A Priority Based Optical Header Contention Resolution in Optical Burst Switching Networks

Suman Naskar
Himanshu Rajput

Department of Computer Science and Engineering
National Institute of Technology, Rourkela
Rourkela-769 008, Orissa, India

A Priority Based Optical Header Contention Resolution in Optical Burst Switching Networks

A thesis submitted on

$9^{th} May, 2011$

in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

by

Suman Naskar

(Roll no. 107CS011)

Himanshu Rajput

(Roll no. 107CS057)

Under the guidance of

Prof. Dr. Ashok Kumar Turuk

Department of Computer Science and Engineering

National Institute of Technology Rourkela

Rourkela-769 008, Orissa, India

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Orissa, India.

Certificate

This is to certify that the work in the thesis entitled ***A Priority Based Optical Header Contention Resolution in Optical Burst Switching Networks***, submitted by ***Suman Naskar*** and ***Himanshu Rajput***, bearing roll numbers ***107CS011*** and ***107CS057*** respectively, is a record of an original research work carried out by them under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of ***Bachelor of Technology*** in *Computer Science and Engineering* during the session 2007-2011 in the *Department of Computer Science and Engineering, National Institute of Technology Rourkela.* Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Place: NIT Rourkela
Date: May 9, 2011

Dr. A. K. Turuk
Professor and Head
Department of CSE
NIT Rourkela

Acknowledgment

This dissertation, has benefited in various ways from several people. Whilst it would be simple to name them all, it would not be easy to thank them enough.

We would like to thank our supervisor, Prof. Ashok Kumar Turuk for giving us the guidance, encouragement, counsel throughout our work. His undivided faith in this topic and ability to bring out the best of analytical and practical skills in people has been invaluable in tough periods. Without his invaluable advice and assistance it would not have been possible for us to complete this thesis.

Our sincere thanks to Pushpendra Chandra for his continuous encouragement, support and invaluable advice.Lastly we would like to express our gratitude towards our parents without whom nothing would ever have been possible.

Date: 09/05/2011
Place: Rourkela

Suman Naskar
Himanshu Rajput

Abstract

OBS is a promising switching paradigm for the next-generation Internet. In OBS, data packets are assembled into variable size data burst which are transmitted optically over Dense Wavelength Division Multiplexing(DWDM) networks without O/E/O conversion. The control packet is sent before the data burst to reserve resources and configure switches along the path .The control packet is sent along the separate control channel and goes through O/E/O conversion. We have discussed various OBS signalling protocols and Burst Scheduling Algorithms. As the data channel bandwidth will grow it will lead to the overloading of the control path.

In this thesis we have proposed an algorithm to resolve the contention of the optical header. The algorithm assigns the priority to each control packet arriving at the same time .The control packet with highest priority is selected for processing. Simulation results have shown that the technique is effective in improving the throughput.

List of Figures

List of Tables

Contents

1 Introduction

Over the past two decade or so,there has been a tremendous growth in Internet traffic.So, optical communication is the only solution to the ever increasing bandwidth requirements.Theoritically speaking,optical fibers can feed bandwidth demand of upto 50 THz.Above this,optical fibers are immune to electrical interferences and they provide an extremely low error-rate of the order of 10-12 bits.Optical fibers cant be tapped easily;so theyre much more secure[1,2].

Wavelength Division Multiplexing (WDM) techniques are now implemented as the network backbone. The main reason behind this is that these techniques offer gigabit level data rates/wavelength.Virtually speaking,in WDM therere many fibers in a single fiber.Its analogous to Frequency Division Multiplexing(FDM) of the electronic field.Here the full available bandwidth is divided into many non-interfering wavelengths. The best feature of this technology is:

- **Transparent :** Various wavelengths can carry data at different bit-rates and implementing different transport protocols,i.e,SONET,ATM etc.
- **Scalable :** Though number of wavelengths are limeited in WDM networks but each wavelength can be reused innumerable number of times.
- **Flexible :** Any existing optical network can be easily upgraded to a WDM network.

WDM networks can be classified as[2] :

- **DWDM(Dense WDM) :** Fiber bandwidth is divided into more than 8 channels.
- **CWDM(Coarse WDM) :** Fiber bandwidth is divided into less than 8 channels.

The main research motive behind developing various WDM techniques is to eliminate the frequency and amount of O/E/O (Optical-Electronic-Optical) conversions.This results in increased transmission rates as the signal will then persist mostly in the optical domain only.

Classically,data communication is implemented through two main types of switching techniques,i.e,Circuit Switching and Packet Switching.During the early years,these two techniques were even perceived as the mode of communicating in the optical domain also.But as time passed and technology advanced these techniques were found to be either rudimentary or too far fetched.OCS(Optical Circuit Switching) proved to me more rudimentary as it couldnt handle the ever increasing variations in traffic load.OPS(Optical Packet Switching) proved to be too much far fetched as it didnt match with the present technology available at this point ,as optical buffers ,i.e,FDLs(Fiber Delay Lines) are not yet so much developed.

So,another relatively new and far less implemented switching technique was then introduced.This technique is called Optical Burst Switching(OBS).It was developed keeping in mind ,all the pros and cons of the earlier techniques,i.e,Circuit and Packet Switching.Burst Switching is not so popular in the electronic arena,but its a big blessing to the optical arena.Its a perfect middle-way solution to the problems of both circuit switching and packet switching.

1.1 Optical Networks

Different types of optical networks are as follows:

1.1.1 Optical Circuit Switched Networks

In this mode of communication,end-to-end optical paths between source and destination is first routed in the network before the transmission of data along the optical path.this end-to-end optical path can comprise of multiple nodes and wavelengths. OCS is a two-way reservation protocol .Here each call for data transmission between source and destination consists of 3 distinct phases[16]:

- **Circuit Set-Up**
- **Data Transfer**
- **Circuit Tear-Down**

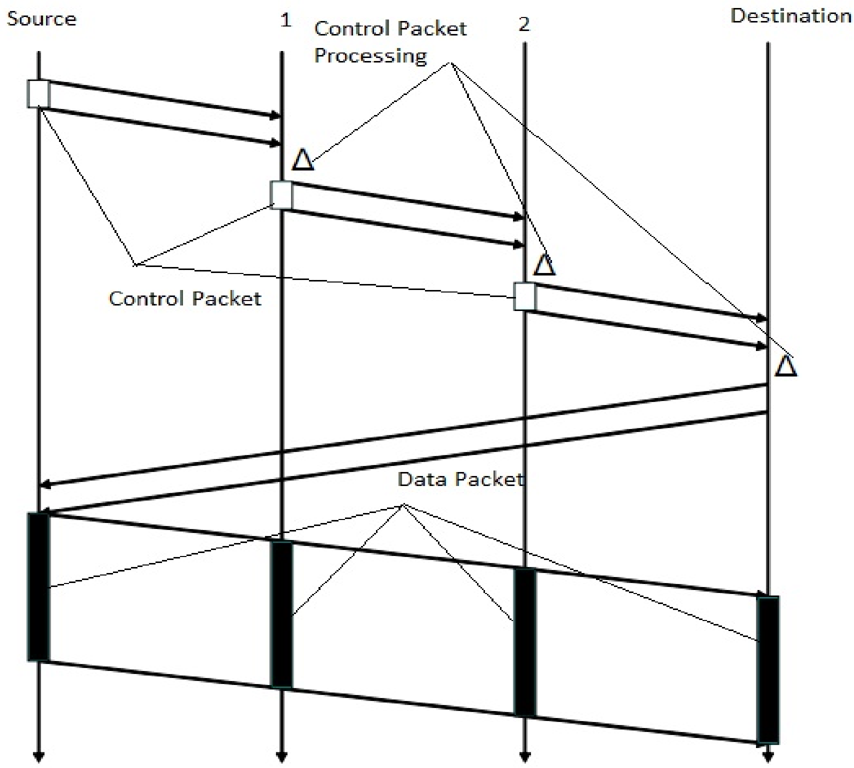

Figure 1: OCS Paradigm

Details of these 3 phases are:

1. In the first phase,a circuit is being set-up between the source and the destination which is based on the concepts of Wavelength Routing .Source sends a request call to the network and it expects an acknowledgement from the destination node,in case an available path is there,before sending the data.Circuit is set-up by reserving any fixed wave-channel of mentioned bandwidth,at every node falling in between the path from source to destination.These nodes are configured such that,these wave-channels between adjacent links can be set as an established path during the whole duration of the call.Thus,there is no need of optical buffers in any of these intermediate nodes[17].

2. In the second phase,data is transferred from source to destination.Since path is fully set and reserved there is no need of optical-electrical-optical conversion(O/E/O) conversion.

3. In the last phase,the established circuit is broken after the transmission is over.

OCS is very efficient for networks where connection duration is much longer compared to connection set-up time.This also efficient in networks where nodes communicate with each other at a constant bit-rate.An example of such network is SONET/SDH.

But the main problem with this network scheme is that the present IP-centric networks are very bursty in nature.OCS cannot adapt itself efficiently for dynamic traffic.In this case OCS either wastes some bandwidth during low traffic loads or there is too much overhead for frequent setup or release[18].

1.1.2 Optical Packet Switched Networks

In OPS mode of communication data is transferred in the unit of packet.These packets are buffered at the intermediary nodes and then are routed at every node to get to the destination.Every packet will have different delay corresponding to its packet size.Packets are switched as datagrams or virtual-circuits[19-22].Every packet is processed in every intermediate node.Since this processing goes on in electronic domain,so there is need of optical buffers i.e,FDLs at every intermediary nodes.The scheme followed in every node is store and forward.Here packet is first buffered,then it is converted to electronic form from optical form,then its processed an finally its again converted back to optical form.Now its forwarded to the next hop.

Each packet consists of two parts:

- **Header**
- **Payload**

An overview of OPS networks:

1. Firstly,Header and Payload of the packet is separated.
2. Header is then processed electronically whereas Payload is buffered optically.
3. After processing,a new header is generated ,then its converted to optical domain and added to the payload.

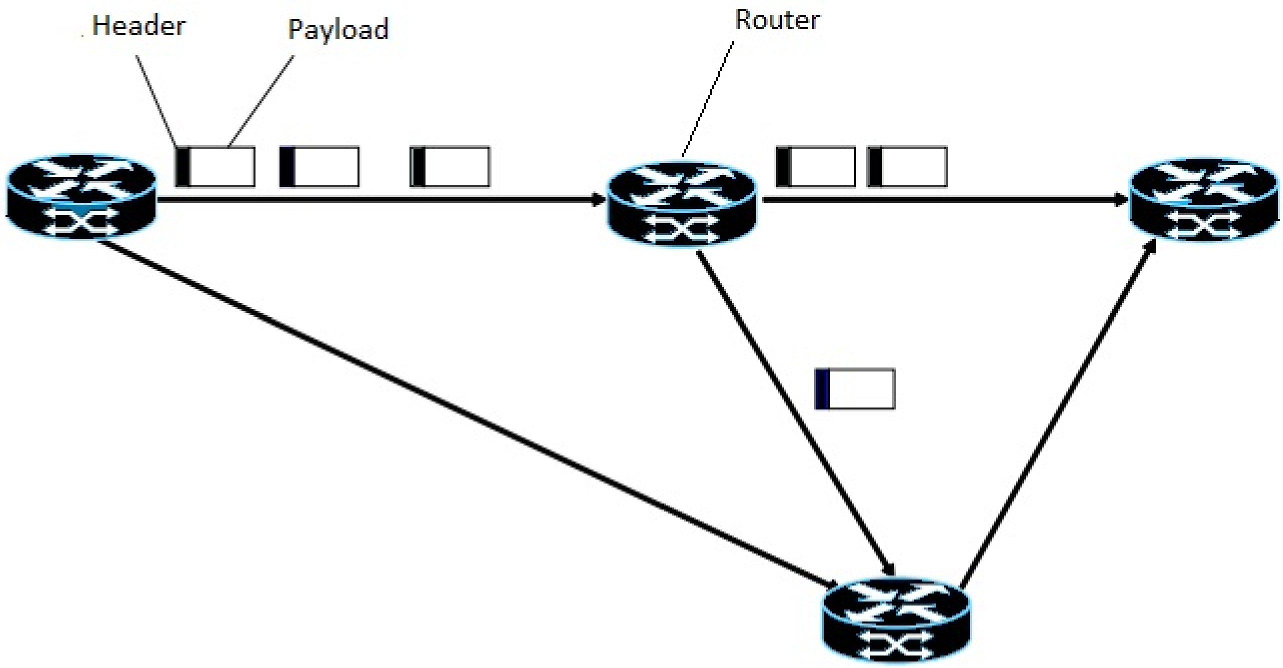

Figure 2: OPS Architecture

4. The packet is then routed to the next hop.

OPS networks can be broadly classified into 2 types[16]:

- **Synchronous :** These are networks where Packets are of equal size.
- **Asynchronous :** These are networks where Packets are of unequal size.

OPS couldve been a very efficient scheme if the optical buffers i.e optical RAMs were more technologically advanced.Packet switched networks statistically shares /multiplexes the resources and hence increases the utilization of bandwidth.

1.1.3 Optical Burst Switched Networks

OBS basically tries to combine the advantages of OCS and OPS while trying to overcome their limitations.

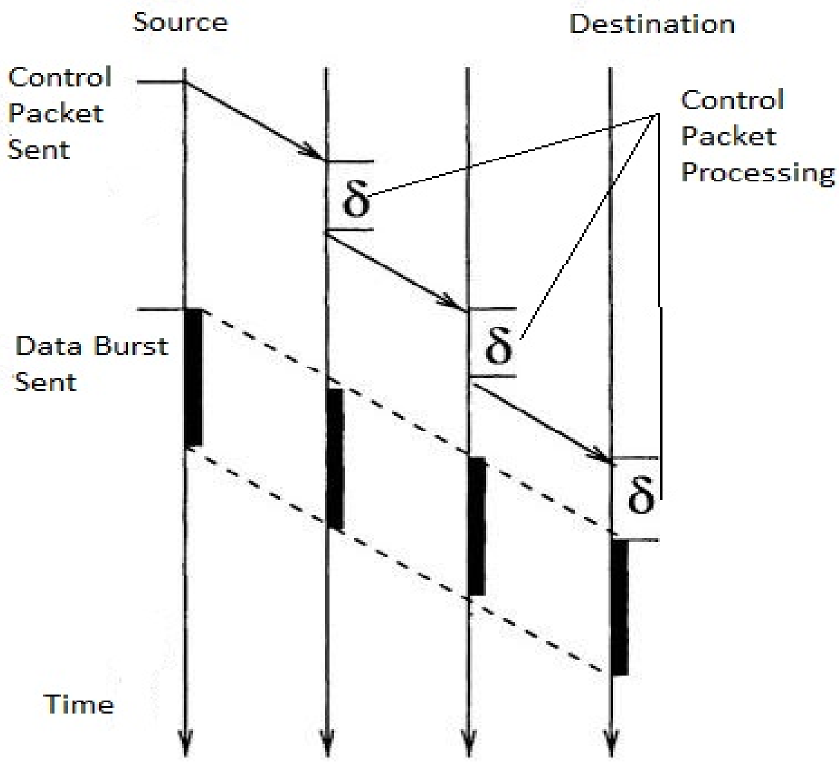

Figure 3: OBS Paradigm

In OBS networks,Data is assembled in the source node to form Data Bursts.Bursts are aggregation of small data packets.Typically its length varies from some microseconds to many hundreds of microseconds.Each burst has a corresponding control packet.Control Packet contains information about the data burst.Different attributes of control packet are:

- *length of data burst*
- *source address*
- *destination address*
- *offset time*

Control Packet(CP) is sent through a separate wavelength called Control Packet Wavelength Channel.Its sent ahead of the Data Burst(DB).When a Control Packet reaches a node,Optical-Electronic conversion takes place.The CP is then processed in the node and reservation for the incoming DB is done.A new Cp is then processed out containing the next hop address[25-26].Then theres Electronic-Optical Conversion and CP is further forwarded.

Here no or negligible Optical Buffer is required as theres prior reservation of bursts at a node,so there is no need of waiting or queuing.As the control packet length is small so processing overhead(O-E-O conversions) is also very less.In this technique theres no prior static path being set-up,rather path is being set-up dynamically at every progressing node.Thus it rectifies the flaws of both OCS and OPS.

Now the three switching paradigms can be compared among themselves by considering various criterias like *Bandwidth Utilization,Setup Latency,Switching Speed,Processing Complexity & Traffic Adaptivity.*

Table 1: Comparision between Different Switching Paradigms[7]

Switching Paradigms	Bandwidth Utilization	Setup Latency	Switching Speed	Processing Complexity	Traffic Adaptivity
OCS	Low	High	Slow	Low	Low
OPS	*High*	*Low*	*Fast*	*High*	*High*
OBS	*High*	*Low*	*Medium*	*Low*	*High*

1.2 Motivation

Wavelength division multiplexing(WDM) can act as an alternative to traditional electronic networks to meet the ever-increasing demand for the bandwidth. For use in all-optical WDM networks, there are three switching paradigms namely, optical circuit switching (OCS), optical packet switching (OPS), and optical burst switching (OBS). In bursty network, Optical circuit switching(OCS) provides coarse granularity bandwidth and cannot adapt to the dynamic traffic well, which leads to the inefficient resource utilization.On the other hand technical constraints like no RAM buffer, costly all-optical packet processing, need to synchronize packet header and payload make Optical Packet Switching(OPS) infeasible. OBS combines the benefit of OCS and OPS while avoiding the limitations of both of them. In OBS control header is sent on different path which reserve resources and configure switches along the path.

The burst is sent after an offset time. As the traffic increases the control path gets overloaded. Different methods for the resolution of contending control packets have been proposed. Random method selects the control header randomly. Minimum offset first method selects the control header with minimum offset while maximum offset first methods selects the control header with maximum offset.

In this thesis we proposed a priority based algorithm to resolve contention of control packets in OBS network.

1.3 Thesis Organization

Rest of the thesis is organized into the following chapters : Chapter 2 gives brief introduction of OBS network architecture.In chapter 3 OBS signalling protocols are described.In Chapter 4 burst scheduling algorithms are discussed.Chapter 5 describes various contention resolution schemes.In chapter 6,the main area of research,i.e,Control Packet Contention Resolution Schemes have been thorougly discussed.In chapter 7,the proposed algorithm of ours,i.e,Maximum Priority scheme has been discussed thoroughly.In Chapter 8 our simulations and results have been analysed.In Chapter 9 we've drawn a conlusion of our work.Finally we've proposed some future work in this field.

2 OBS Architecture

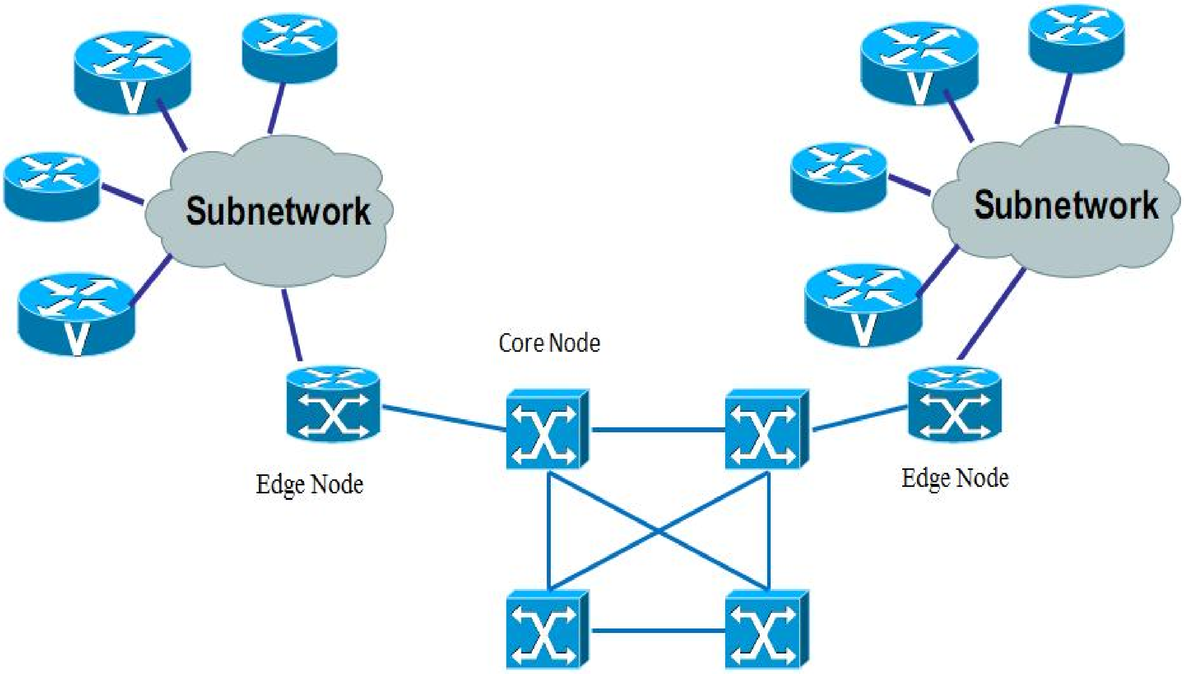

Figure 4: OBS Node Architecture

An optical burst switch network consists of nodes linked by fibre links. Each fiber link supports multiple wavelength channels using wavelength division multiplexing (WDM).Nodes in OBS network are of two types: edge nodes(ingress and egress nodes) and core nodes. Source node is the ingress node and destination node is the egress node[16]. Figure 4 shows the OBS functional diagram. The main functions of an ingress node are burst assembly, signaling, generating the burst header, determination of the offset time, and RWA. The core nodes are responsible for switching bursts from all of the input ports to the scheduled output ports based on the control packets, and contention resolution.

Data bursts from input traffic are assembled by ingress nodes before sending to the OBS core network. Data bursts are put into different queues. Burst scheduling unit selects the next burst which is transmitted according to a burst scheduling algorithm. For each outgoing burst an offset time is set by the setting unit. Then the ingress node sends the burst header packet towards the egress node on a dedicated control

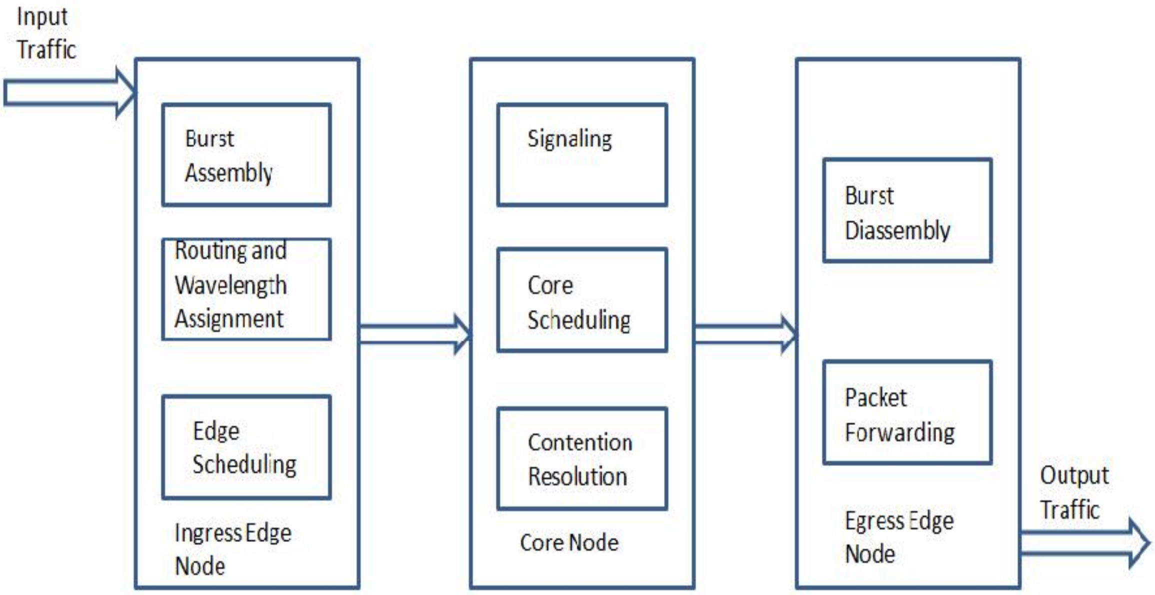

Figure 5: Functionality of Nodes in OBS Network

channel. The burst header packet carries information about the arrival time, size of the data burst and configure switches at the nodes along the path. Then, the data burst is transmitted in the all-optical domain after its offset time.For reservation of wavelength each core node uses a burst scheduling algorithm. FDLs are used as buffers to resolve wavelength contentions. At egress nodes bursts are disassembled into IP packets and forwarded to adjacent access networks.

3 Wavelength Reservation Schemes

These reservation schemes helps us to determine how and when to reserve and release a bandwidth.Reservation Schemes are broadly of two types[16]:

- *Immediate Reservation Schemes*
- *Delayed Reservation Schemes*

In Immediate Reservation Schemes,wavelength for data burst is reserved ,immediately after Control Packet arrives to that particular node.If wavelength cant be reserved at that point,then the data burst is dropped.In Delayed Reservation Scheme Control Packet and Data Burst are separated by an offset and the wavelength for the data burst is reserved after the offset time,i.e,just before the first bit of data arrives.Here also if wavelength cant be reserved,then the data burst is dropped.

Some reservation schemes have been proposed in OBS which is determined by *offset-time,wave-channel bandwidth and control management.*These schemes are:

- **Tell-And-Wait(TAW)**
- **Tell-And-Go(TAG)**
- **Just-In-Tme(JIT)**
- **Just-Enough-Time(JET)**

3.1 TAW

TAW is a 2-way reservation scheme.Here,before data burst is sent from the source node,its control packet is released.The Control Packet goes to each and every node along its transmission path and reserves wave-channel for the data burst.The control Packet goes on doing it until it reaches the destination.If theres successful reservation upto the destination node,then it sends an ACK(Acknowledgement) back to the source in the reverse direction of the transmission path.The source upon receiving this ACK signal,releases its data burst.Upon unsuccessful reservation upto the destination,the destination node sends back a NACK(Negetive Acknowledgement) signal

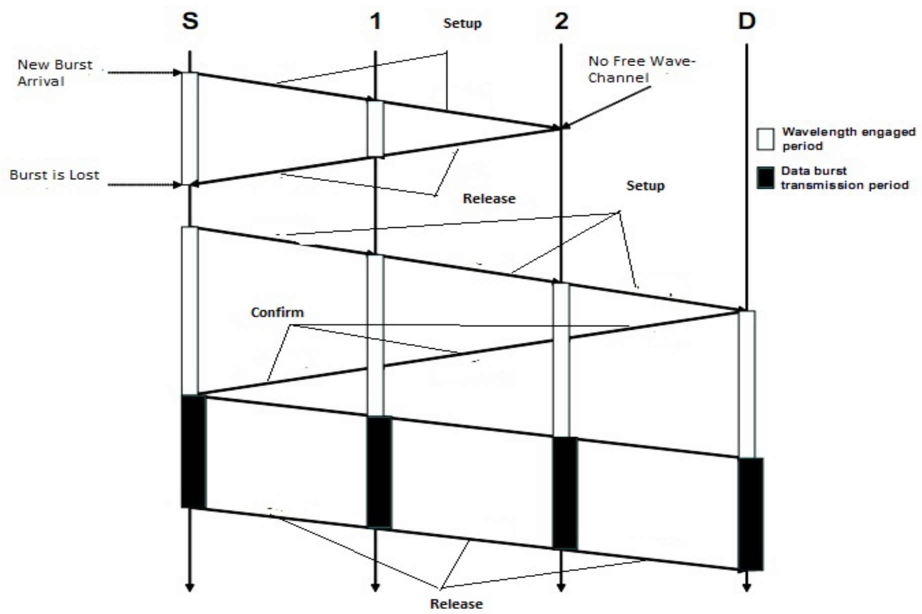

Figure 6: TAW Protocol

in the reverse direction of the transmission path.On its way back it frees the reservation made in every node for the upcoming data burst[16].NACK upon reaching to the source,drops the data burst.

3.2 TAG

Burst is sent from source before making any pre-reservations.Until source receives an Acknowledgement(ACK) from destination,a copy of data burst is held in the source node.If there is failure in reservation at any intermediate node,then a NACK is sent back to the source[2].In this reservation scheme,at any intermediary nodes,burst might be delayed for Control Packet processing.So,buffer may be required.

3.3 JIT

JIT is a one-way scheme having an *immediate reservation strategy*.Here resource for data burst is reserved immediately after the processing of the Control Packet.The reserved wave-channnel is booked until the end of transmission of bursts.If required wave-channel is not reserved at that specific time,then theres reservation failure[2].

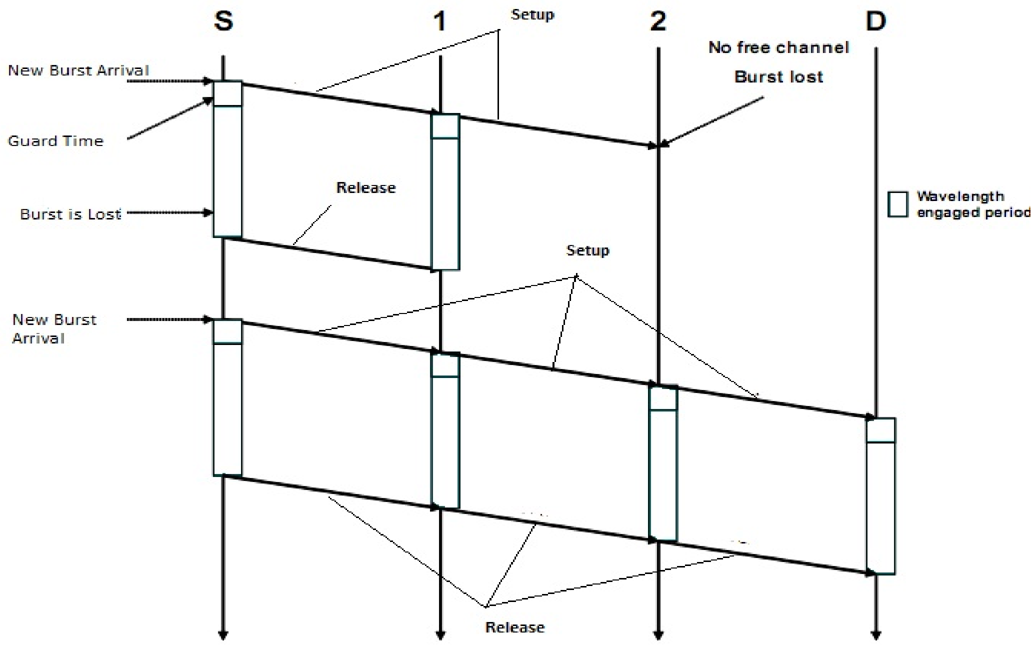

Figure 7: TAG Protocol

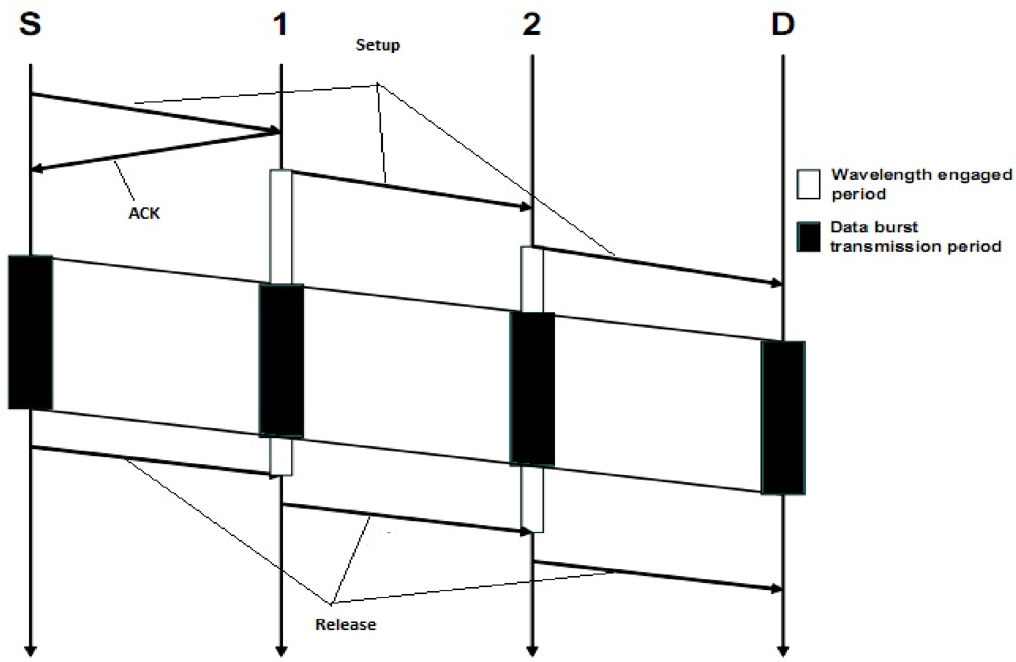

Figure 8: JIT Protocol

3.4 JET

JET is the most frequently used OBS reservation protocol.Its also a one-way reservation procedure.This scheme applies *delayed reservation strategy*.Here,the reservation is done from the expected arrival time of the burst rather than of the control packet.The offset set in the control packet plays an important role in reservation in this scheme[16].In short,it can be said that in this scheme resource is booked at any node only for the transmission time of the incoming bursts.

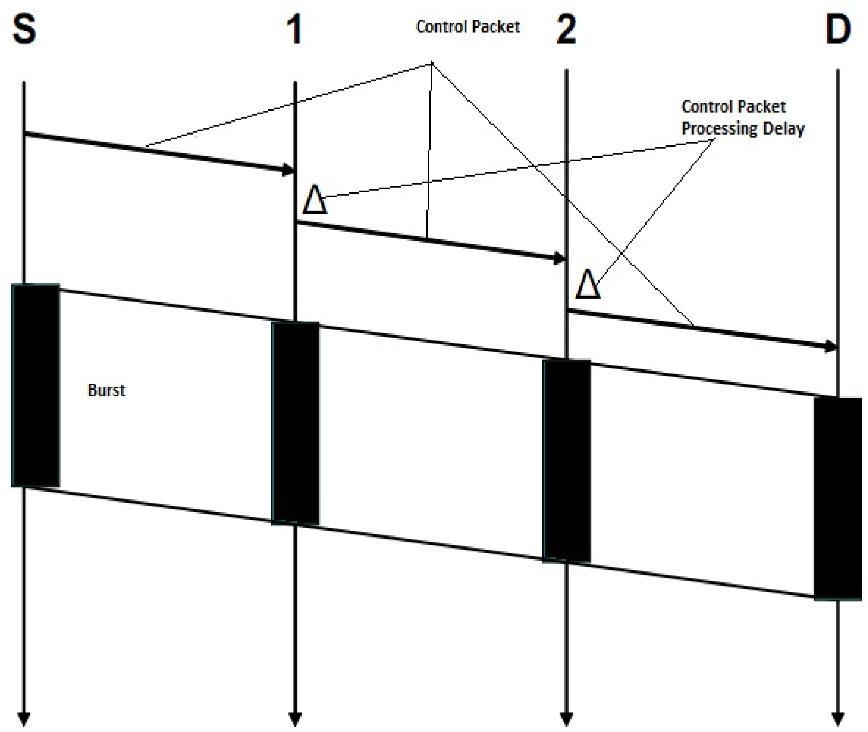

Figure 9: JET Protocol

4 Burst Scheduling Algorithms

At every node,the Control Packet first arrives.It's processed and a wave-channel scheduling algorithm is deployed,in order to reserve an wave-channel for the incoming data burst[2].All required information is obtained from the Control Packet by the scheduler.Scheduler tracks the time slot availablity in each and every wave-channel.It selects one among them.The main motive behind this selection should be reduction of burst loss.The algorithm should also be non-complex as these nodes are operated in very high speed and bursty environment.Another point that should be kept in mind is that control packet should be processed successfully before the arrival of data burst[3].Here if Channel A is scheduled then,

If Control Packet arrives at time $t = \alpha$
If Offset Time $t = \beta$
If Burst Reservation Duration Time $t = \gamma$
A is reserved for duration :

$$T_{interval}=[\alpha+\beta,\alpha+\beta+\gamma] \tag{3.1}$$

Now we will discuss various known scheduling algorithms[4,5].Algorithms are distinguished mainly in terms of their complexity and performance.But these scheduling algorithms can more or less be classified into two broad categories:

- ***Without Void Filling[4]*** **:**This scheme implements the technique where a wave channel is scheduled for an incoming data burst, which arrives at time t ;only when it is completely unscheduled at time t.e.g:FFUC,LAUC etc.
- ***With Void Filling[5]*** **:**This scheme implements the technique where a wave channel is scheduled for an incoming data burst at time t;only if there is a void in the wave channel between two successive data burst reservation at time t.e.g:FFUC-VF,LAUC-VF,Min-EV,Max-EV etc.

4.1 Without Void Filling

The main aim of these algorithms is to find *Unscheduled Channel.*At time t,a channel is said to be unscheduled;only if,no data burst uses the channel at or after t[2].

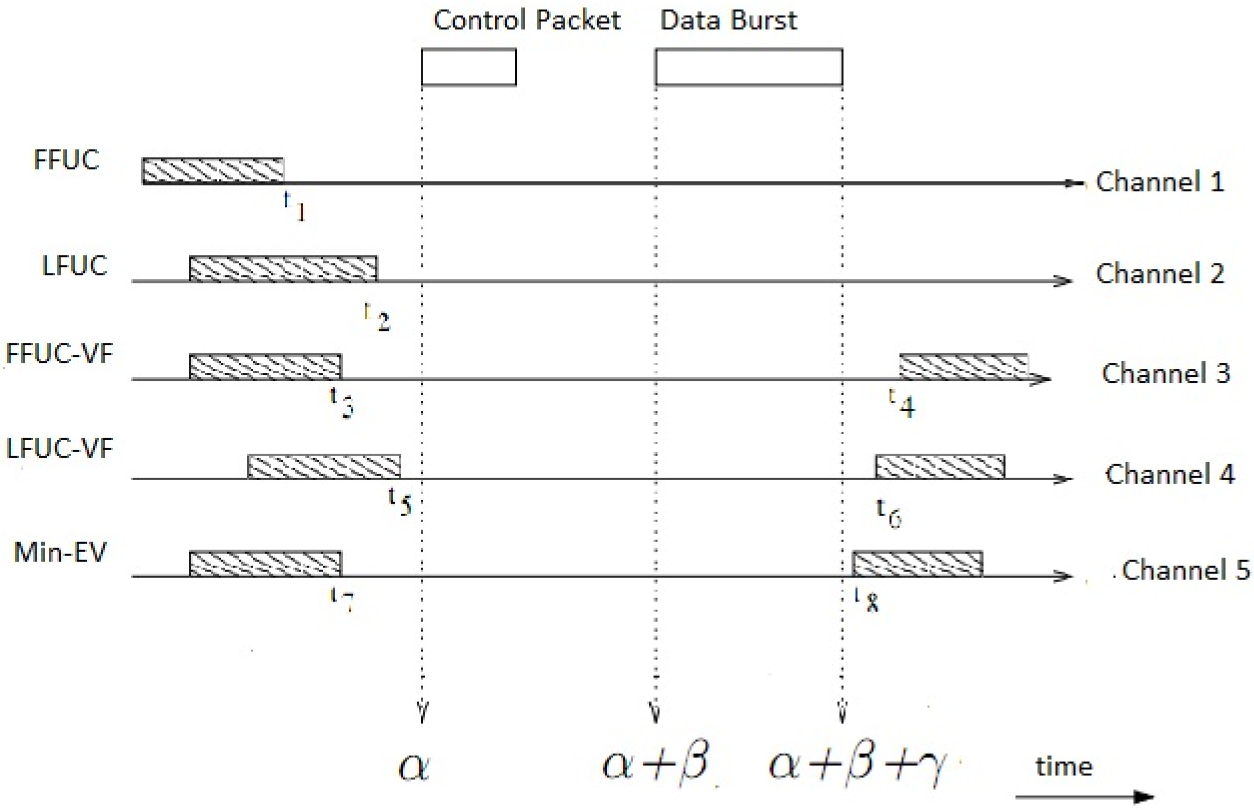

Figure 10: Burst Scheduling Schemes

4.1.1 First Fit Unscheduled Channel (FFUC)

First Fit Unscheduled Channel(FFUC) schedules an unscheduled channel for the incoming data burst[5,6,7].FFUC keeps track of all the unscheduled channels at any particular point.Then when a request for reservation of wave-channel arrives,it simply scans all the unscheduled wave-channels to find the first available fit wave-channel for it.

Suppose there are 3 available unscheduled wave channeles A,B and C which are available in this order only.Then on implementing FFUC,channel A will be allotted for the incoming data burst as this is the first available one.

The main advantage of this algorithm is that it is fast,because it checks relatively lesser number of channels before scheduling a channel from them.The best case complexity of this algotithm is $O(\log n)$.Here n denotes the no of wave-channels alloted to carry data burst[9,10].

The main disadvantage of this algorithm is that there is no scope of optimum utilization of network's full resources.This occurs because:

1. it stops after finding the first available fit channel.
2. it doesn't consider the voids between two scheduled data bursts that may easily accomodate this present incoming data burst.

4.1.2 Latest Available Unscheduled Channel(LAUC)

Latest Available Unscheduled Channel(LAUC) schedules an unscheduled wave-channel where the void between two consecutive scheduled bursts is minimum[6,8].Suppose there are two wave channels A & B.Let,A was last alloted at time t_a and B was alloted at time t_b.If the time of arrival of a new incoming burst be t_c.If ,(t_c-t_a) > (t_c-t_b) ,then the new burst is alloted to channel B.

Likewise incase of FFUC,LAUC also has a best case complexity of $O(\log n)$ .Above this,incase of LAUC network resources are more efficiently utilized whenn compared with FFUC.

4.2 With Void Filling

The main aim of these algorithms is to find *Void Channel* in the most efficient way.A channel is said to be void,if it has an unused space between two consecutive data burst reservations[2].

4.2.1 First Fit Unscheduled Channel With Void Filling(FFUC-VF)

First Fit Unscheduled Channel With Void Filling(FFUC-VF) checks all the wave-channels in a particular order.It checks the voids in them and when it finds the first suitable fit void among them,it allocates the incoming data-burst to that particular void[7].

Suppose there are two wave channels A & B.Let,both of them have voids of required size for the new incoming burst.But,the new data burst will be allocated to channel A only as it is checked before B.If there are maximum of n number of data bursts scheduled to every wave-channel and if there are k number of wave-channels then the complexity of FFUC-VF algorithm is $O(k \log n)$[2].This is because,if we apply binary search algorithm in every channel to find suitable voids,then the best case time consumed is log n.Now,if we compute this for the k channels we get the above complexity.

The main advantage of this technique is that there is optimum utilization of the available resources.But,the visible disadvantage of this technique is that the time of execution of tis algorithm is more compared to the previous ones.

4.2.2 Latest Available Unscheduled Channel With Void Filling(LAUC-VF)

Latest Available Unscheduled Channel with Void Filling(LAUC-VF)[7,8],scans all the wave-channels alloted for data transfer,to find all the voids that are available for the time $T_{interval}$ as in Equation (3.1).Then it selects a wave-channel from all these available channels such that the time interval between newly arriving data burst and the end time of the last scheduled data burst is minimum[2].

Suppose there are two channels A & B.Now,the time difference between the newly arriving data burst and end time of the last scheduled data burst by using the parameters of Equation (3.1) are: $(\alpha+\beta\text{-}t_A)$ & $(\alpha+\beta\text{-}t_B)$ respectively.Here if $(\alpha+\beta\text{-}t_A) > (\alpha+\beta\text{-}t_B)$,then channel B is alloted.

The complexity of this algorithm is same as that of FFUC-VF.State Information of all data channels are needed to be maintained in order to implement LAUC-VF at any node.This makes implementation of LAUC-VF more complex.But,it utilizes network's resources more efficiently.

4.2.3 Minimum End Void(Min-EV)

Minimum End Void(Min-EV) is just a small variation of LAUC-VF[10].Like the previous technique it also scans all the available data channels to find a fit void among them.Then it checks that in the selected data channel the void between the newly scheduled data burst end time and the previously scheduled data burst start time is minimum[2].

Suppose there are 3 channels A,B & C.Then using the parameters of Equation (3.1) we find the following values: $(t_A\text{-}(\beta+\gamma))$, $(t_B\text{-}(\beta+\gamma))$ & $(t_C\text{-}(\beta+\gamma))$.Now,Min-EV selects that data-channel which has the minimum value among the above values.The complexity and performance of this algorithm is more or less same as that of LAUC-VF.

Changing slight parameters many other similar scheduling algorithms like this one can be adapted.Some of these are Minimum Start Void(Min-SV),Maximum Start Void(Max-SV) & Maximum End Void(Max-EV).

5 Contention Resolution Schemes

One the biggest area of research in the field of optical communication is Contention Resolution.Contention occurs when more than one data burst tries to access the same wave-channel as the output link at any particular node.In electronic arena this would never be any problem as it can be easily resolved by using electronic buffers like RAM.But in Optical arena as the technology is not yet that developed to apply this strategy effectively,resolving contention is an open fielf of research.In OBS networks this contention problem can however be solved by applying more than one of the the following strategies:

- **Using FDLs**
- **Wavelength Conversion**
- **Deflection Routing**
- **Burst Segementation**
- **Feedback Based Contention Resolution**

However if contention is still not resolved by any of these above mentioned schemes,then we eventually have no choice other than dropping the burst.

5.1 Using FDLs

This is the classic way of dealing contention problems.In the optical arena till date Fiber Delay Lines(FDLs) provide the only basic solution of providing optical buffers.Here one of the data burst is buffered in this optical fiber while processing is done with the othe data burst.But the problem with the success of this scheme is that till date technology is not yet that advanced to implement this solution successfully.

Presently available FDLs are very bulky and they require fiber of something around one kilometer to delay one packet for 5 μsec[11].Other problems with this procedure is that FDLs provide only some fixed delay[12] and data is queued in them in the same order as they're entered[2].So,FDLs are not at all commercially viable.

5.2 Wavelength Conversion

Wavelength Conversion is the technique in which the problem of contention among bursts is resolved by scheduling the bursts in different wave-channel in outgoing link.This approach utilizes space domain to resolve contention.In optical domain,there are innumerable number of wavelengths.In this technique,one or more bursts will be sent through different wavelength.So,no more than one burst will be using a wave-channel[1,14].

Suppose there are 4 nodes A,B,C & D and two connections between node pairs (A,D) & (C,D) are required to be established.Let us also assume that in both of these connections wave-channel W_1 is being used.At node B,both these try to acquire wave-channel W_1 for further transmission and hence creates contention.Let,connection (A,D) is allowed and the other one would then have been dropped.But in this technique for the other one an incoming wave-channel of W_1 is converted into an available wave-channel of W_2 for the outgoing link of B⟶D.In this way connection (C,D) is also established.

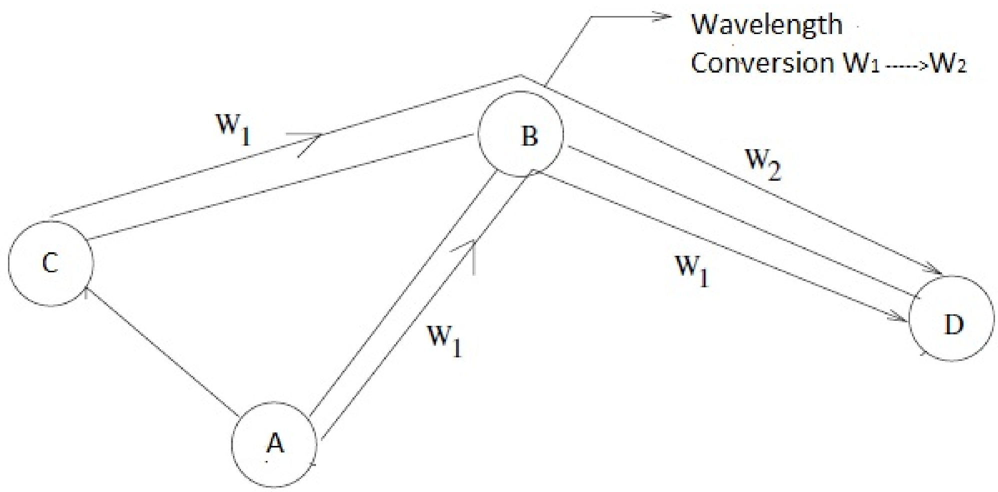

Figure 11: Wavelength Conversion

Optical switches of different conversion capabilities are differentiated as follows:

- **No Conversion :** In this the incoming wave-channel cannot be converted into another wave-channel.
- **Full Conversion :** In this the incoming wave-channel can be converted into any desired outgoing wave-channel.
- **Limited Conversion :** The conversion abiliti of these optical switches are limited.Only some specific incoming wave-channel can be converted into some limited number of outgoing wave-channels.

But the main problem with this technique is that developed technology is highly immature and thus deployment cost is very high[14,16].

5.3 Deflection Routing

Deflection Routing is a very good way of dealing with contention problems in OBS networks.In this process in case of contention a data burst is deflected to an alternate output port and hence it follows a different route to the destination[13,16].

Suppose there are 5 nodes A,B,C,D & E.Let data bursts are needed to be sent from nodes A & B both to node E.So two control packets denoted as C(A,E) & C(B,E) are first sent to node D.Assume, C(A,E) reaches first at node C.So,output link CE is booked by C(A,E).Now,when C(B,E) arrives,it doesn't get the output link and it might be needed to be dropped.In this deflection routing technique,other output links are checked by node C.It checks whether they're idle or busy.Here node D is idle at this time.So,the burst B(B,E) is forwarded via node D via the new link of C⟶D⟶E.In this way connection between B & E is established.

The advantages of this technique is that it's easy to implement.No additional hardware is required here,rather one just needs to change the routing protocol in any particular node in order to implement it.It's one small drawback of increasing the end-to-end delay.

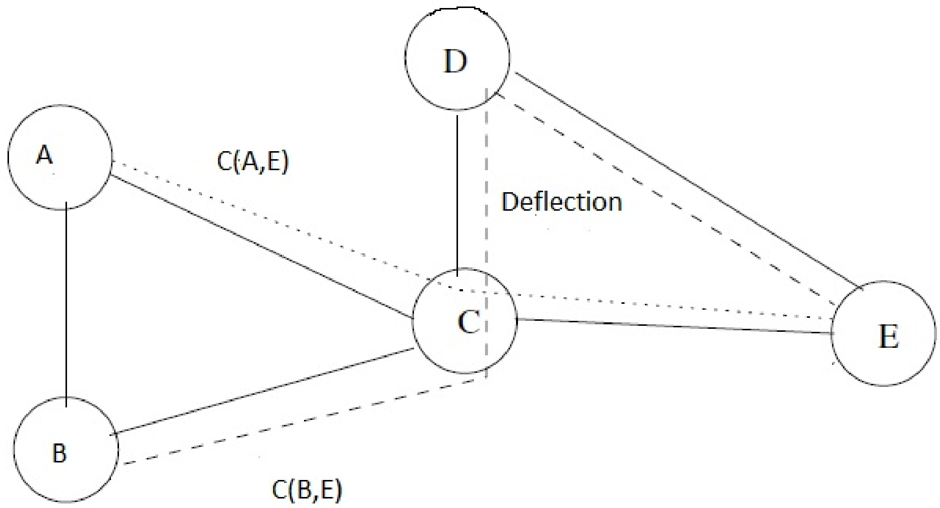

Figure 12: Deflection Routing

5.4 Burst Segementation

Burst Segmentation is one of the most practical implementaionn technique of handling burst loss.This is a technique to reduce the amount of packet loss rather than burst loss[12].Here,data burst is seen as to be composed of a number of segments.Now when two or more data bursts are overlaping,the ove rlapped segments of one of the burst is only droppef,rather than dropping the entire burst.Here performance is highly increased as it's measured in terms of packet loss rather than burst loss.But,it's bit difficult to implement as it requires complex control handling algorithms.

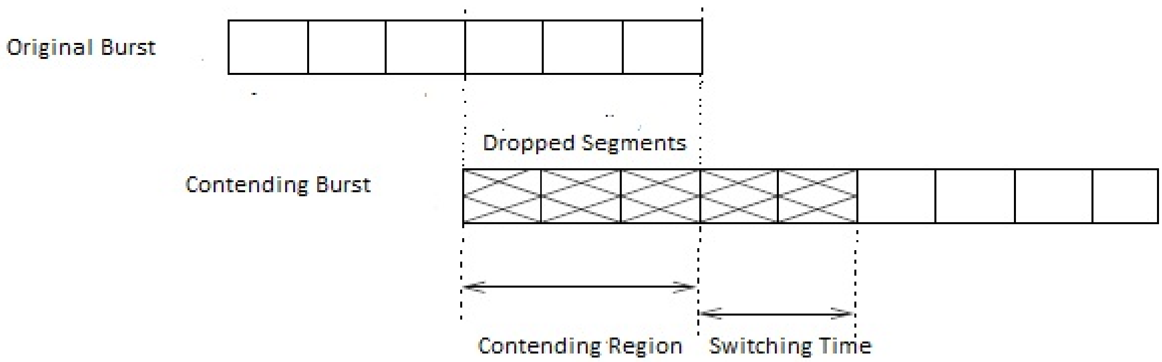

Figure 13: Burst Segmentation

5.5 Feedback Based Contention Resolution

All the above contention resolution schemes are reactive in nature.That is they comes to operation only after the core nodes are facing contention problems.So it can be said in the above mentioned techniques burst are sent via one-way reservation schemes and no feedback regarding successful transmission of bursts is there.Feedback Based Contention Resolution technique follows a proactive approach where it tries to avoid contention by studying the feedback log[1,2].

In these schemes,there is reduction of contention by dynamic adjustment of data flow at the source node inorder to avoid traffic congestion in the network altogether.Data may be sent in alternative paths,some data may be sent via under utilized nodes,inshort a load balancing scheme is followed globally[16].But the main problem with this scheme is that overhead is very much increased,so performance may be hampered. Now Comparing all the above mentioned techniques we draw the following table:

Table 2: Comparision between Different Contention Resolution Schemes

Scheme	Advantages	Disadv- -antages	Operation Type
FDLs	Simple to implement	Technologically not feasible	Reactive
Wavelength Conversion	Efficient solution	Expensive	Reactive
Deflection Routing	Extra hardware not required	Arrival is out of order	Reactive
Burst Segmentation	Packet Loss Ratio is less	Control Handling is complicated	Reactive
Feedback Based	Collision Free Transmission	High Overhead Cost	Proactive

6 Control Packet Contention Resolution Schemes

When more than one Control Packet arrives simultaneously at a particular node,then we need to apply these Control Packet Contention Resolution Schemes.In normal circumstances,one of the packet is dropped.But the main motive behind this resolution is to detect which one of the control packet is to be forwarded and which one is to be dropped or buffered.This is a very important area of study in OBS. networks.Since the incoming Control Packets are first converted in electronic signals before processing them,so various operations can be performed on them.

Control Packets are structures containing meta-data,i.e,it contains the information of the type and kind of the incoming data.These mainly contains the following informations about the incoming data burst:

- **Burst ID :**Every burst has an Identification ID called Burst ID.
- **Source IP :**This contains the IP address of the source from where the burst is generated.
- **Destination IP :**This contains the IP address of the destination to which the burst is to be sent.
- **Offset :**Offset duration is the time gap between the control packet end time and data burst arrival time.In Equation (3.1) it is denoted as β.
- **Wavelength :**It is the wave-channel through which data burst will be arriving.
- **NextPort :**It is the output port number through which the burst is to be sent.
- **Arrival Time :**It denotes the arrival time of the burst.Using parameters of Equation (3.1) it is denoted by $(\alpha+\beta)$.
- **Reservation Duration :**It denotes the duration for which the burst is to be reserved.In Equation (3.1) it is denoted by γ.
- **Size of Burst :**It contains the size of the incoming burst measured in *bytes*.

There are some already proposed Control Packet Contenton Resolution Schemes.By resolving this contention effectively we can improve the throughput of the overall performance of the network.Some of the known schemes are:

- *Random Selection[27-29]*
- *Maximum Offset First[27-29]*
- *Minimum Offset First[27-29]*

6.1 Random Selection

6.1.1 Algorithm

```
1.  /*Finding a random numbered Control Packet out of the given Control Pack-
    ets[30]*/
2.    while(randomBegin=1){
3.      if(randomtimes=CPnumber)
4.        break
5.      randomNumber:=random()%CPnumber
6.      for(i:=0;i<100;i:=i+1){
7.        if(randomNumber=randomHistory[i]){
8.          randomBegin:=1
9.          break
10.       }//end if
11.       else if(randomNumber ≠ randomHistory[i]){
12.         randomBegin:=0
13.       }//end if
14.     }//end for
15.   }//end while
16.   randomBegin:=1
17.   for(i:=0;i<100;i:=i+1){
18.     if(randomHistory[i]=-1){
19.       randomHistory[i]=randomNumber
20.       randomtimes:=randomtimes+1
21.       break
22.     }//end if
23.   }//end for
24.   updatect1:=currentHeadOfCP
25.   for(i:=0;i<randomNumber;i:=i+1){
26.     if(updatect1⟶next ≠ NULL){
```

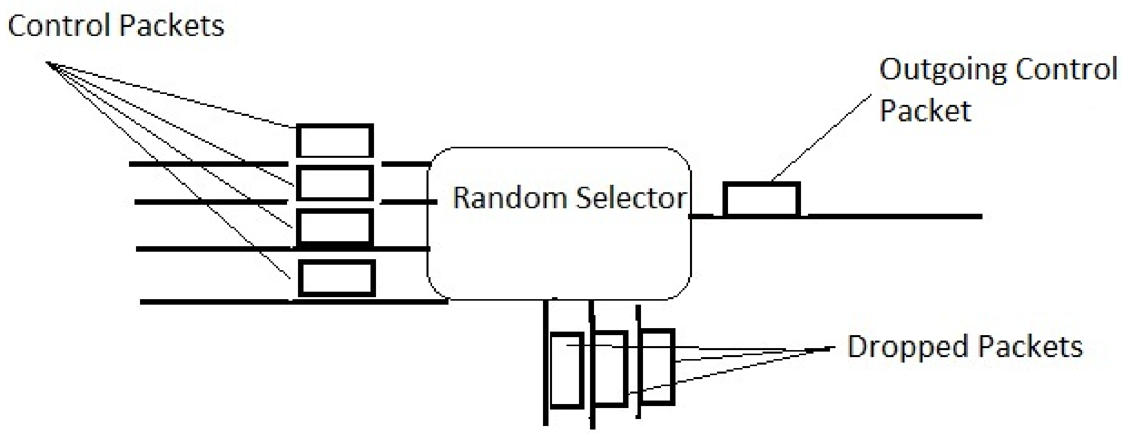

Figure 14: Random Selection

```
            updatect1:=updatect1⟶next
            if(updatect1:=nextHeadOfCP){
                updateCP:=currentHeadOfCP
            }//end if
        }//end NOT if
        }//end if
    }//end if
```

Random Selection Process selects a control packet randomly,out of all the contending incoming packets.After selecting one of the packets among them;it either drops or buffers the other packets.The effect of this process on throughput is totally random,as noone can predict the performance of this selection procedure.

6.2 Maximum Offset First

6.2.1 Algorithm

```
/*Finding the Control Packet having the Maximum Offset among all CPs in contention[30]*/
    for(tempCP:=currentHeadOfCP;tempCP≠nextHeadOfCP;tempCP:=tempCP⟶next){

        if(tempCP⟶update=0){
            if(tempCP⟶offset > maxOFFSET{
                maxOFFSET:=tempCP⟶offset
                updateCP:=tempCP
```

7. *}//end if*
8. *}//end if*
9. *}//end for*

Maximum Offset First selects a control packet that has the maximum offset among all the contending incoming packets.Here also after selecting a packet,the rest is dropped.This process affects the throughput of the network least favourably among all the present Control Packet Contention Resolution Schemes.

6.3 Minimum Offset First

6.3.1 Algorithm

1. */*Finding the Control Packet having the Minimum Offset among all CPs in contention[30]*/*
2. *for(tempCP:=currentHeadOfCP;tempCP≠nextHeadOfCP;tempCP:=tempCP⟶next){*
3. *if(tempCP⟶update=0){*
4. *if(tempCP⟶offset < minOFFSET{*
5. *minOFFSET:=tempCP⟶offset*
6. *updateCP:=tempCP*
7. *}//end if*
8. *}//end if*
9. *}//end for*

Minimum Offset First selects a control packet that has the minimum offset among all the contending incoming packets.Here also after selecting a packet,the rest is dropped.This process affects the throughput of the network most favourably among all the present Control Packet Contention Resolution Schemes.

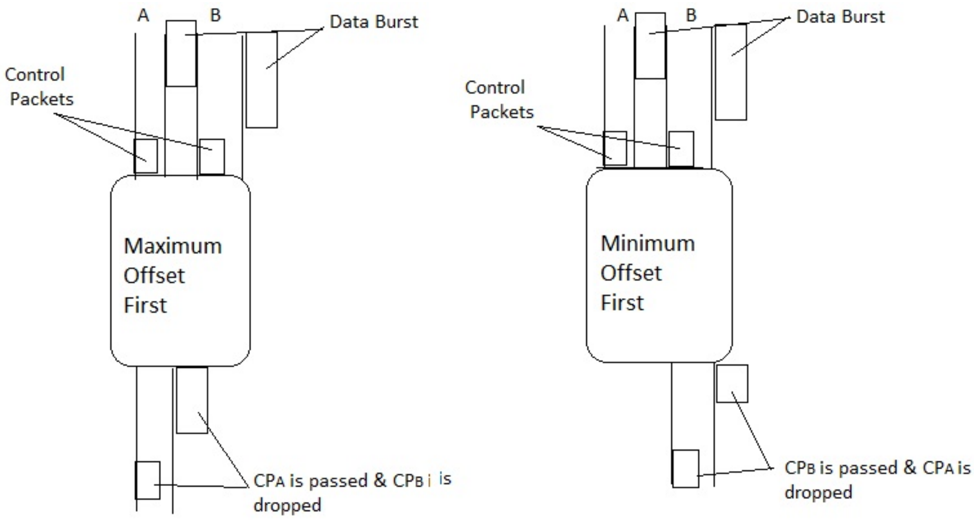

Figure 15: Maximum Offset First & Minimum Offset First

7 Maximum Priority Scheme

Maximum Weighed Priority is our new proposed algorithm to resolve burst header contention.The main idea of this technique is to prioritise the incoming data bursts according to a set weighed priority.

Burst Size of the incoming burst is divided by the total amount of time that is to be invested behind that burst,i.e,the total overhead cost attached to it.Here overhead consists of *Offset Time* & *Reservation Duration.*So the burst for which this factor is high will contribute more to increase the overall throughput of the OBS network.So, this *Priority* can be mathematically denoted as:

$$Priority = \frac{BurstSize}{OffsetTime + ReservationDuration}$$

We have done several simulations on this new algorithm and analysed the performance of it in terms of throughput and compared it with other existing ones,in the next section.The algorithm is given next.

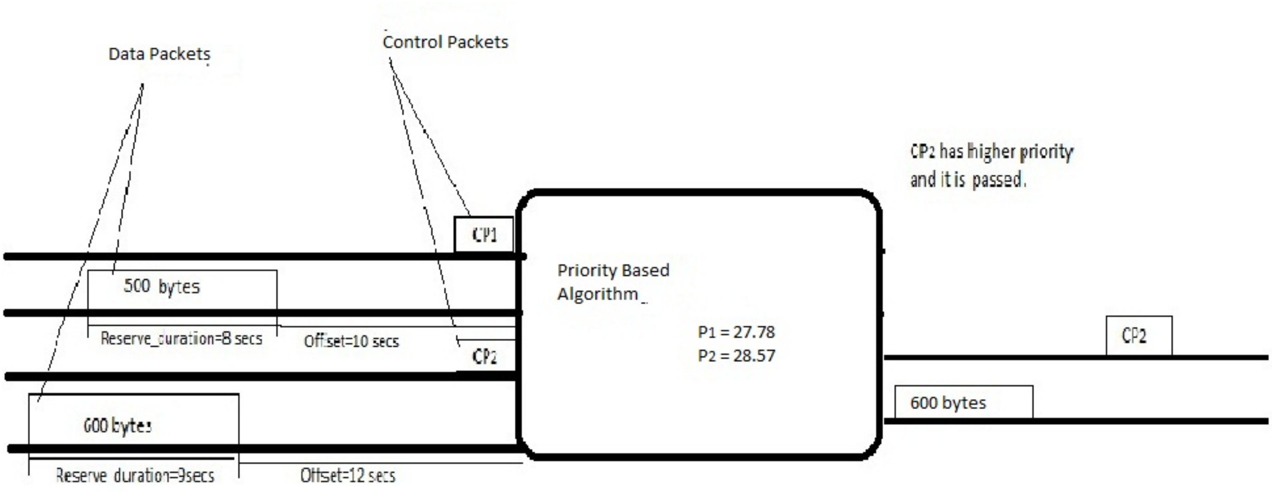

Figure 16: Max Priority Scheme

7.1 Algorithm

```
/*Finding the Control Packet having the Maximum Priority among all CPs in contention*/
for(tempCP:=currentHeadOfCP;tempCP≠nextHeadOfCP;tempCP:=tempCP⟶next){

    if(tempCP⟶update=0){
        priority:=tempCP⟶size / (tempCP⟶reserveDuration + tempCP⟶offset)

        if(priority>maxPRIORITY){
            maxPRIORITY := priority
            updateCP := tempCP
        }//end if
    }//end if
}//end for
```

8 Simulations & Results

In this section we have evaluated the performance of various Burst Header Contention Resolution Schemes through simulations.All simulations have been done in *NCTUns simulator*.

8.1 Topology

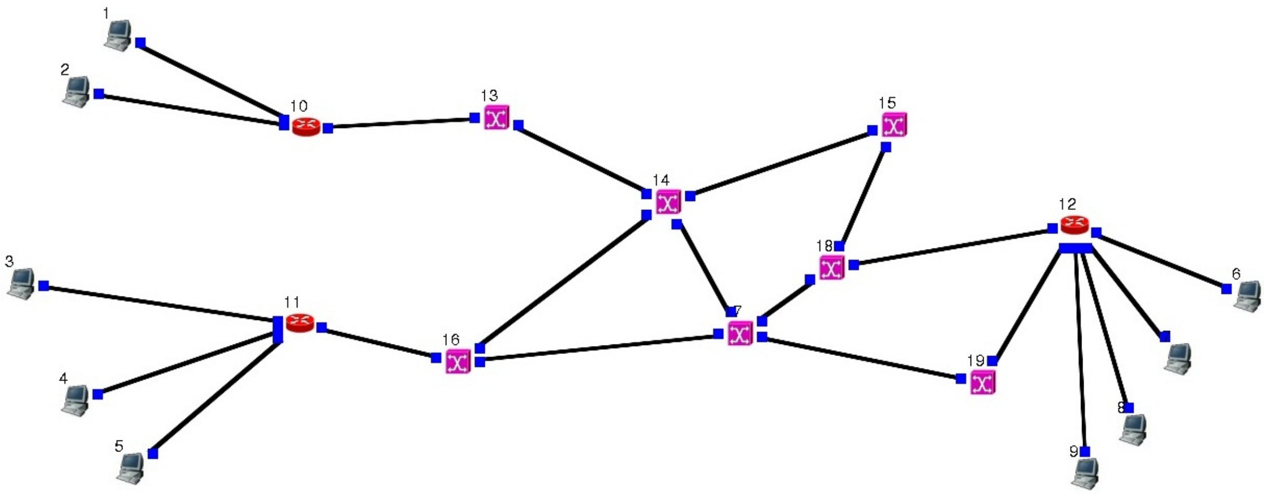

Figure 17: Simulated Topology

In the above drawn topology,we have simulated various schemes and analysed the results.

8.2 Simulation Parameters

The main purpose of our simulations is to measure the change in *throughput* by applying various burst header contention resolution schemes.Here we have studied all the nodes but we've concentrated mostly on Nodes 12,18 & 19 in our study.Since these are the nodes nearer to the destination,so these nodes would provide us the most optimum comparative throughput study of various schemes.

Table 3: Various Simulation Parameters

Parameter	Value
Simulator	NCTUns
Minimum Burst Size	600 bytes
Maximum Queue Length	60000 bytes
Control Packet Processing Time	2ns
Reservation Protocol	JET
Number of FDL	0
Bandwidth/channel	1000 mbps
Edge Nodes	3
Core Nodes	7
Total Number of channels/link	3
Data Channels/link	2
Control Channels/link	1
Burst Segmentation Method Used	Only Head of Second

8.3 Simulations

Figure 18 shows the *Throughput ofControl Packets in kbps v/s Time* at router(node 12) using various Burst Contention techniques while Figure 19 shows the *Throughput of Data Bursts in kbps v/s Time* at node 12.Figure 20 and 21 shows the *Throughput of Data Bursts in kbps v/s Time* at node 18 and node 19 respectively.The random method gives the fluctuating values of the throughput.Maximum offest first method is less effective than the minimum offset first method.The priority based method has shown better reults and is quite effective in improving the throughput as compared to other methods.

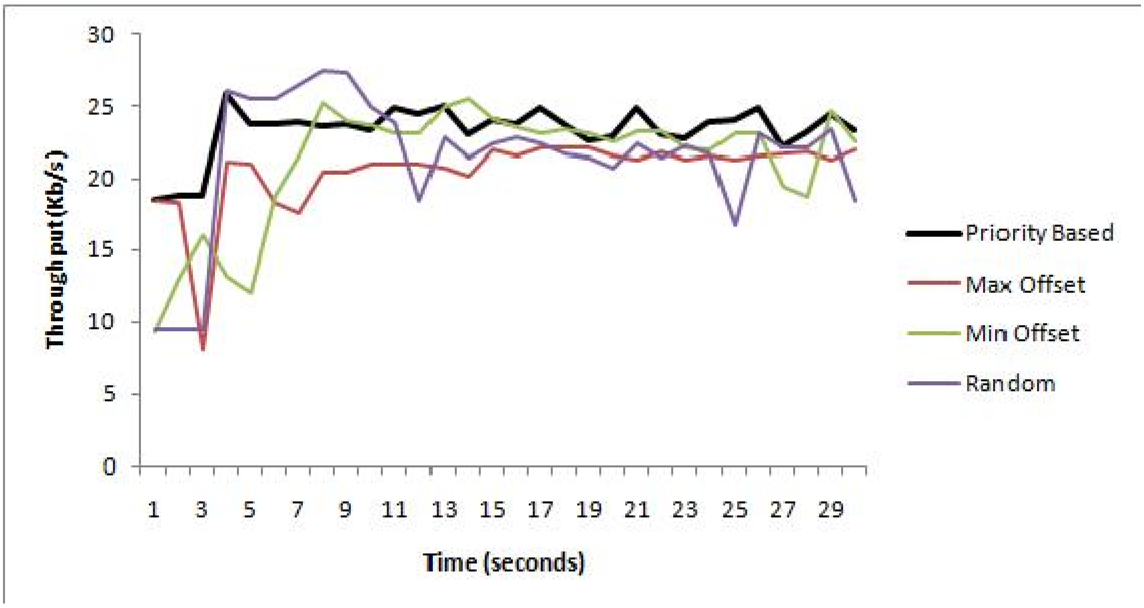

Figure 18: Throughput of Control Packets in kbps v/s Time at Node 12

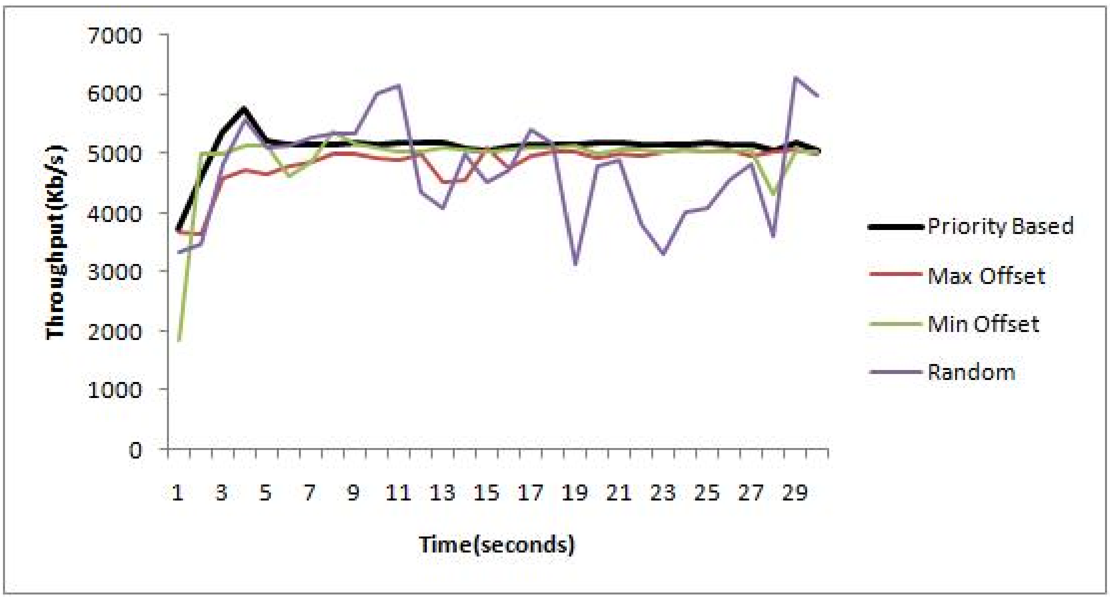

Figure 19: Throughput of Data Bursts in kbps v/s Time at Node 12

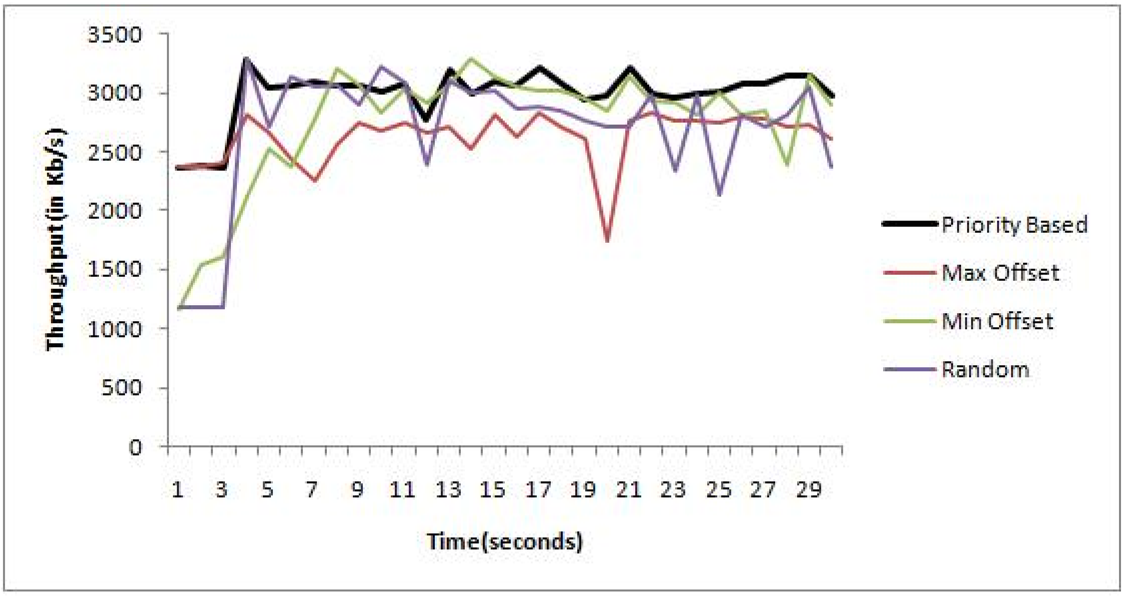

Figure 20: Throughput of Data Bursts in kbps v/s Time at Node 19

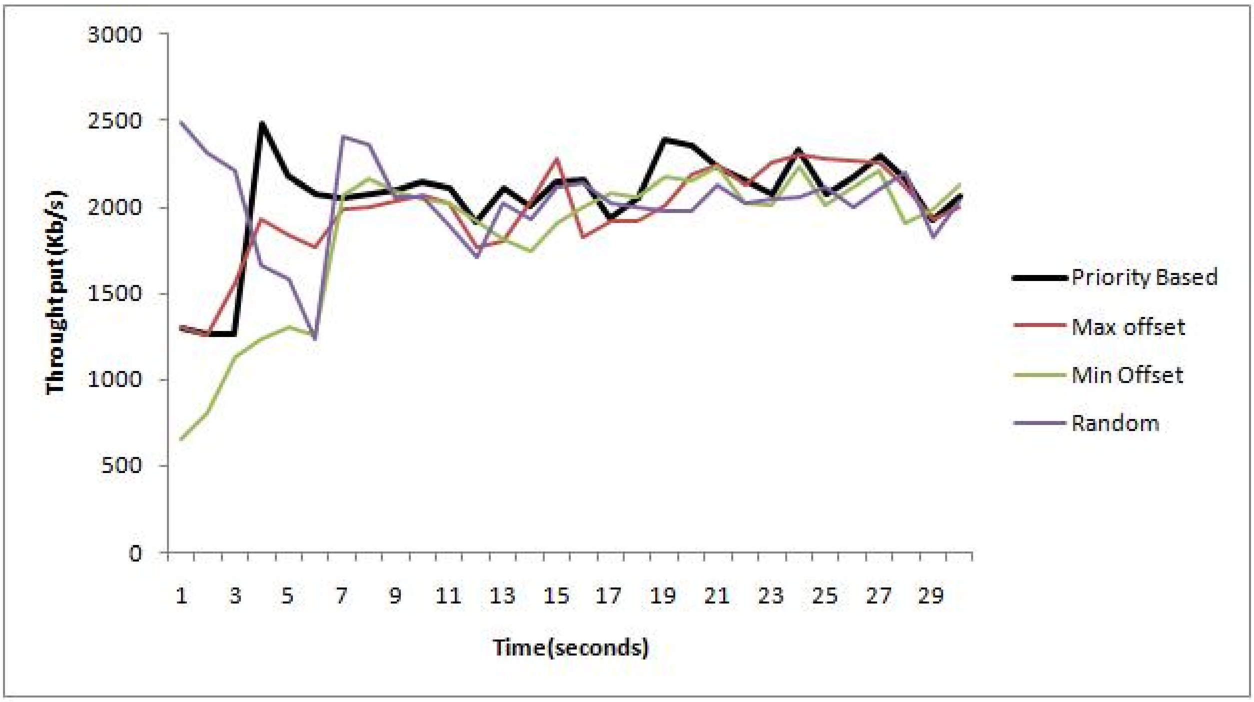

Figure 21: Throughput of Data Bursts in kbps v/s Time at Node 18

9 Conclusion

OBS is a promising switching paradigm that allows data to be carried optically.High bandwidth of data channels can lead to overloading of control channel.We have proposed Priority Based Resolution Method for contending optical headers.Its efficiency is compared with other algorithms. Simulation results have shown that the proposed technique is efficient in improving the throughput.

References

[1] R.S. Kaler Amit Kumar Garg. A Novel Technique for Resolving Burst Contention in OBS Networks. *International Journal of Electronics*, 97(3):295–308, March 2010.

[2] Mrinal Nandi. A Technique to Minimize Contention in Optical Burst Switching Networks. Master's thesis, National Institute of Technology,Rourkela, 2008.

[3] Te-Lung Liu Ching-Fsang Hsu and Nen-Fu Huang. Performance Analysis of Deflection Routing in Optical Burst-Switched Networks. *In Proceeding of IEEE,INFOCOM 2002,New York,NY*, pages 1011–1016, June 2002.

[4] J. Spath K. Dozer, C. Gauger and S. Bodamer. Evaluation of Reservation Mechanisms for Optical Burst Switching. *AEU International Journal Of Electronics and Communications*, 55(1):2017–2022, January 2001.

[5] Robert Inkret Marije Ljolje and Branko Mikac. A Comparative Analysis of Data Scheduling in Optical Burst Switching Networks. *In Proceeding of Optical Network Design and Modelling*, pages 493–500, 2005.

[6] Marc Vandenhoute Yijun Xiong and Hakki C. Cankaya. Control Architecture in Optical Burst Switched WDM Networks. *IEEE JSAC*, 18(10):1838–1851, October 2000.

[7] Vinod M. Vokkarane and Jason P.Jue. Segmentation-Based Non Preemptive Channel Scheduling Algorithms for Optical Burst-Switched Networks. *Journal Of Lightwave Technology*, 23(10):3125–3137, October 2005.

[8] C. Qiao M. Yang and S. Dixit. QoS Performance of Optical Burst Switching in IP-Over-WDM Networks. *IEEE JSAC*, 18(10):2062–2071, October 2000.

[9] S.Q. Zheng M. Yang and D. Verchare. A QoS Supporting Scheduling Algorithm for Optical Burst Switching DWDM Networks. 2001.

[10] Jikai Li Jinhui Xu, Chunming Qiao and Guang Xu. Efficient Channel Scheduling in Optical Burst Switching Networks. volume 3, pages 2268–2278, 2003.

[11] M.C. Chis D.K Hunter and I.Andonovic. Buffering in Optical Packet Switches. *IEEE/OSA Journal of Lightwave Technology*, 16(12):2081–2094, 1998.

[12] J.P Jue V.Vokkarne and S. Sitaraman. Burst Segmentation:An Approach for Reducing Packet Loss in Optical Burst Switched Networks. pages 2673–2677, 2002.

[13] H KIm S Lee, K Sriram and J Song. Contention Based Limited Deflection Routing in OBS Networks. 2003.

[14] B Ramamurthy and B Mukherjee. Wavelength Conversion in WDM Networking. *IEEE JSAC*, 16(7):1061–1073, 1998.

[15] G A Castanon A. Bononi and O K Tonguz. Analysis of Hot-Potato Optical Networks with Wavelength Conversion. *IEEE Journal of Lightwave Technology*, 17(4):525–534, April 1999.

[16] Yuqi Fan. *Burst Scheduling,Grooming and QoS Provisioning in Optical Burst-Switched Networks*. PhD thesis, Wright State University, 2009.

[17] B. Hao. *Analysis of Physical Constraints in an Optical Burst Switching Network*. PhD thesis, Technishe University, Berlin, 2005.

[18] W.Willinger W.E. Lealand, M.S. Taqqu and D. V. Wilson. On the Self-Similar Nature of Ethernet Traffic. *IEEE/ACM Transactions on Networking*, 2(1):1–15, April 2000.

[19] D.Blumenthal et al. Special Issue on Photonic Packet Switching Technologies,Techniques,and Systems. *Journal od Lightwave Technology*, 16(12):2065–2067, December 1998.

[20] T.S. El-Bawab and J.D Shin. Optical Packet Switching in Core Networks:Between Vision and Reality. *IEEE Communication Magazine*, 40(9):60–65, September 2002.

[21] F. Poppe L.B. Sofman D. Papdimitrion T.S. El-Bawab, A. Agarwal and B. Russeau. The Evolution to Optical-Switching-Based Core Networks. *Optical Networks Magazine*, 4(2):7–18, March-April 2003.

[22] C. Guillemot M. Renaud, F. Massetti and B.Bostica. Network and System Concepts for Optical Packet Switching. *Optical Networks Magazine*, 35(4):96 – 102, April 1997.

[23] C. Siva Ram Murthy T. Venkatesh. *An Analytical Approach to Optical Burst Switched Networks*. Springer-ISBN 978-1-4419-1509-2, Van Godewijckstraat 30. Dordrecht Zuid-Holland 3300 AA Netherlands, 2010.

[24] Jikai Li Guang Xu Jinhui Xu, Chunming Qiao. Efficient Burst Scheduling Algorithms in Optical Burst Switched Networks Using Geometric Techniques. *IEEE Journal on Selected Areas in Communication*, 22:1796 – 1811, Nov 2004.

[25] Joao Pires Joao Pedro, Paulo Monteiro. Performance Study of Obs Networks Using Traffic Engineering in the Wavelength Domain and Delayed Ingress Burst Scheduling. *Proc. IEEE Globecom*, 2008.

[26] Albert M. K. Cheng Jian(Denny) Lin, Yuhua Chen. Online Burst Header Scheduling in Optical Burst Switching Networks. *Proc. 22nd IEEE International Conference on Advanced Information Networking and Applications*, pages 363 – 369, 2008.

[27] et al. S.Y. Wang. The Design and Implementation of NCTUns 1.0 Network Simulator. *Computer Networks*, 42(2):175–197, 2003.

[28] The Protocol Developer Manual for the NCTUns 6.0 Simulator and Emulator.

[29] The GUI User Manual for the NCTUns 6.0 simulator and emulator.

[30] The NCTUns Simulator.