsulating it into optical link frames [11-13].

Step 7: Corresponding device ("1" or "2") will receive the incoming encapsulated IP packet in the optical form at its link wavelength and check its header/trailer. If all found ok then that device has to process the received frame.

Step 8: After step 7, the device knows that it is the intended receiver for the received frame and will further de-encapsulate it. Strip other things from encapsulated IP packet (headers and trailers) and actual IP packet in the electrical form is obtained.

Step 9: Further similar steps from step 3 to step 8 as above is repeated till actual IP destination subnet ID/mask is found in the routing table of destination router is found.

Step 10: After step 9 it is assumed that the IP packet is received by the actual destination router or destination subnet pool. In our example we are considering Figure 3 as shown below.

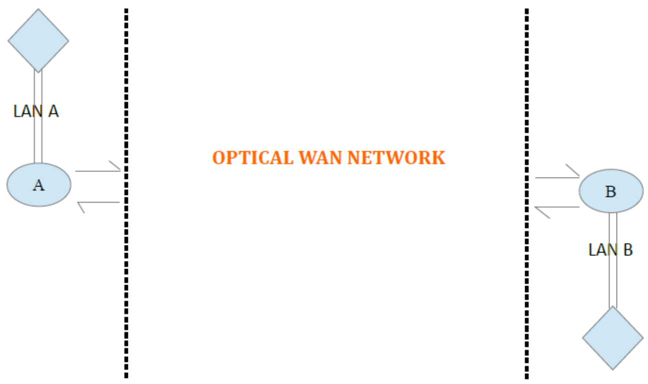


Figure 3. Two Party Communications through Optical WAN

As per our observation LAN A is the source and LAN B is the destination, thus router "B" has received the encapsulated IP packet in the optical form at its link wavelength corresponding to its optical port's wavelength. Router B will de-encapsulate the optical frame and extract the IP packet from it in the electrical form. Further finding that the destination IP address from the received packet belongs to that of the pool of LAN B. Router B will further encapsulate the IP packet into Ethernet frame and send the Ethernet frame at destination MAC address corresponding to the destination host IP address from LAN B (using ARP look-up from MAC address table for host IP address) but the signal will be in the electrical form as no further electrical to optical conversion is required.

Host will check the FCS field of the received Ethernet frame, finding the MAC address to be correct; it will de-encapsulate the frame and extract the data from the IP packet.

Similarly, host from LAN B can communicate with that of LAN A as stated above.

4. Conclusion

Considering above stated methodology, we are finding that routing of IP packets in an all-fiber WAN network is possible with link wavelength assignment. We have assigned single and fixed wavelength to each of the individual link being shared by the layer 3 devices (where routing is taking place). A layer 3 device (router) is actually a type of optical cross-connect which is used to receive incoming optical signal (encapsulated IP packet) at certain wavelength, convert it into electrical during de-encapsulation process (extract the IP packet) and further transform the IP packet with certain headers and trailers into optical signal at certain wavelength to which the signal is to be passed through. So fiber based communication for IP traffic for a larger area network is possible, we can further involve the concept of Virtual Routing and Forwarding (VRF) for the purpose of scalability of the similar network to span the network in larger domain with supporting multiple party communication with high density traffic passing through the backbone.

5. Discussion

- How much efficient and feasible is the process of converting an electrical signal into optical and further from optical to electrical the actual IP packet, also the process of wavelength transformation so that a packet received at "λ_a" need to be transformed with certain modifications at "λ_b"?
- The IP packets and datalink frames are actually the digital signals, but what will be the type of optical equivalent signal corresponding to encapsulated IP packet.
- Link wavelength assignment is strictly a problem and complexity increases if the number of links increases.
- Do the link-wavelength assignment be the manual method just configuring a router and assigning an IP address to it or be there some intelligent mechanism is possible to reduce the extra burden on network admin and make a way for the scalability of the same network?
- Every optical port of the Router consists of a set of lasers(tunable lasers) so as to generate the optical signal at desired wavelength during transmission, as well each of the optical port needs to have devices to convert the received optical signal into electrical with no distortions. This makes the router ports more complex and sophisticated. Hence cost increases for manufacturing such device.
- Adding of the link-wavelength to the next hope IP address in the routing table of each of the devices, it may require space, consuming more of the router memory for RIB and the FIB.

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