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Optical Burst Switching (OBS) for DWDM transmission medium: an Overview

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Abstract: This paper presents a review on optical burst switching (OBS) for dense wavelength division multiplexing (DWDM) technology. The DWDM technology is explained in brief. Then the three generations of optical networks are briefed. The different switching schemes in optical networks are compared. The advantages and issues related to OBS are reviewed. Lastly the simulator tool nOBS based on ns-2 is overviewed.

Keywords: DWDM, OBS, nOBS, optical network.

I. INTRODUCTION

With the increasing use of multimedia on the internet there is an increasing demand for high bandwidth networks. Today's networks carry high speed data traffic along with voice traffic. The up gradation of existing networks for such traffic is very expensive. Optical technology is found to be best to satisfy the growing demands of bandwidth and future network services. Optical fibers can support bandwidth up to 50 THz. The BER for an optical fiber is in the order of 10^{-12} which is very low. Optical signals are immune to electrical interferences. The light wave is of high frequency. Hence the wavelength is short. Thus more digital data can be carried by an optical fiber than a copper wire of the same length. Dense Wavelength Division Multiplexing (DWDM) provides large no of wavelengths with high bandwidth on optical fiber. An all optical network, along with DWDM technology, makes the optical domain intelligent and scalable. To make the DWDM optical network more efficient the use of optical switching technique called Optical Burst Switching (OBS) was proposed. Various OBS approaches have since been described.

The paper is arranged as: Section I briefs about the DWDM technology. Section II discusses the optical networking along with the issues related to the optical layer. The OBS technique is briefed in section III. Section IV reviews the tool nOBS based on ns-2.

II. DWDM TECHNOLOGY

DWDM is a fiber-optic transmission technique. Many different wavelengths are multiplexed on a single optical fiber. (refer figure 1). Hence each optical fiber has a set of parallel optical channels using a slightly different wavelength. The data can be transmitted in parallel-by-bit or serial-by-character pattern on the light wavelengths. DWDM allows transmission of voice, video-IP, ATM, SONET/SDH on a single fiber. Hence it is a crucial element in optical networks. The following diagram represents the no. of channels available on a DWDM link.[7]

The DWDM transmission system is build on an optical layer which is similar to the other layers of networking. The transmission system and the optical nodes together constitute an optical network. To make an efficient use of the optical network there has to be strong switching technique and efficient algorithms to overcome some drawbacks of the optical network like lightpath establishment on a wide range of wavelengths. [7]

III. EVOLUTION OF OPTICAL NETWORK

Optical Layer Architecture: An architecture has been defined for the optical layer which simplifies optical networking. We will consider a multi-wavelength mesh network to understand the architecture. The path between two nodes is defined as a lightpath and corresponds to a wavelength on each link on that path. There are two aspects to optical network topology: physical topology and virtual topology. Physical topology has the optical nodes interconnected by a pair of point-to-point optical links in a mesh network. Virtual topology is the lightpath established between two optical nodes. The method of lightpath establishment in an optical network has evolved from first generation to third generation till date.

The first generation of optical network is a point-to-point network where optical links are placed between the nodes. Here the data has to be converted from optical to electronic, processed electronically and converted back to optical continuously. This increases the processing time and acts as an overhead in terms of time and cost. The second generation is the wavelength add-drop multiplexer (WADM). The optical data is added only at the WADM

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locations. Some selected wavelengths can be terminated at the WADM locations while some remain untouched. Hence the bypassed traffic is more than the dropped traffic. The third generation is of switching techniques: optical circuit switching (OCS), optical burst switching (OBS), and optical packet switching (OPS). [6]

Comparison of the switching techniques: OCS depends on lightpath establishment which can be static and dynamic. The lightpath establishment in both the types cannot successfully satisfy the dynamically varying demands of bandwidth of the internet traffic. The internet traffic is more dynamic and bursty in nature. Hence, it becomes difficult to maintain the current state information of the optical network.

Other approach is optical packet routing, where the packet moves in the optical domain without conversion from optical domain to electronic domain at each node. The header of the packet is processed in the electronic domain and the optical switch is reconfigured as per the contents of the header. This requires fast switching time. Current switching technologies and optical buffering are not matured to support packet switching.

Optical burst switching is most suitable for the current technology for an optical network. OBS combines the best features of OCS and OPS. In this switching network, the data from the upper layer is collected and aggregated into variable sized bursts. These data bursts are optically switched through the network. The data burst consists of many IP packets. A control burst is priory switched through the network. The control burst configures the switches along the route. An offset-time is set up between the control burst and the data burst to allow processing of the control burst. Hence, no conversion of data between optical domain to electronic domain is required in OBS.[6]

IV. OPTICAL BURST SWITCHING

In an OBS network, various types of client data are aggregated at the ingress (an edge node) and transmitted as data bursts which later are disassembled at the egress node. During burst assembly/disassembly, the client data is buffered at the edge where electronic RAM is cheap and abundant. For each data burst, a control burst containing the usual "header" information of a packet including the burst length information is transmitted on a dedicated control channel. Since a control burst is significantly smaller than a data burst, one control channel is sufficient to carry control bursts associated with multiple (e.g., hundreds of) data channels. A control burst goes through O/E/O conversion at each intermediate OBS node and is processed electronically to configure the underlying switching fabric. There is an offset time between a control burst and the corresponding data burst to compensate for the processing/configuration delay. If the offset time is large enough, the data burst will be switched all-optically and in a "cut-through" manner, i.e., without being delayed at any intermediate node (core). In this way, no optical RAM or fiber delay lines (FDLs) is necessary at any intermediate node. Nevertheless, the burst-level granularity leads to a statistical multiplexing gain which is absent in optical circuit switching. Also, it allows a lower control overhead per bit than that in optical packet switching. [6]

For OBS, the formation of a burst is a major issue. Burst assembly is the process of assembling the incoming data into bursts at the ingress node(refer fig 4). The burst assembly can be achieved by various techniques depending on the wavelength reservation schemes. The reservation scheme can be broadly classified as immediate reservation scheme (eg. Just In Time, JIT) and delayed reservation scheme (eg. Just Enough Time, JET). Various algorithms are being discussed to handle this issue efficiently.[1][2][3][4]

V. SIMULATIONS FOR OPTICAL NETWORKS

OWns was one of the first optical network simulator developed on ns-2. OIRC OBS-ns was the next version of OWns. It supported only the shortest path algorithm and did not support a network of OBS sub-network and edge electronic nodes. nOBS can simulate any routing algorithm using source routing. nOBS facilitates the analysis of the performance of OBS networks with wavelength convertors and FDLs. Various burst assemblies, routing and scheduling algorithms can be implemented with nOBS. It is developed over the ns-2 simulation tool.

About nOBS: In nOBS the network topology is designed as OBS clouds and edge nodes. The edge nodes are the ingress and egress nodes. The burstification and deburstification of the optical packets is the responsibility of these edge nodes. [5]

The different parameters of burst formation can be specified by the user through the edge nodes. The burst consists of packets from different TCP flows being forwarded to the same egress node. The control burst is also generated and transmitted by the edge node. The control burst contains information about scheduling and transmission of the data packets. The optical switches in the OBS core configure the switching matrix based on the information in the control burst. The edge node transmits the optical data burst sometime after transmitting the control packet i.e. Just-Enough-Time (JET) protocol. This

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is the offset time required to configure the optical switches before transmitting the bursts. This reservation protocol facilitates nOBS to reserve just the required amount of resources for traversing through the links. The scheduling of the bursts is done by the core nodes. The use of wavelength convertors and fiber delay lines by the core nodes is optional. The wavelength convertors and FDLs are arranged in a pool which can be shared and accessed by all the ports. The scheduling algorithms Latest Available Unused Channel with Void Filling (LAUC-VF) and Minimum Starting Void (Min-SV) can be used in nOBS.

Architecture of nOBS – nOBS is developed on version 2.27 of ns-2, the optical nodes and optical links are created by making some changes in the existing components of ns-2. The optical node, nOBS node,(refer fig. 5) can function as ingress, egress and core nodes. The address classifier is replaced by optical classifier which can classify between the TCP and optical packets. There are two links that are now associated with the classifier, the optical link and the access link. The modules in the optical node are OpClassifier, OpSRAgent, Burst Agent and Burst Scheduler. These modules are designed based on their functionality. This makes it easier to understand the node functionality and make modifications or additions of algorithms. The same functionalities of Burst Scheduler, OpSRAgent and OpClassifier are required by the optical ingress, egress and core nodes. The Burst Agent is not required by the core node. But some users may need it to add traffic agents or to burstify/deburstify at the core node. The same node architecture is shared by the ingress, egress and core nodes. Also it is not necessary to specify the node type in the simulation script while creating a node.

The electrical packet arrives from the higher layer to the optical node through the access link. It is then processed by OpClassifier. If the next hop of the packet is in the optical domain the packet is forwarded to the Burst Agent where it is assembled in a buffer as a pair of burst and control packet pair. After the assembly of burst it is sent to OpClassifier which forwards it to the Optical Source Routing Agent (OpSRAgent). The OpSRAgent adds the information regarding the routimg in optical domain to the control packet and burst. It checks for a suitable interval for transmission with the burst scheduler block. The scheduler block consists of OpScheduler, OpConvertorScheduler and OpFDLScheduler where the record of outgoing channels, convertors and FDLs is kept. The OpSRAgent transmits the control packet on finding a suitable interval. It transmits the burst after the offset time. Else the burst is dropped. If the next hop for an optical packet is not in the optical domain, OpClassifier sends this optical packet to the BurstAgent for deburstification . If the optical packet is a control packet, it is dropped. If it is a burst, then the packets inside the burst are sent to the OpClassifier, which forwards them to OpSRAgent. OpSRAgent sends these packets through outgoing electrical links towards their destination nodes. Original Queue of ns2 blocks the link for other packets during the transmission of a packet, until a scheduler event created by LinkDelay signals the end of the packet transmission. The OpQueue module in nOBS immediately forwards all incoming packets to OpLinkDelay without any blocking, packet dropping or queuing since wavelength reservation, contention resolution and FDL buffering operations are already performed by Burst Scheduler and OpSRAgent in the node architecture.[5] This simulation tool is found to give near accurate results.

VI. CONCLUSION

With the above discussion we can conclude that DWDM along with OBS can give us an efficient optical network. DWDM provides to accommodate ever increasing bandwidth requirements. Transmission of email, video, multimedia, data and voice carried in IP, asynchronous transfer mode (ATM), synchronous optical network / synchronous digital hierarchy respectively over the optical layer. DWDM infrastructure increases the distance between network elements. Hence initial network investment reduced for service provider. Recent work in OBS on QoS support, IP/WDM multicast, TCP performance in OBS networks, contention resolution are coming up to make OBS more efficient. DWDM and OBS together make all optical mesh network feasible and optical internet based on OBS paradigm can be the near future. Hence all optical mesh can be designed using OBS where the bandwidth is completely utilized on every wavelength on a DWDM medium reducing the blocking probability of the optical mesh network for large traffics. ns-2 simulation tool is a popular tool with network researchers. nOBS based on ns-2 is also proving to be a near accurate tool to simulate optical network on OBS paradigm. It supports many algorithms and various burst assembly methods can also be simulated using this tool.

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Figures for reference:

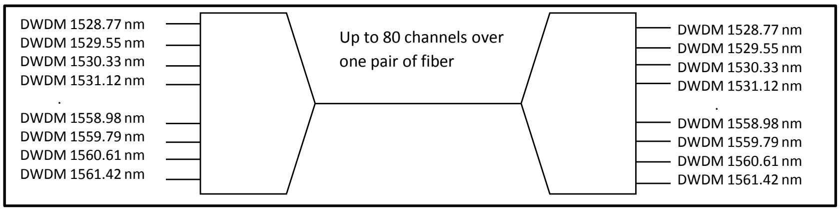

Fig. 1: Theoretically available DWDM channels in the C and L-band depending on channel spacing

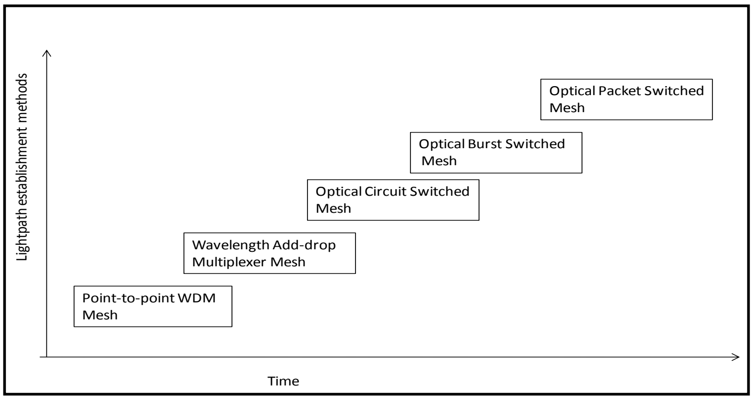

Fig. 2: Three generations of optical networks.

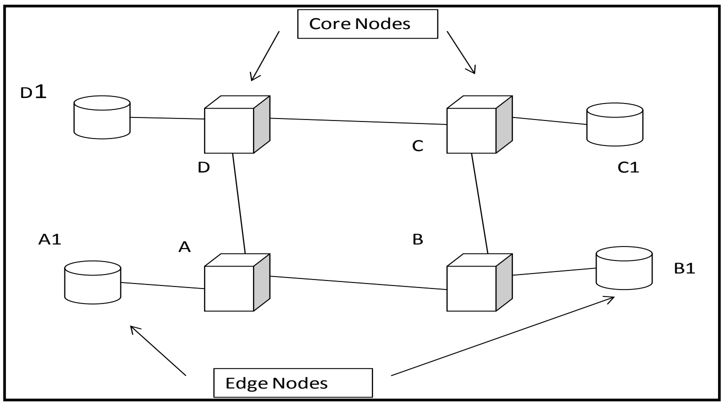

Fig. 3: An OBS Network

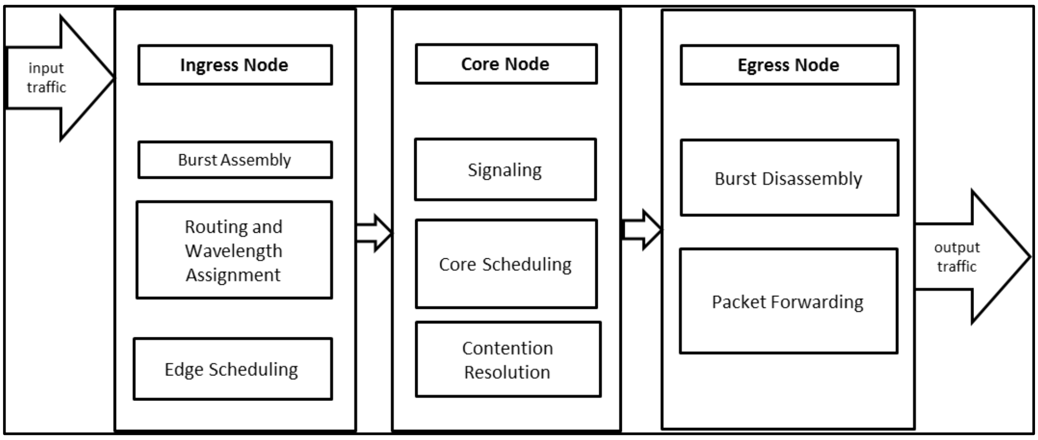

Fig. 4: OBS Functional Diagram

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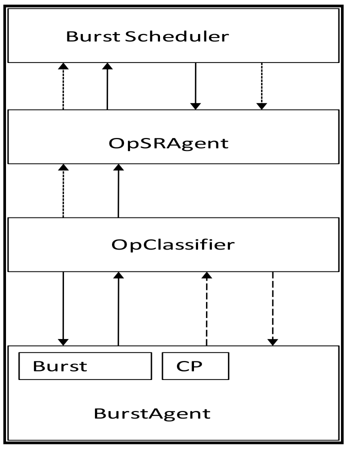

Fig. 5: nOBS Node

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BIOGRAPHIES

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