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Energy Efficient Optical Burst Chain Switching with QOS Aware Networks

[1]P. Maheswara Venkatesh and [2]Dr. A. Sivanantha Raja

[1]*Dept.of ECE, Anna University, BIT Campus -Tiruchirappalli, Tamilnadu, India*
[2]*Dept.of ECE, A.C. College of Engineering and Technology, Karaikudi, Tamilnadu, India.*

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ABSTRACT

Today's ICT (Information and communication Technology) is emerging with tremendous challenges which were prevailing throughout the world. One among them is the energy conservation which plays a vital role in telecommunication network .Perhaps the paradigm to reduce energy consumption in access networks enriches the energy savings in the internet energy conservation without diluting the QoS **(**Quality of Service). WOBAN, a novel hybrid access paradigm with the combination of high capacity optical backhaul and wireless front end provides very high throughput in a cost effective manner , meanwhile to improve the energy efficiency which is the main task of the strategy. The scenario is to replace optical burst switching (OBS) network architecture to Optical Burst Chain switching (OBCS) to achieve high performance with energy efficient . Here switching unit is burst chain it consist of non-periodic bursts in one wavelength. We discussed wide-ranging simulation result for throughput, delay and energy to demonstrate its superior performance over OBS networks.

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INTRODUCTION

Communication in the optical domain offers increased bandwidth. The equivalent of FDM in the optical domain is termed as wavelength division multiplexing(WDM). In WDM transmission, multiple optical rays of different wavelengths are transmitted through an optical link. It was first demonstrated in Bell Labs in 1997.Their range of the transmitted wavelengths are in the nanometer range. This method creates a number of virtual fibres inside a single fibre, which can transmit light of different wavelengths.

All-optical second-generation optical networking achieves the reconfiguration of optical wavelength circuit paths (light paths) by properly configuring the optics within the optical network elements. The deployment of reconfigurable All-optical switching seeks to eliminate electronic switching and switch the data in its optical form, thus eliminating the opto-electronic components which contribute a large fraction of the cost of electronic routers. Optical switching has other potential benefits, including bit-rate independence, protocol transparency, and low power consumption.

Switching Techniques:

Various optical switching architectures have been developed for high speed switching in optical wavelength division multiplexing (WDM) networks to carry huge amount of traffic in optical backbone networks. These architectures include, optical circuit switching (OCS), optical packet switching (OPS), optical burst switching (OBS).

Optical Circuit Switching:

In telecommunication, an optical switch is a switch that enables signals in optical_fibers or integrated optical_circuits (IOCs) to be selectively switched from one circuit to another. In OCS networks, light paths are used to transmit data between two end nodes where a light path is defined as an all-optical circuit switched medium with possible wavelength conversion at the intermediate nodes along the transmission path. In OCS, the network is configured to establish a circuit, from an entry to an exit node, by adjusting the optical cross connects circuits in the core routers in a manner that the data signal, in an optical form, can travel in an all-optical manner. A dedicated path is established between source and destination node. Hence the collision is avoided. Ideally, the packets that enter the network should be transported from the ingress to the egress point in an all-

Corresponding Author: Mr. P. Maheswara Venkatesh, Assistant Professor, Department of Electronics and Communication Engineering, Anna University -BIT Campus, Tiruchirappalli 620024, Tamilnadu, India.
E-mail:mahesh_ven@yahoo.com

optical form.

The technology needed to process the headers of the packets using only optics is not yet available, and thus, the packets need to be converted to electrical form so that current electronic integrated circuits can interpret the header and make the convenient routing decisions. After the routing has been decided, the packet is again converted to optical form and inserted into the fiber. Although OCS is easy to implement, it suffers from poor statistical multiplexing gains if the source node does not have any data to send, thereby leading to poor resource and bandwidth utilization. The resources will not be efficiently used to the unpredictable nature of network traffic (burst traffic).

***Optical Packet Switching*:**

Packet switching is a technology that splits data in network communications into manageable small pieces, called packets. By sending a large file in several small chunks over a network, packet switching minimizes the impact of data transmission errors. Traffic bottlenecks are avoided too, allowing data to flow in the most efficient manner possible over the network .Here, a message is split up into packets of fixed size. Besides the block of data to be sent, a packet has a header that contains source and destination addresses, control information, acknowledgement and error checking bits. With message switching, there was no limit on block size, which means that routers must have disks to buffer long blocks. It also means that a single block may tie up a line for minutes restricting switches for the other traffic.

To get around these problems, packet switching was invented. Packet switching makes sure that no user reserves the transmission line for very long time. However, the most important concern is contention, which occurs at a switching node whenever two or more packets try to leave on the same output interface, on the same wavelength, at the same time. Unlike in electronic RAMs where as many as a million packets can be buffered during times of contention, buffering in the optical domain remains a very complex and expensive. Spools of fiber can implement fiber delay lines (FDL) that can buffer light by delaying the signal; however the size of the optical crossbar increases with bigger FDLs, there by making all optical switches very expensive.

***Optical Burst Switching*:**

Optical burst switching (OBS) is an optical networking technique that allows dynamic sub-wavelength switching of data. OBS is viewed as a compromise between the yet unfeasible full optical packet switching (OPS) and the mostly static optical circuit switching (OCS). It differs from these paradigms because OBS control information is sent separately in a reserved optical channel and in advance of the data payload. These control signals can then be processed electronically to allow the timely setup of an optical light path to transport the soon-to-arrive payload. This is known as delayed reservation.

The purpose of optical burst switching (OBS) is to dynamically provision sub-wavelength granularity by optimally combining electronics and optics. OBS considers sets of packets with similar properties called bursts. Therefore, OBS granularity is finer than optical circuit switching (OCS). OBS provides more bandwidth flexibility than wavelength routing but requires faster switching and control technology. OBS can be used for realizing dynamic end-to-end all optical communications

In OBS, packets are aggregated into *data* bursts at the edge of the network to form the data payload. Various assembling schemes based on time and/or size exist .Edge router architectures have been proposed. OBS features the separation between the control plane and the data plane. A control signal (also termed burst header or control packet) is associated to each data burst. The control signal is transmitted in optical form in a separated wavelength termed the control channel, but signaled out of band and processed electronically at each OBS router, whereas the data burst is transmitted in all optical form from one end to the other end of the network. The data burst can cut through intermediate nodes, and data buffers such as fiber delay lines may be used. In OBS data is transmitted with full transparency to the intermediate nodes in the network. After the burst has passed a router, the router can accept new reservation requests

Assembly Algorithms:

Usually, assembly algorithms can be classified as timer-based, burst length-based and mixed timer/burst length-based ones .In the timer-based scheme, a timer starts at the beginning of each new assembly cycle. After a fixed time T, all the packets that arrived in this period are assembled into a burst. In the burst length-based scheme ,there is a threshold on the burst length .A burst is assembled when a new packet arrives making the total length of current buffered packets exceed the threshold. If the value is too large, the packet delay at the edge might be intolerable. If the value is too small, too many small bursts will be generated resulting in a higher control overhead .While timer-based schemes might result in undesirable burst lengths, burst length-based assembly algorithms do not provide any guarantee on the assembly delay that packets will experience .To address the deficiency associated with each type of the assembly algorithms mentioned above, mixed timer/threshold-based assembly algorithms were proposed.

During this offset period, packets may continue to arrive. Including those packets in the same burst is usually unacceptable because the reservation at the downstream nodes may have already been made based on the original burst length record in the control packet. Leaving those packets for the next burst on the other hand, will increase the average delay especially when the traffic load is heavy. One way to minimize this extra delay is to perform burst length prediction: let the control packet carry a burst length of l + f(t) instead of l, where l is the exact burst length when the control packet is sent out, and f(t) is the predicted extra burst length as a result of additional packet arrivals during the offset time t. Assume that the total length of packets actually arriving during the offset time is l(t). If $l(t) < f(t)$, part of bandwidth reserved will be wasted. Otherwise (i.e., if $l(t) > f(t)$), only a few extra packets (whose total length is about l(t) - f(t)) are delayed to be transmitted in the next burst.

Assembled Burst Traffic Characteristics:

We have focused on the statistical characteristics of burst traffic, which can be divided into two categories: short range (small time scales) and long range (large to infinite time scales). In most of these studies, the packet arrivals into an assembly queue from many independent traffic sources were assumed to be Poisson. For a timer-based assembly algorithm, the size of a burst is equal to the sum of the size of all the packets arriving in a fixed time period, to be a Gaussian distributed random variable according to the central limit theorem. The short range burstiness in the input packet traffic is alleviated due to burst assembly and the smoothed assembled burst traffic can enhance the network's performance. An important characteristic of today's Internet traffic is its long range dependency, which increases data loss and delay and decreases network resource utilization in electronic packet switched networks .Although that burst assembly algorithms could reduce the long range dependency in the input IP packet traffic, that long range dependency in the traffic will not change after burst assembly .On the other hand, the results showed that the influence of the long range dependency on the performance of an OBS node is negligible because of its buffer less nature .If a timer-based assembly scheme is used, the bursts inter-arrival time will be a constant.

On the other hand, Just-In-Time (JIT) can be considered as a variant of tell-and-wait as it requires each burst transmission request to be sent to a central scheduler. The scheduler then informs each requesting node the exact time to transmit the data burst. Here, the term Just-In-Time means that by the time a burst arrives an intermediate node, the switching fabric has already been configured. Since centralized protocols are neither scalable nor robust, provided a distributed version of JIT protocol called Reservation with just- In-Time, which requires a copy of the request to be sent to all switches (each has a scheduler) concurrently .These schedulers are not only synchronized in time, but also share the same global link status information, which makes the implementation difficult. The another distributed version of the JIT protocol based on hop- by-hop reservation which adopts some features of the Just Enough Time (JET) protocol JET is the most prevailing distributed protocol for OBS networks today which does not require any kind of optical buffering or delay at each intermediate node.

Furthermore, if a burst length-based assembly algorithm is used, the variance of the inter arrival time of the bursts coming from different edge nodes may become small when the traffic load is heavy. In such cases, undesirable persistent collisions of bursts from different sources might happen if these sources are adversely synchronized. Adding a randomized extra offset time at each edge node may prevent such synchronization among the sources.

Burst Reservation Protocols:

Burst switching Concept was introduced for centralized TDMA systems and ATM networks in early 1990, protocols suitable for high speed WDM optical networks .Widjaja.I (1995) the author evaluated two burst level admission control mechanisms for ATM networks: tell-and-wait and tell-and-go.In the former, when a source has a burst to transmit, it first tries to reserve the bandwidth/wavelength from the source to its destination by sending a short request message. Every intermediate node receiving this message will make a reservation on a specific output link If the requested bandwidth is successfully reserved on all the links along the path, an ACK will be sent back to inform the source to send out the burst immediately; Otherwise, a NAK will be returned to release the previously reserved bandwidth, and initiate the retransmission of the request message after a back off time. In tell-and-go ,on the other hand, the source transmits bursts without making any bandwidth reservation in advance. At an intermediate node, the burst needs to be delayed before the switch control unit makes an appropriate reservation on an outgoing link .If the reservation fails at any intermediate node, a NAK will be sent back to the source to initiate the retransmission of the burst after a back off time .Various performance comparisons between these two conceptual approaches were given in Widjaja.I (1995) .It has been found that tell-and-wait outperforms tell-and-go when the propagation delay is negligible with respect to the using a FDL at each input port.

It accomplishes this by letting each control packet carry the offset time information and make the so called delayed reservation for the corresponding burst, i.e. ,the reservation starts at the expected arrival time of the burst .In the example shown in Figure the bandwidth is reserved for the first burst starting from the burst arrival

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time instead of the arrival time of control packet. At each intermediate node, the offset time is updated (reduced) to compensate for the actual control packet processing/switch configuration time.

The delay experienced by a control packet might vary for different reasons. In addition, when we consider deflection routing in an OBS network, the minimal offset time for the primary path might not be enough if the burst takes a longer alternate path. In such a case, an extra offset time can be added. Another important feature of JET is that the burst length information is also carried by the control packet, which enables it to make a closed-ended reservation (i.e., only for the burst duration with automatic release) instead of an open ended reservation (i.e., which would not be terminated until a release signal is detected).

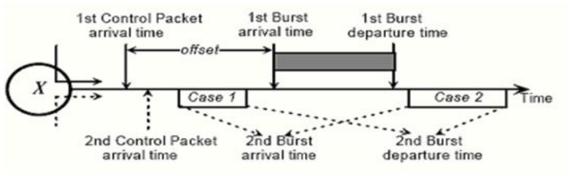

Fig. 1: Jet Protocol.

This closed-ended reservation helps the intermediate node make intelligent decisions as to whether it is possible to make a reservation for a new burst and thus the effective bandwidth utilization can be increased. An example is shown in Fig 1 ,where the reservation for the 2nd burst arrival in Cases 1 and 2 can succeed if and only if at the time when the 2nd control Packet arrives, the intermediate node makes closed-ended reservations for both the first and second bursts.

Burst Switching:

In a conventional electronic router/switch, contention between packets can be resolved by buffering. However, in OBS networks, no or limited buffering is available and thus burst scheduling and contention resolution must be done in a different manner.

*Scheduling Algorithms***:**

When wavelength conversion capability is assumed, an incoming burst may be scheduled onto multiple wavelengths at the desired output port. A burst scheduler will choose a proper wavelength for this burst taking into consideration the existing reservation made on each wavelength and make a new reservation on this selected channel.

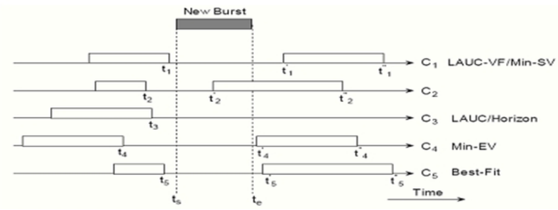

Fig. 2: Illustration of scheduling algorithm.

The scheduling horizon is defined as the latest time at which the wavelength is currently scheduled to be in use. In Figure time t1‖ is the scheduling horizon for channel C1. A simple scheduling algorithm: Turner.J, (1999) , which is also called the LAUC (latest available unscheduled channel) algorithm in Xiong Y, (2000) works as follows, for each wavelength, a single scheduling horizon is maintained. Only the channels whose scheduling horizons precede the new burst's arrival time are considered ―available‖ and the one with the latest scheduling horizon is chosen. The horizon is then updated after making the reservation for the next burst. The basic idea for this algorithm is to minimize bandwidth gaps/voids created as a result of making a new reservation. In Figure, channel C3 will be reserved if Horizon is applied. Simplicity in both operation and implementation is the main advantage of the Horizon-based algorithms. However, they waste the gaps/voids between two existing reservations, e.g., t0, t1 on channel C1 in Fig2 . When a FDL set is available or the offset-time based QoS scheme to be mentioned, many such voids will be generated. Therefore, algorithms capable of void filling .i.e., making new reservation within existing gap are desirable.

Optical Burst Chain Switching (OBCS):

Reservation Process:

In the proposed optical burst chain switching (OBCS) scheme, the source node connection and destination pair regularly measures the arrival rate for the connection, which is used as the predicted bandwidth demand.

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This predicted bandwidth demand will be attached to a PROBE packet, which collects the time slot availability information at a wavelength along the end-to-end path. Once the probe packet reaches the destination, the probe packet will have the latest information on the time slot availability along the end-to- end path. Now the destination node will choose sufficient slots to meet the predicted bandwidth demand. After that, a RESERVE packet will be sent back to reserve the chosen time slots along the same path, and the time slot availability will be updated at each node along the backward path accordingly after reservation. In OBS, each burst is associated with a control packet and there is a time gap (offset) between the burst and the control packet.

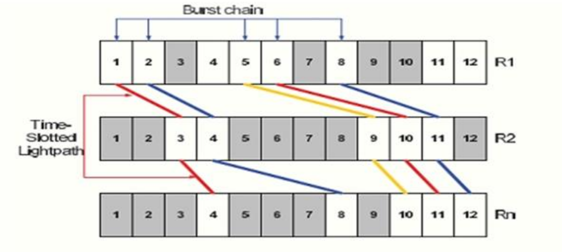

Fig. 3: Burst chain and time slotted light path.

In the proposed scheme, there is also a time gap between the reservation and the actual burst sending time. The burst chain will be switched inside the core nodes as a whole unit without collision, thus leading to high performance transmission without any wavelength converters and large amount of optical buffers (FDLs). Note that the burst chain is valid for burst transmission only for one frame (the subsequent frame). The same process will repeat to build burst chains for subsequent frames, thus enabling dynamic bandwidth allocation for each source for bursty traffic. The proposed scheme consists of the following four phases.

Probing Phase:

Let denote the time gap (offset) between the sending time of the PROBE packet and the beginning of the next frame. Let denote the frame size. The edge node starts probing for the subsequent frame at the ***(F-δ)***-th slot of the current frame. We use the measurement result within one frame time period to determine the arrival rate for the subsequent frame. So we use last time slots from the previous frame plus ***F-δ*** – time slots from the current frame as a measurement period. The measured average arrival rate by the edge node will be used as the predicted traffic arrival rate for this probing and reservation process. The number of requested slots for the initial frame is determined by the traffic waiting in the buffer at edge nodes. The probe packet is then sent to the destination node along the pre-determined routing path by shortest path first algorithm1. We assume each node knows the propagation delay on each of its links. Due to the propagation delay, the slot position number in the first node needs to be converted to the time slot position number in the second node using following formula

$$Ti+1= (Ti+di+1) \bmod F \qquad (1)$$

Where ***Ti*** is the time slot number in the node ***I,F*** is the frame size, and ***di,i+1*** is the propagation delay between the two consecutive nodes ***I*** and ***i+1***. Due to the FDLs installed for each wavelength, an incoming slot is allowed to be delayed/switched within a certain range in the proposed scheme ,which is determined by the maximum number of FDLs provided in each wavelength at each input link. Once a probe packet passes a wavelength at a node, the obsolete time slot information will be removed. A wavelength is randomly chosen for a probe message. An important issue is how many slots for which each node needs to maintain under this scheme.

Time Slot Searching Phase:

Once the PROBE packet reaches the destination, the destination will start searching for enough time slots according to the information collected by the PROBE packet .Note that the time slot searching process is done at the last node locally. The searching process will start from the first slot in the first frame for the first node. Once a slot ***i*** is found to be available, the algorithm will check whether the reserved bandwidth does not exceed the predicted bandwidth requirement for the time period from the beginning of the frame to time slot ***i*** so as to satisfy the following inequality.

$$N\,req/F \geq N\,resv/I \qquad (2)$$

Where ***N req*** is the requested number of timeslots, ***N revs*** is the number of timeslots which has been already reserved before timeslots ***i*** with in the same frame for the same request. If the above condition can be met, then time slot ***i*** will be reserved.

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Backward Reservation Phase:

A reserve packet with the burst chains determined above at the destination node will be sent back to reserve the chosen time slots and configure the time slot switching along the backward path. During this phase, if the chosen time slots are still available at an intermediate node, the time slots will be reserved. If some chosen time slots at an intermediate node have been reserved by other RESERVE packets arriving earlier, the corresponding time-slotted light path needs to be released. A RELEASE packet will be sent from that intermediate node to the destination node along the same forwarding path to release those corresponding time slots at all downstream nodes. The corresponding time- slotted light path will also be deleted from the RESERVE packet. The RESERVE packet will continue its journey until it reaches the source. If the RESERVE packet cannot reserve required time slots and the time left is still enough to finish another probing and reservation process before offset δ ,another PROBE packet will be sent to reserve more slots. If the remaining time to the start of the next frame in the source node is larger than the round trip time to the destination, we consider that the time left is still enough for another reservation process.

To limit the signaling overhead, a maximum number of probing retries in each frame is set in our scheme. Therefore, the process will repeat until either enough time slots are reserved, or there is no enough time left to finish another probing and reservation process before offset δ , or the number of probing retries exceeds the maximum number of Probing retries allowed.

***Remark for Inequality*:**

The left side of Inequality (2) is the average predicted requested bandwidth. The right side of Inequality (2) is the average reserved bandwidth for the time period from the beginning of the frame to time slot ***i.*** The proposed algorithm reserves time slots and checks time slot availability and Inequality (2) from the beginning of a frame .If Inequality (2) holds, then the average reserved bandwidth does not exceed the average bandwidth requirement for the time period from the beginning of the frame to time slot ***i*** . Otherwise, some reserved time slots will be wasted. For example, if ***N req*** is 100 slots, frame size is 1000 slots.

If all the first 100 slots are available, Inequality (2) will guarantee that the algorithm will not reserve all the first 100 slots for that request. Otherwise, the average reserved bandwidth (100/100=1) for the time period from the beginning of the frame to time slot 100 is larger than the requested bandwidth (100/1000=1/10), thus leading to the waste of a large amount of time slots during the first 100 time slots. since for the first available slot ***N resv*** = 0 and then Inequality (2) always holds in this case. The white slots mean available slots. Suppose that slot 1 in R1 is available and it meets the above condition, slot 1 in R1 is reserved. Then, the searching process will check whether that particular slot (slot 1) is also available in the second node (R2). If not, the algorithm will search at the second node for the first available time slot within a feasible range, which is determined by the maximum number of FDLs provided at each wavelength at each node.

If the algorithm can find such available time slot (slot 3) in the second node (R2),then such slot (slot 3) will be reserved and the same process will repeat for the next node (R3) until the last node. Thus, (1->3- >4) is found for this connection. We call (1->3>4) a time-slotted light path. Then, we consider slot 2 at R1 and select another time slotted light Path (2->4->8) in a similar manner. Next, the searching process will check the next available slot (slot 4) in R1.

Since the algorithm cannot find an available slot in R2 within a feasible delay range, say, 4 slots, which is determined by the maximum number of FDLs, for the time slot 4 in R1,the algorithm will release the unfinished light path originating from the time slot 4 in R1, and go back to the first node (R1) to search for next available slot, and begin another searching process until all the required slots are reserved, or the searching process reaches the end of the frame in the first node.

Thus, several time slot light paths will be set up by the PROBE packet. Then, we can build the burst chain at R1 by time slots (1, 2, 5, 6, 8) and this burst chain will be switched as a whole unit to the burst chain (3, 4, 9, 10, 11) at R2. Note that they are not the final burst chains for switching since the backward reservation may not be able to reserve those time slots in the backward path due to simultaneous reservation by cross traffic. Some time slot light paths may be removed from the burst chains in the next phase.

Burst Chain Building And Sending Phase:

The source will assemble the incoming IP packets to bursts with the same size as a time slot. At the beginning of each slot, if the current slot is reserved by the burst chain, one burst waiting in the source buffer will be sent to the destination. If there is no burst waiting in the buffer at that time, that particular slot will be wasted. That is reason why we have the requirement as shown in Inequality (2) to reduce the number of wasted time slots. The same probing and reservation process will repeat for every frame periodically to support burst traffic. As also adopted by other TDM WDM network, there will be a guard time (10ns) between two consecutive time slots to allow timing uncertainties. As mentioned , solid state switches can finish switching operation within 10ns. The guard time will be enough for an intermediate switch to finish switching between

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time-slotted light paths to different destinations.

RESULT AND DISCUSSION

Here we have chosen weighted fair queuing technique .The reason to go for this weighted fair queuing is that the IP packet loss is very less when compared with other queuing techniques like FIFO, PQ as shown in fig 4.

Fig. 4: IP Packet loss.

The Traffic received in this technique is more when compared with other techniques as shown in fig 5.

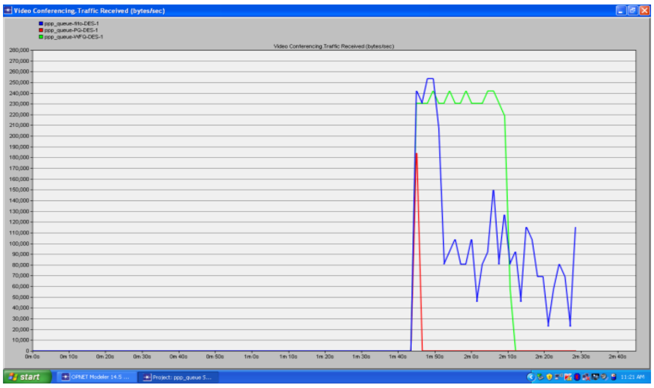

Fig. 5: Video conference traffic received.

To perform optical burst chain switching techniques the RSVP must enable. We can see the Probing and reserving phase are equal. This shows that all the resources are reserved as shown in Fig6.

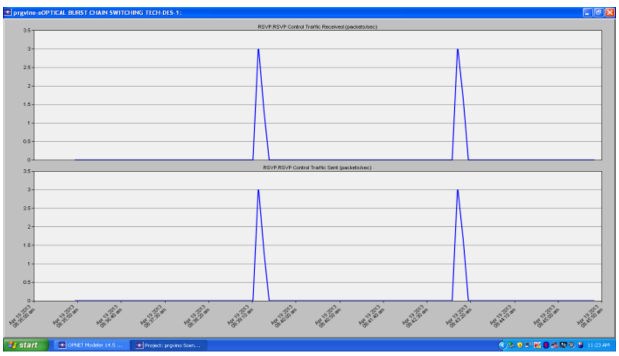

Fig. 6: RSVP Status.

At similar situation if we send data in OBS and OBCS, the OBCS transfer high data when compared with OBS. Traffic send in OBS is 3600 bytes/sec shown in fig 7.

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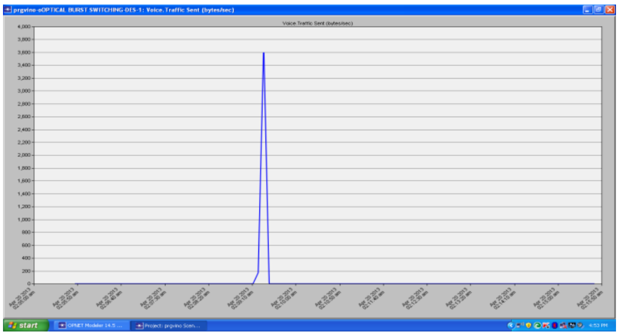

Fig. 7: Traffic sent in OBS.

Similarly traffic sent in OBCS is 12500bytes/second and 9750 bytes/second as shown in fig 8.

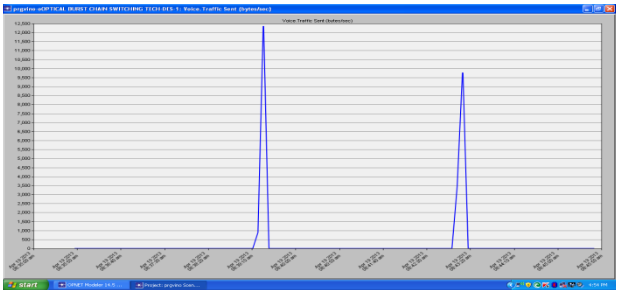

Fig. 8: Traffic sent in OBCS.

Packet delay variation in OBS is more than OBCS as shown in fig.9.

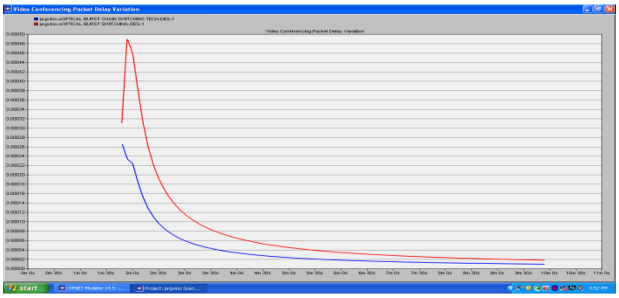

Fig. 9: Packet delay variation.

Packet end to end delay is more in OBS when compared with OBCS shown in fig.10.

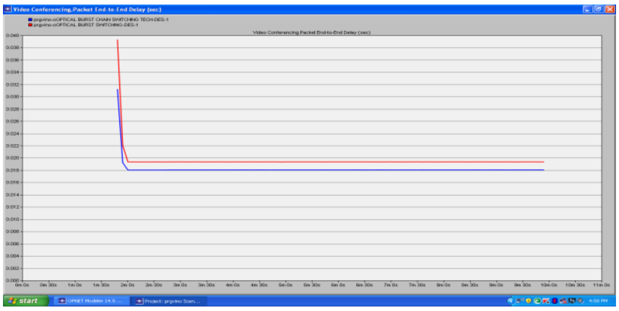

Fig. 10: Packet end to end delay(sec).

In addition there is no packet loss in OBCS as shown in fig.11

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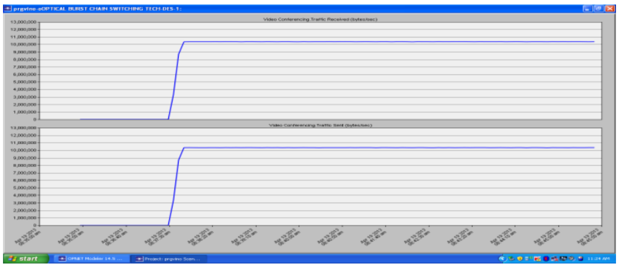

Fig. 11: Traffic sent and received in video conference.

Conclusion:

Shortest path was calculated depending on available bandwidth and distance. Then the path is reserved and burst gets transferred in that path. Thus the data rate gets increased in optical burst chain switching when compared with optical burst switching. We obtain high performance burst transmission for burst traffic by using full wavelength converters and electronic buffer at edge node. Here packet end to end delay, packet delay variation and packet loss is reduced while comparing with optical burst switching technique. So the packet loss and delay is less consequently the energy consumption of OBCS is less than OBS networks.

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