PERFORMANCE ANALYSIS OF A SINGLE-NODE HIERARCHICAL TIME SLICED OPTICAL BURST SWITCHING (HITSOBS) NETWORK

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ABSTRACT

Hierarchical Time Sliced Optical Burst Switching (HiTSOBS) is a time variant of OBS that aims at supporting Quality of Service. In this paper, we analyze the performance of HiTSOBS to determine the best burst size for a given number of time slots. These evaluations were carried with/without buffer at the core network. Simulation results demonstrate that smaller burst sizes such as 9 KB and 12.5 KB have better performance than bigger burst sizes such as 125 KB when buffers are assumed at the core network. However, without buffer at the core node, bigger burst sizes achieve better performance in terms of burst loss probability while smaller burst sizes have better delay performance.

KEY WORDS

Optical burst switching (OBS), Hierarchical Time Sliced Optical burst switching burst loss (HiTSOBS), Burst Loss Probability (BLP).

1. INTRODUCTION

Optical fiber cable is, theoretically, an unlimited guided transmission medium in terms of bandwidth. Different WDM technologies further increase the available bandwidth in a single fiber optic cable. Three switching approaches have been proposed and researched to make better use of such a huge bandwidth offered by fiber optic technology, which is in the order 40 to 100 Gbps per channel (Garcia, 2008). The three switching paradigms are: optical circuit switching (OCS) (Ghafoor *et al.,* 1990), optical burst switching (OBS) and optical packet switching (OPS) (Guillemot *et al.*, 1998) and (Yao *et al.*, 2001). Among these three switching technologies, OBS, which is described in (Qiao and Yoo, 1999), is seen as the viable technology for future all-optical network to meet the bandwidth requirements of high definition applications (multimedia and non multimedia such as medical applications) because of its high bandwidth utilization compared to OCS and its low processing overhead compared to OPS. However and due to lack of buffer at the core node of OBS (no optical memories are available), this switching paradigm still suffers from high burst loss at the event of burst contention. Burst contention occurs when two or more bursts contend for the same output port at the same. In such cases, one of contending bursts may be dropped or delayed if FDL are used and are not full. To deal with burst loss issue in OBS, researchers have proposed different schemes and different variants of OBS. On one hand, contention management techniques are classified into two; contention avoidance and contention resolution techniques. On the other hand, OBS architectures are also categorized into two main categories: non-slotted and slotted OBS variants as described in (Farahmand *et al.*, 2003; Venkatesh and Murthy, 2010).

Contention avoidance techniques strive to prevent the contention form happening or minimize its occurrence and are mainly implemented in space domain. Moreover, these schemes are proactive. Among contention avoidance are those proposed in (Nandi *et al.*, 2009), (Triay and Cervello-Pastor, 2010), (Huang *et al.*, 2008), (Chi *et al.*, 2007), (Pedro *et al.*, 2007a) and (Perelló *et al.*, 2010). Contention resolution techniques are reactive in nature; that is, they wait for contention to happen and then try to resolve it. Reactive contention management techniques are implemented in three domains: time domain by using fiber delay line (FDL) as in (Pedro *et al.*, 2007b), (El Houmaidi *et al.*, 2007), (Rajabi *et al.*, 2010), (Pedro *et al.*, 2008) and (Pedro *et al.*, 2009); wavelength domain as proposed in (Chu and Liu, 2010) and (Gauger, 2004); space domain through defection routing as proposed in (Ogino and Tanaka, 2005) and (Pedrola *et al.*, 2009). Burst segmentation (Vokkarane *et al.*, 2002) is another contention resolution mechanism where instead of dropping the entire contending burst, a part of it is dropped.

There are many variants of non-slotted OBS and time slotted OBS as discussed in (Venkatesh and Murthy, 2010). In this paper we study and analyze the performance of a newly developed time variant OBS known as Hierarchical Time Sliced OBS (HTSOBS) (Sivaraman and Vishwanath, 2009).

The rest of this work is organized as follows: section 2.0 goes through the literature review of time variant OBS; in section 3.0, performance evaluation mechanism is described in section 4.0; concluding remarks are found in section 5.0.

2. TIME VARIANT OPTICAL BURST SWITCHED NETWORKS

As the favorite candidate for future all-optical networks, Optical Burst Switching technology has received a lot of attention from scientists and researchers to solve its main issue (i.e., very large burst loss) which is caused by data contention at the buffer-less core node. To reduce burst loss and increase network performance, many variations to the JET (Hwang *et al.*, 2003) and JIT (Wei and McFarland Jr, 2002) based OBS have been proposed in the literature. Time variant is one of them and it is the focus of this paper. Due to space limitation, the reader is referred to (Venkatesh and Murthy, 2010), (Maier, 2008) and (Maier and Reisslein, 2008) for more details on other OBS variants. In what follows, the main time variants of OBS are discussed.

In time variant OBS, bursts are switched in time domain instead of wavelength. The drive behind time based OBS proposals is to avoid the use of wavelength converters to resolved contention at the core node. Although the use of such converters does improved network performance, wavelength converters are still at their infancy stage and are not cost effective (Venkatesh and Murthy, 2010). In (Ramamirtham and Turner, 2003), the authors were the first to propose a time based OBS architecture, Time Sliced OBS (TSOBS) which does not use wavelength converters and yet performs better than JET/JIT based OBS. In this OBS architecture, a wavelength is divided into periodic frames each of which is further subdivided into a number of time slots. The data burst is divided into a number of segments with each segment having duration equal to that of the time slot. Thus, the length of the burst is measured in terms of the number of slots it occupies. Each burst is transmitted in consecutive frames with each segment of the burst using the same slot in every frame. Each incoming link is assumed to have a synchronizer to align the boundaries of the slots with the switch fabric. In this architecture, the Burst Control Packet (BCP) contents the arrival time of the first segment of the burst, the position of the time slot in the frame, and the number of slots required to transmit the burst. If all the frames have free slots in the required position, then the burst is transmitted; otherwise, it is delayed using the FDLs for the required number of slots. The main drawback of TSOBS is the rigidness of its frame structure and the use of FDL which are also not yet mature (Venkatesh and Murthy, 2010). In time variant OBS, the frame size is an important performance parameter that has to be pre-configured at all intermediate core nodes. Using small frame size will increase contention probability due to the fact that the overlapping bursts are more likely to pick the same slot number, while applying large frame sizes will inevitably induce larger end-to-end delays due to each flow having access to a reduced fraction of the link capacity; this will lead to significant queuing delay at the ingress edge node. This loss-delay trade-off, determined by frame size, is identical across all traffic flows, and cannot be changed in TSOBS architecture.

Slotted Optical Burst Switched (SOBS) proposed in (Zhang *et al.*, 2007) is another time variant OBS. In SOBS, time division multiplexing (TDM) is incorporated into wavelength division multiplexing (WDM) so as to divide the entire λ-bandwidth into smaller base bandwidths. This approach is also referred to as the slotted WDM (sWDM), bursts are then transmitted in time domain instead of optical domain as in pure OBS and it eliminates the need for optical buffers and wavelength converters. SOBS uses a synchronizer at the edge node which eliminates the randomness in the burst arrival and thereby losses due to contention. To avoid the wastage of bandwidth, it creates bursts of equal length. The author in (Rugsachart, 2007) and following the TSOBS (Ramamirtham and Turner, 2003) principle proposed a variant of time slotted OBS called Time-Synchronized Optical Burst Switching (SynOBS), which not only assumes the presence of fiber delay lines, but also considers the impact of full wavelength conversion. Several FDL reservation mechanisms are proposed and analyzed using discrete time Markov chains to compute the burst drop probability. They suggested that, timeslot size must be chosen with care to achieve the best timeslot utilization, which subsequently reduces burst blocking probability, the main issue in any OBS network.

The latest time variant of OBS is called Hierarchical Time Sliced OBS (HiTSOBS) and was proposed by Sivaraman and Vishwanath in (2009). HTSOBS was proposed to overcome the shortcomings of TSOBS. Thus, in HiTSOBS not only a variable frame size is used but it is also hierarchical; this flexibility in HiTSOBS allows frames of different sizes to co-exist together in a way that delay-sensitive traffics (voice and video) are supported by frames of higher levels where the frames are of smaller size. While the frames of lower levels support loss-sensitive traffic (email, ftp, web pages and others). Besides, HiTSOBS also allows dynamic changes in the hierarchy of the frames according to the mixture of traffic classes thus obviating the need for any other changes in the network. Similar to the JET/JIT based OBS and TSOBS, a BCP carries the information about the number of slots required to transmit the burst as well as the level at which the burst has to be transmitted. However, in HiTSOBS the bursts are scheduled atomically rather than slice-by-slice to serve the entire burst in a frame at the desired level. In this way, the control plane scheduling remains scalable and data plane operations are minimized (Sivaraman and Vishwanath, 2009). Table 1 summarizes the main characteristics of different time variants OBS architectures.

Table 1: The main characteristics of Time Variant OBS

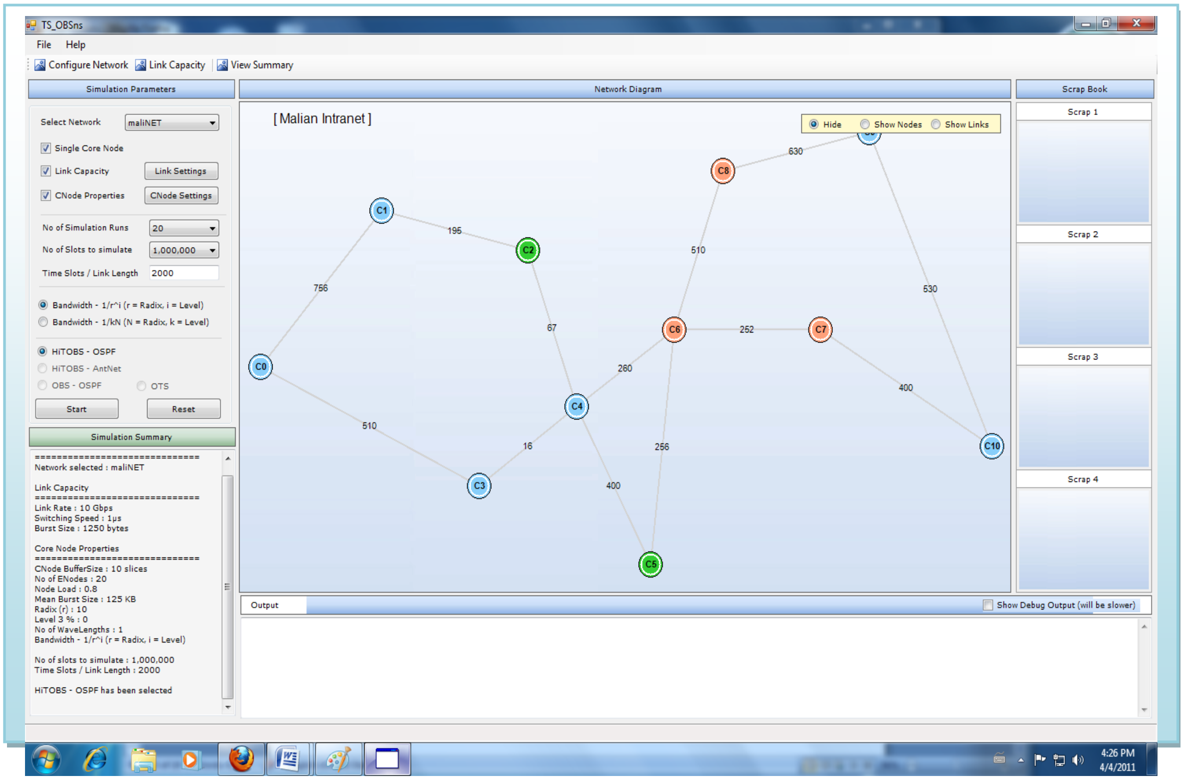
Nº	Features	Time Sliced OBS	Slotted OBS	Time Synchronized OBS	Hierarchical Time Sliced OBS
1	Mode of Operation	Synchronous TDM channeling based	Synchronous Time-slot based	Synchronous Time-slot based	Synchronous TDM channeling based
2	Hierarchical	No	No	No	Yes
3	Frame size	Fixed	Fixed	Fixed	Variable
4	FDL	Yes	No	No	Yes
5	Wavelength Converters	No	Yes	Yes	No
6	Control Header and Burst Transmission	Sequential	Parallel	Sequential	Sequential
7	Offset time	Yes	No	Yes	Yes
8	Burst Size	Variable	Fixed	Fixed	Variable
9	Contention Resolution	Time	Time/Wavelength	Time/Wavelength	Time
10	Burst per time Slot	Many	Many	One	Many

No doubt, HiTSOBS is a good architecture in the sense that it supports QoS through its flexible hierarchy design. But in (Sivaraman and Vishwanath, 2009), the architecture was not implemented and tested in a real OBS environment and or conditions. Therefore and knowing that time variant OBS could be a possible technology of future OBS network as an intermediate solution for all-optical network, it is necessary that, HiTSOBS be tested in a bigger and realistic environment to evaluate its performance, identify its shortcomings and propose ways to overcome them.

This paper is an introduction to such an important work. Here we analyze the performance of single core node HiTSOBS by varying simulation parameters such as burst size, buffer size, frame size, number of levels and number of edge nodes.

3. SIMULATION ENVIRONMENT AND PARAMETERS

To evaluate the performance of HiTSOBS in the optic of implementing it in a more realistic OBS network environment, we have customized and enhanced the event driven simulator used in (Sivaraman and Vishwanath, 2009) to support multi core node and multi wavelength. The enhanced simulator is called TS_OBSns. Figure 1 shows the GUI of this simulator. As in HiTSOBS, we assume a single node OBS and one wavelength link. Simulation topology is depicted in Figure 2. Table 2 lists different evaluation parameters' values used in different simulation scenarios.



Select Network: maliNET
☑ Single Core Node
☑ Link Capacity
☑ CNode Properties
No of Simulation Runs: 20
No of Slots to simulate: 1,000,000
Time Slots / Link Length: 2000
● Bandwidth - 1/r^i (r = Radix, i = Level)
○ Bandwidth - 1/kN (N = Radix, k = Level)
● HiTOBS - OSPF
○ HiTOBS - AntNet
○ OBS - OSPF
○ OTS

```
=================================
Network selected : maliNET

Link Capacity
=================================
Link Rate : 10 Gbps
Switching Speed : 1μs
Burst Size : 1250 bytes

Core Node Properties
=================================
CNode BufferSize : 10 slices
No of ENodes : 20
Node Load : 0.8
Mean Burst Size : 125 KB
Radix (r) : 10
Level 3 % : 0
No of WaveLengths : 1
Bandwidth - 1/r^i (r = Radix, i = Level)

No of slots to simulate : 1,000,000
Time Slots / Link Length : 2000

HiTOBS - OSPF has been selected
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Figure 1: TS_OBSns Simulator GUI

Three scenarios were evaluated. In the first scenario, the number of time slots used for simulation was set to 500K, 1000K and 1500K to see the effect of these on the simulation results, lower than 500K will produce wrong results, the higher the better, however, one should consider the simulation time; the buffer size was set to 10 time slice for all the three number of time slots. With each number of time slots, four different burst sizes were used, namely: 125 KB as in (Sivaraman and Vishwanath, 2009), 19 KB (Um *et al.*, 2008), 12.5 KB (Ozturk *et al.*, 2009) and 9 KB as in (Garcia, 2008). Figures 3.1 through 3.3 shows the loss results obtained for the first scenario while Figures 4.1 through 4.3 show the delay performance for the same scenario. In Figures 5.1, 5.2 and 5.3 the loss results of the second scenario are shown whereas the delay performances are depicted in Figures 6.1, 6.2 and 6.3 respectively. Buffer size was set to 10 in the first scenario and to 0 in the second scenario. In the last scenario, we evaluated the effect of frame size on the performance of HiTSOBS and the results are reported in Figures 7.1 and 7.2 for loss and delay respectively.

Table 2: Simulation Scenarios and parameters

Scenarios	Burst Size (KB)	Number of Time Slot (K)	Number of Edge Node	Buffer Size (Time Slice)	Frame size (Time Slots)	Number of repeated Simulations
1	125 19 12.5 9	500	100	10	10	5
		1000				
		1500				
2	125 19 12.5 9	500	100	0	10	5
		1000				
		1500				
3	125	500	500	10	10	5
					15	

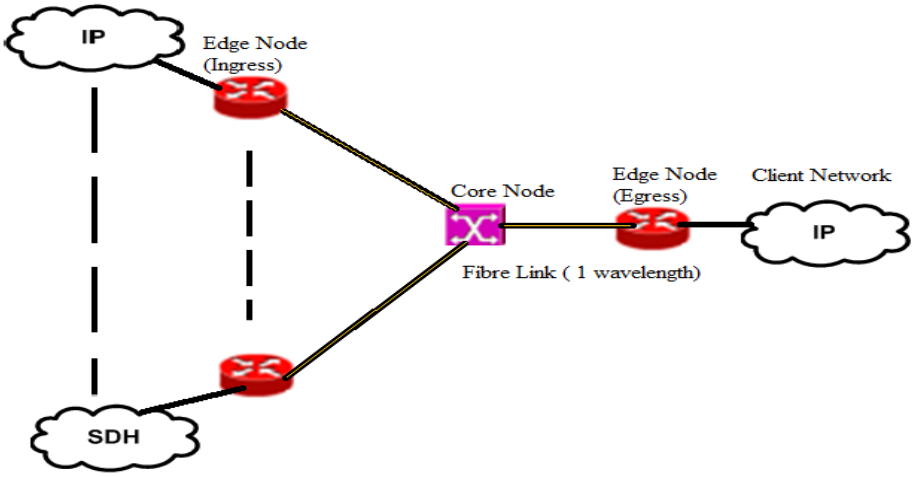

Figure 2: Simulation Topology

4. RESULTS ANALYSIS

In this section, the results of different scenarios discussed in section III are reported. Figures 3.1 – 3.3 show the burst loss probability (BLP) against load for different burst sizes. In all the three graphs, we notice that as load increases, BLP increases. Moreover, bigger bursts experience high BLP compared with small burst sizes. This is because, bigger burst size consist of many time slices which lead to high traffic in the network and as a result, they have higher burst loss probability. It is interesting to note that, number of time slots used for the simulation does not any effect on the performance of the HiTSOBS. However, bigger number of time slots increases the smoothness of the graph.

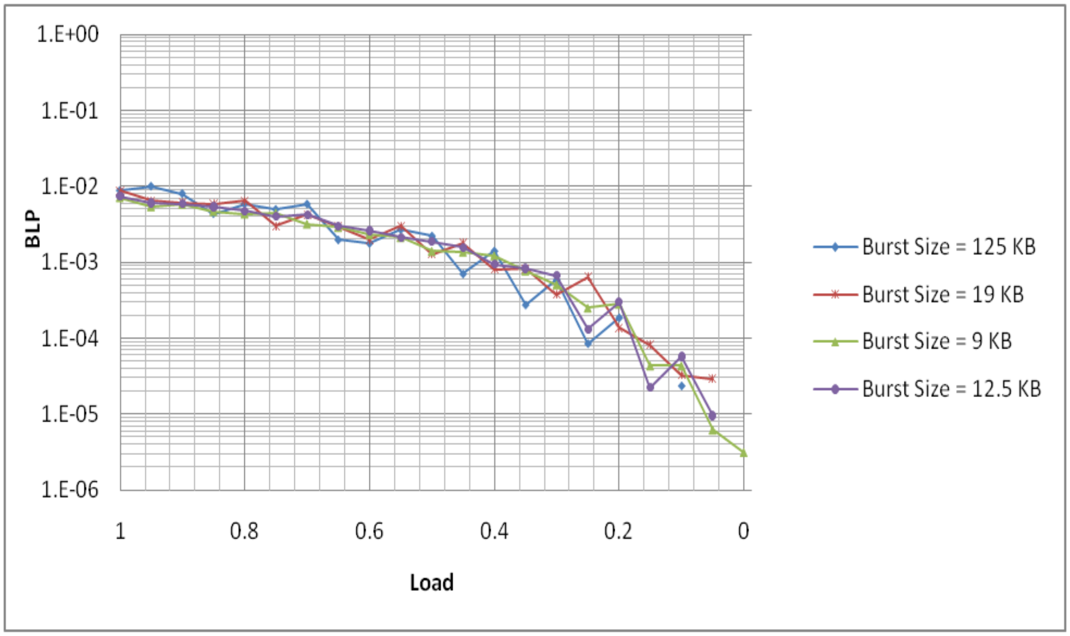

Figure 3.1: Loss vs. Load (Number of Time Slot = 500K, Buffer Size= 10 Time slices)

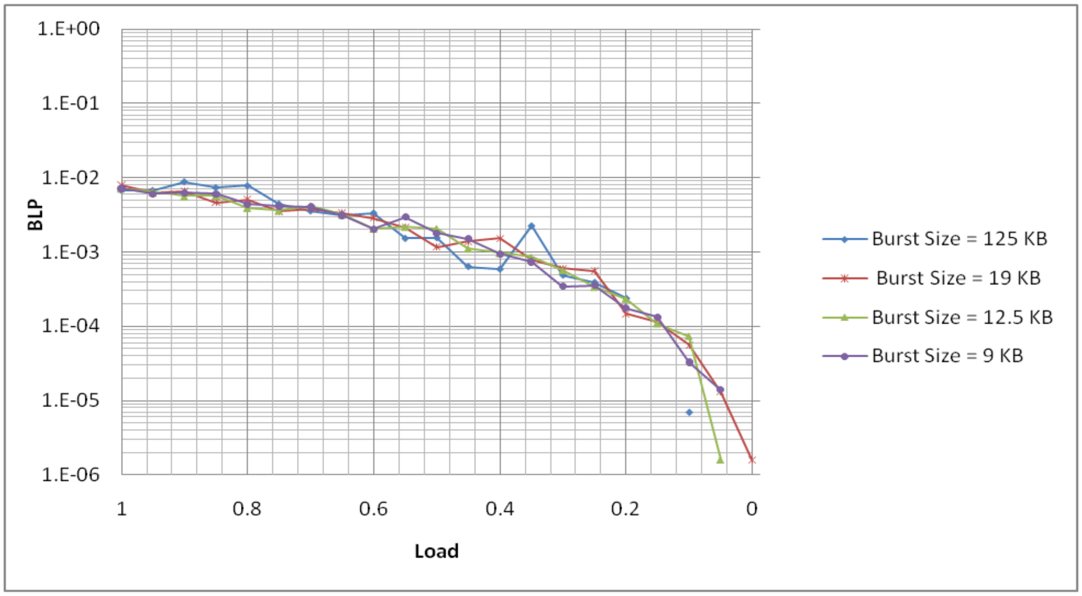

Figure 3.2: Loss vs. Load (Number of Time Slot = 1000K, Buffer Size= 10 Time slices)

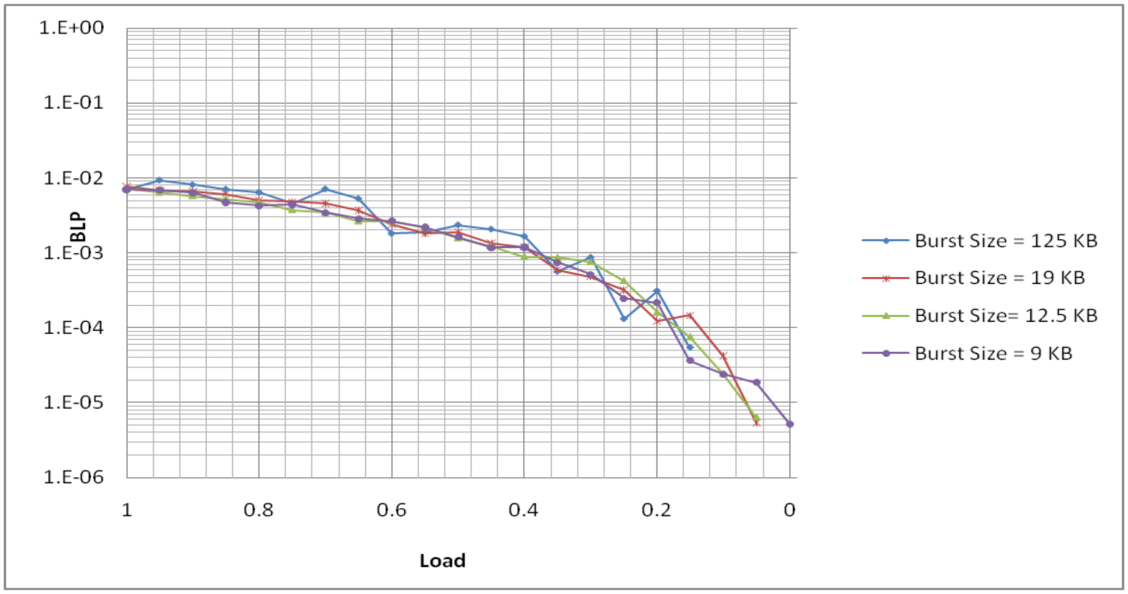

Figure 3.3: Loss vs. Load (Number of Time Slot = 1500K, Buffer Size= 10 Time slices)

Figures 4.1 – 4.3 depict the delay performance of HiTSOBS for different burst size. In these graphs, as network load increases, the delay decrease. This is can be attributed to the fact that, all the burst have been serviced in the first level of the hierarchy. However, smaller burst sizes have lower BLP Similar to the results in 2.1-2.3; number of time slots used for simulation has no effect on the delay performance of HiTSOBS.

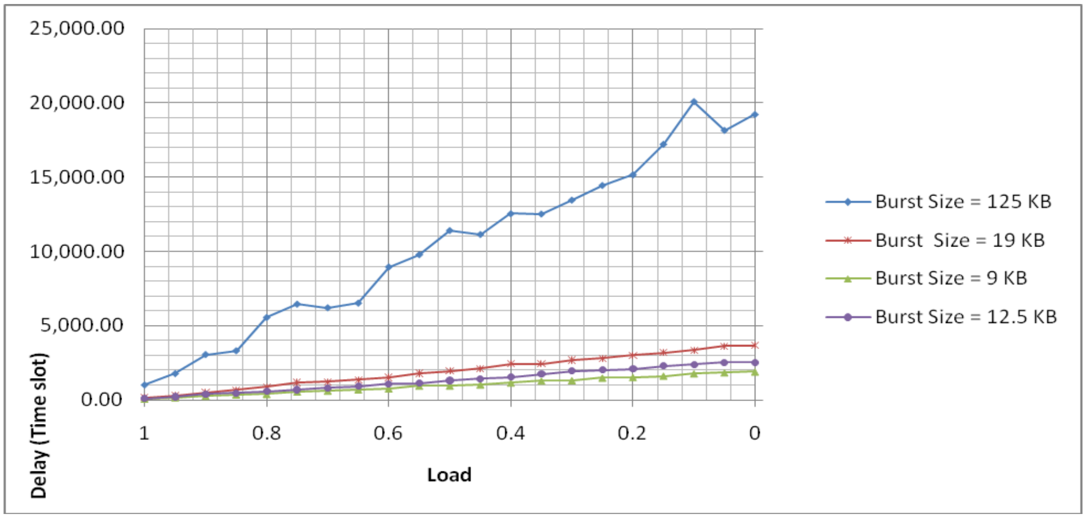

Figure 4.1: Delay vs. Load (Number of Time Slot = 500K, Buffer Size= 10 Time slices)

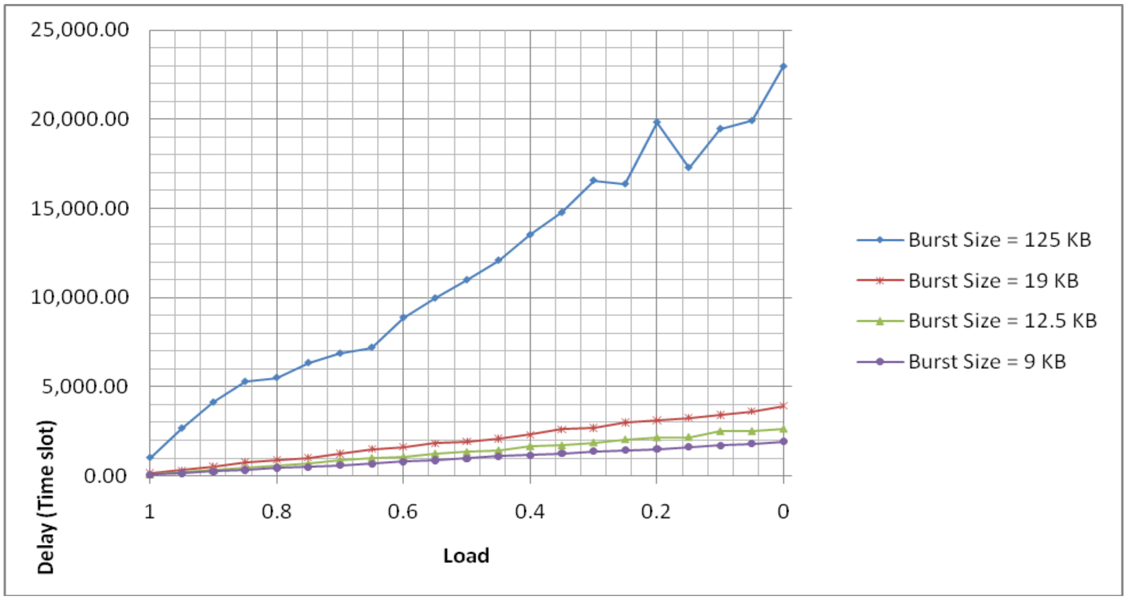

Figure 4.2: Delay vs. Load (Number of Time Slot = 1000K, Buffer Size= 10 Time slices)

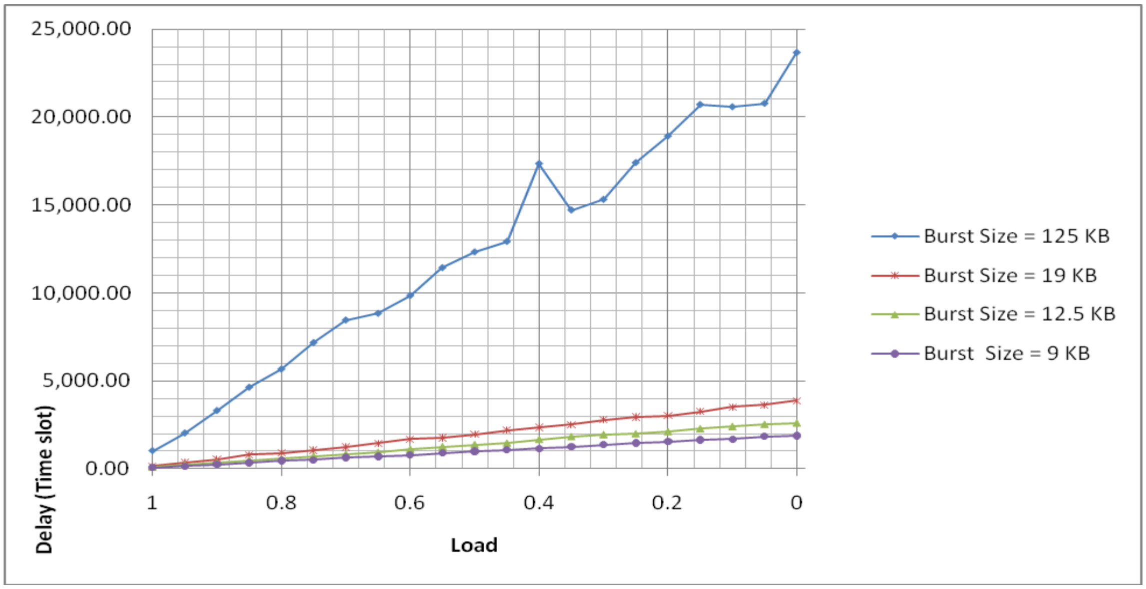

Figure 4.3: Delay vs. Load (Number of Time Slot = 1500K, Buffer Size = 10 Time slices)

The evaluation in case 2 was carried out assuming a buffer-less OBS and the BLP results are shown in Figures 5.1, 5.2 and 5.3. These results prove that, when no buffer is used at the core node, bigger burst sizes have lower burst loss probability at the cost of higher delay. See graphs 6.1, 6.2 and 6.3. However, small burst sizes have lower delay at the expense of higher burst loss. The BLP graph obtained in this simulation are similar to those in (Cheyns *et al.*, 2004).

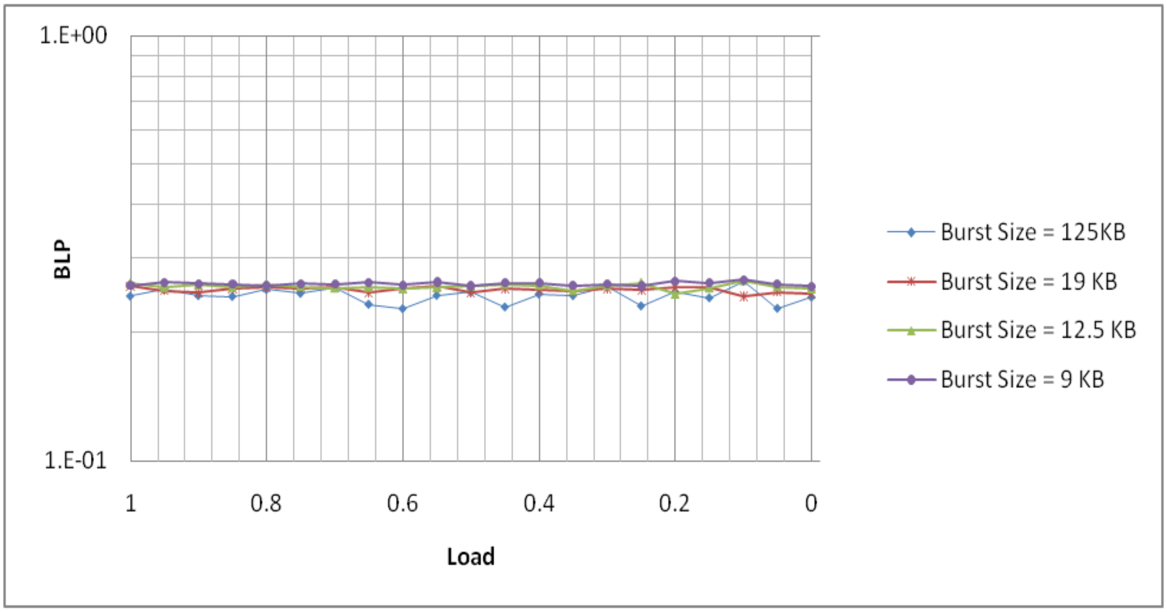

Figure 5.1: Loss vs. Load (Number of Time Slot = 500K, Buffer Size = 0 Time slices)

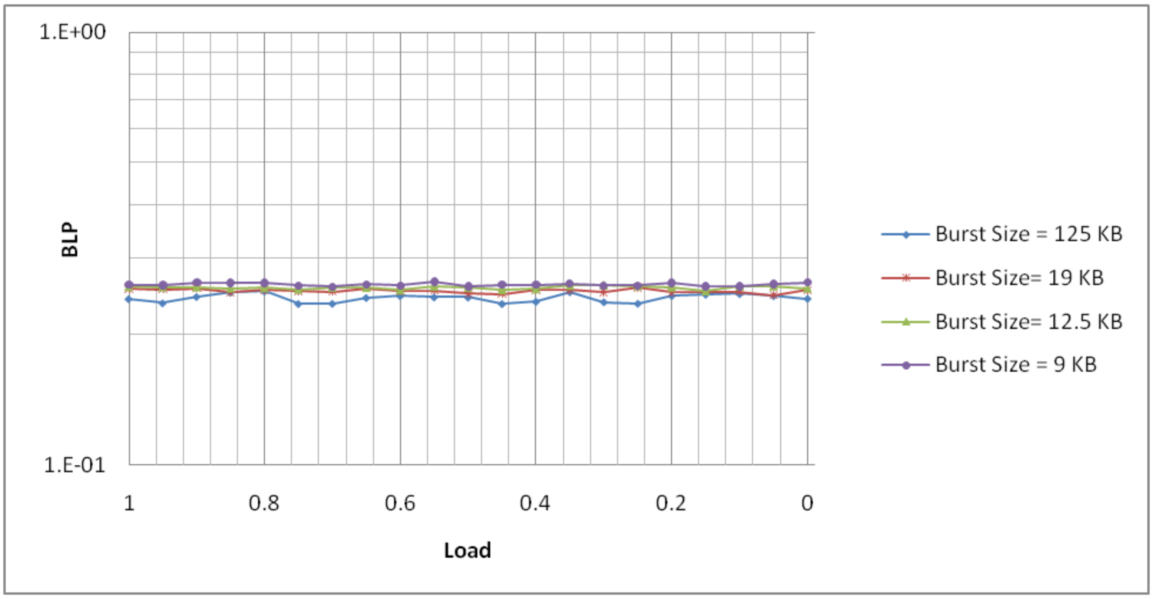

Figure 5.2: Loss vs. Load (Number of Time Slot = 1000K, Buffer Size = 0 Time Slots)

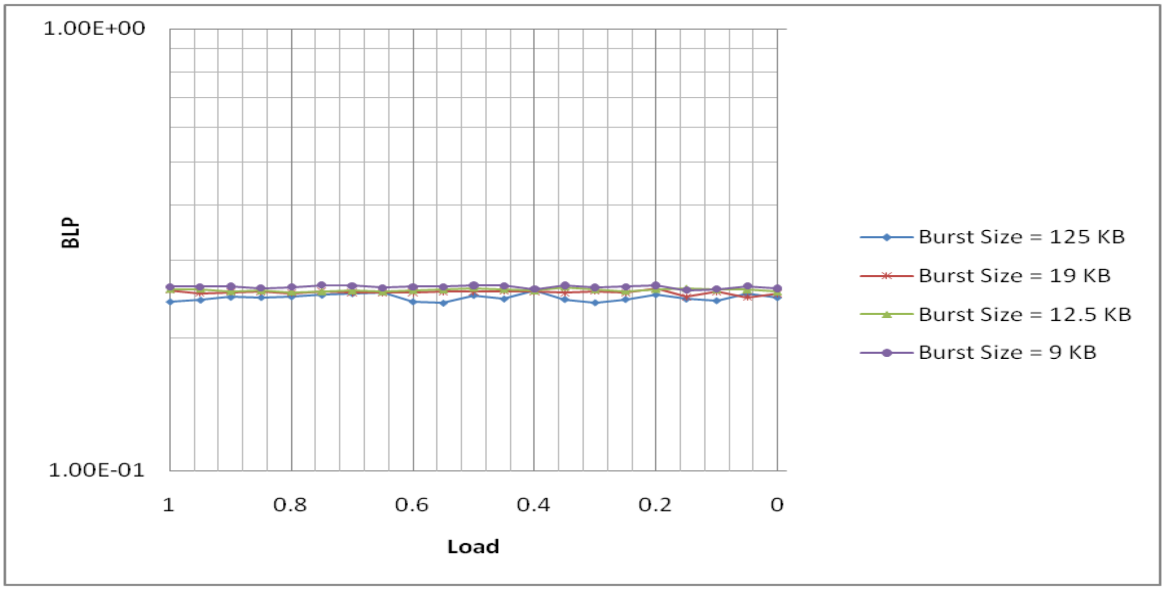

Figure 5.3: Loss vs. Load (Number of Time Slot = 1500K, Buffer Size = 0 Time slices)

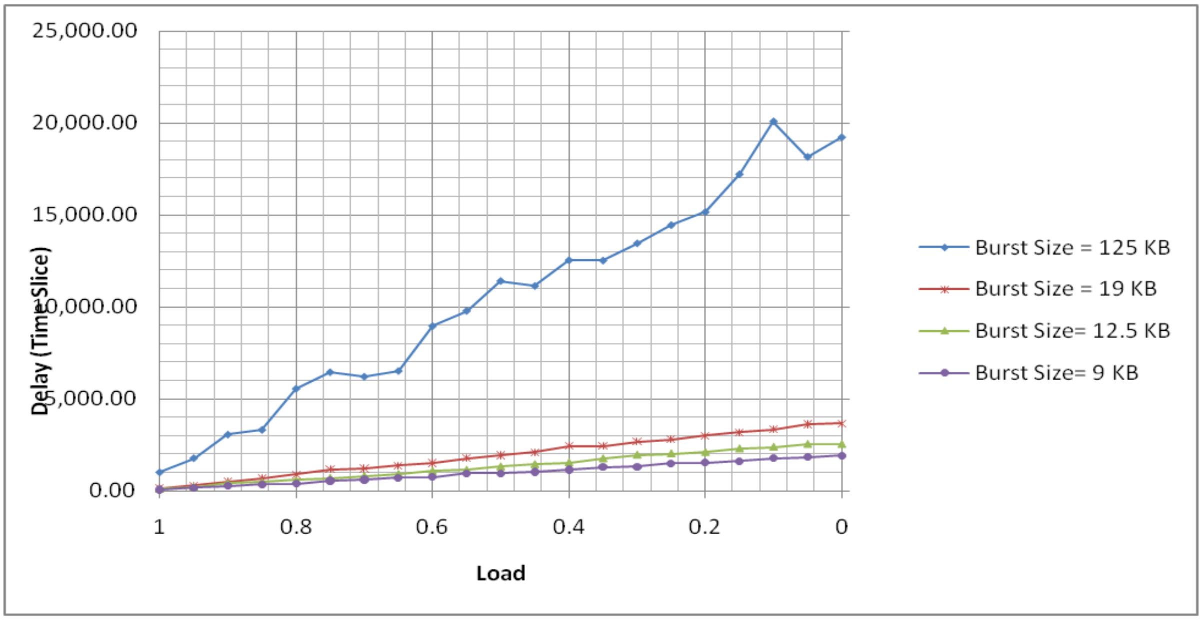

Figure 6.1: Delay vs. Load (Number of Time Slot = 500K, Buffer Size = 0 Time slices)

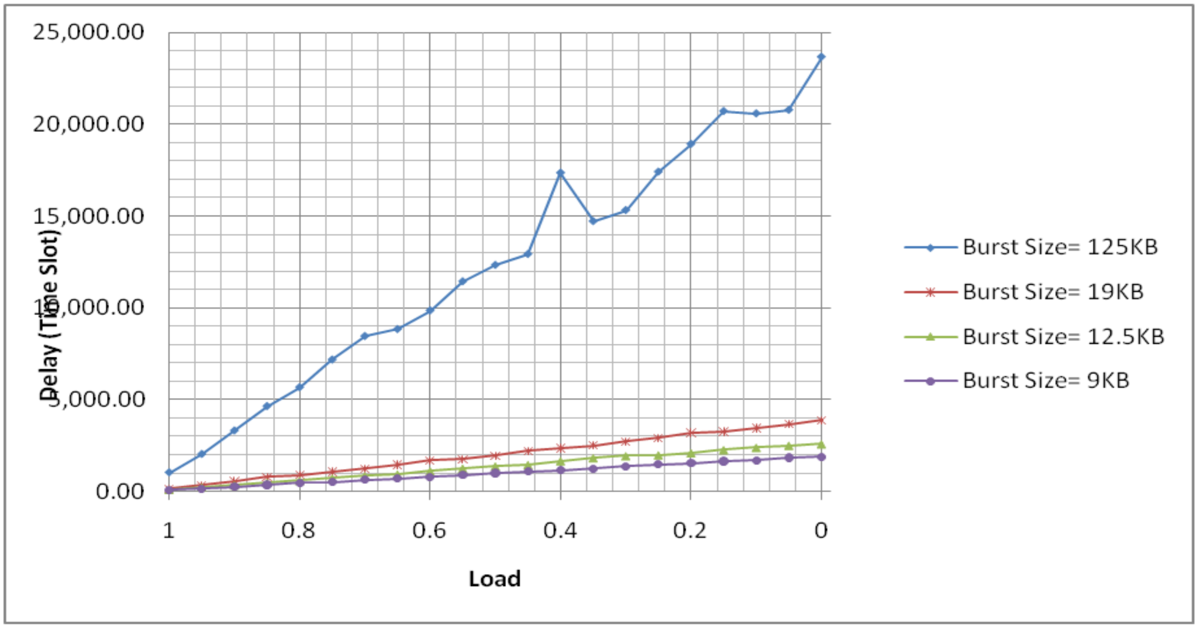

Figure 6.2: Delay vs. Load (Number of Time Slot = 1000K,
Buffer Size = 0 Time slices)

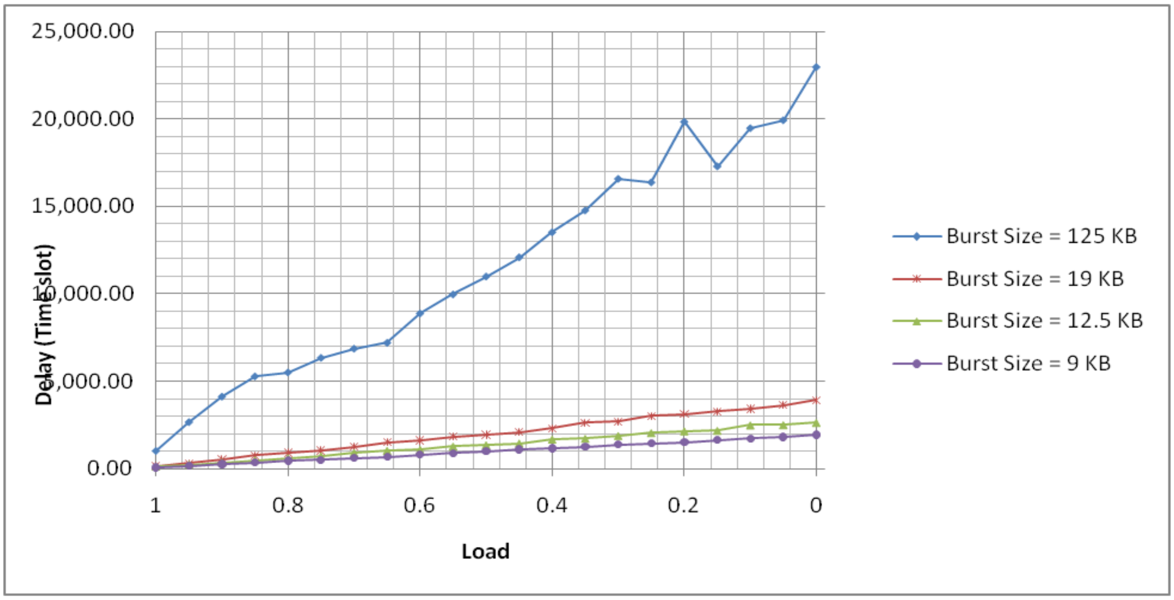

Figure 6.3: Delay vs. Load (Number of Time Slot = 1500K,
Buffer Size = 0 Time slices)

The aim of case 3 of the simulation is to evaluate the effect of frame size on the performance of HiTSOBS. Simulation results are depicted in Figures 7.1 and 7.2 for loss and delay respectively.

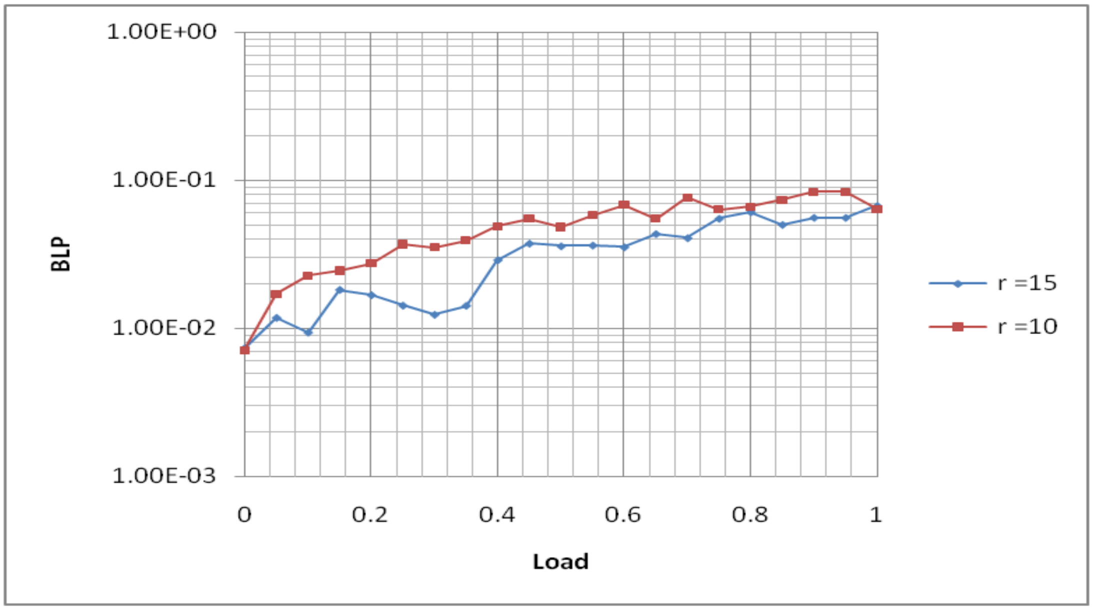

Figure 7.1: Loss vs. Load (Burst Size = 125KB Number of Time Slot = 1500K, Buffer Size= 10 Time slices)

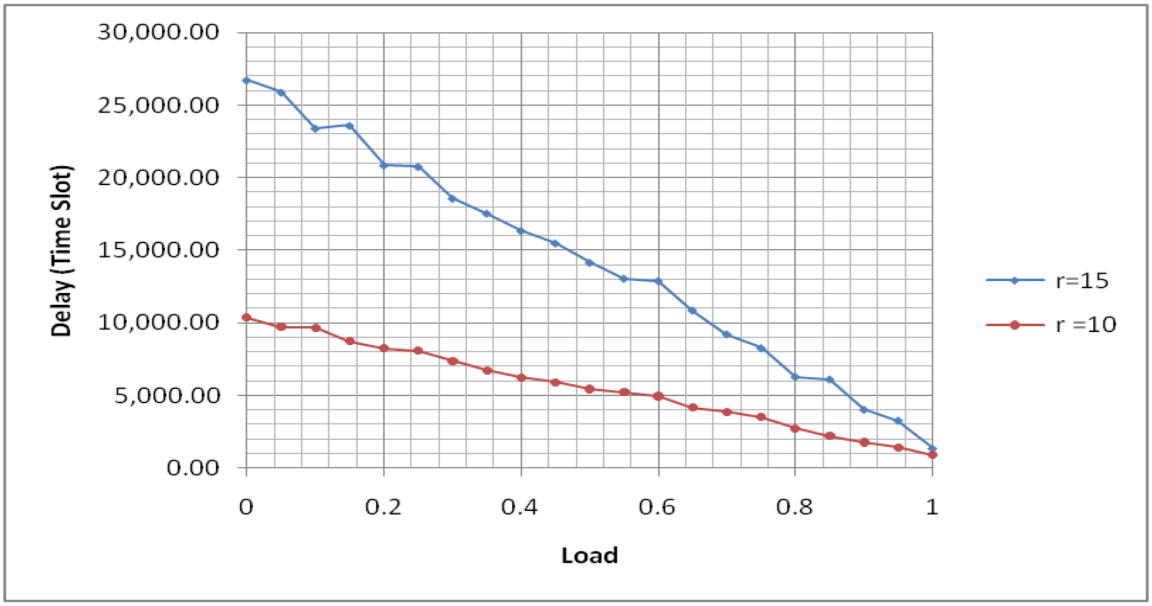

Figure 7.2: Delay vs. Load (Burst Size 125KB, Number of Time Slot = 1500K, Buffer Size= 10 Time slices)

Figure 7.1 above demonstrates that, with same burst size, bigger frame size will to lower BLP while smaller frame size result in higher BLP. Results in figure 7.2 shows that smaller frame size have lower delay while bigger frame sizes have higher delay. This is due to the fact that, the bigger the frame size the more time the bursts have to wait before being serviced.

5. CONCLUSION AN FUTURE WORK

In this paper, we have demonstrated, through scrupulous simulations (5 simulation runs) that HiTSOBS as a technique could improve OBS network performance and thus it is a promising candidate for future OBS networks. However and due to the fact that, the actual implementations of HiTSOBS were tested only in a single core node environment, further analysis is needed to strengthen the results found so far including the one in this paper. Therefore, we have developed a route, wavelength and time slot allocation algorithm for that purpose. The algorithm is being tested and evaluated to validate the viability of HiTSOBS architecture in a more complex and real environment such as the well known NSF network topology.

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