CONTROLLING BURST LOSS RATIO IN OBS USING FEEDBACK CONTROL AND DYNAMIC TECHNIQUES

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Abstract - Optical Burst Switching(OBS) is a switching technique used in optical network where data is sent as bursts. In this switching technique single burst loss can influence loss of multiple data. Hence Burst Loss Ratio (BLR) is the main deciding factor for determining the performance of an OBS network. This paper proposes two level schema by which BLR can be reduced. The first algorithm proposes a closed loop feedback technique in which the destination node senses the data traffic and sends feedback to the source node. The second algorithm provides a link protection and restoration mechanism by providing suitable backup channels by using Label-Stacking and Burst-Multiplexing Techniques. This work provides service level objectives in terms of burst loss ratio (BLR), while guaranteeing QOS requirement of each class of bursts.

Keywords: Optical Burst Switching; Quality of Service; Feedback Control Technique; Link protection and restoration mechanism.

I. INTRODUCTION

Optical burst-switching (OBS) is a switching technology for Optical Networks. OBS had widened over a range of services where data loss is a critical factor. OBS has proven its superiority over other switching technologies such as circuit switching and packet switching technologies. In OBS various packets to a destination are collected in the source (Ingress Node) and assembled as a burst. Before the burst is transmitted to the destination a control packet is sent to the network to allocate bandwidth at each link. After an offset delay time, the data burst itself is transmitted without waiting for positive acknowledgement from the destination node.However, even single burst loss can affect multiple TCP sources since a burst contains packets from different sources having same destination. Data loss can easily occur even because of a single link failure in the OBS network, as data bursts are transmitted by the one-way path reservation in an ingress edge router, and it is still difficult to deploy optical burst buffering in intermediate core routers.In this paper we use two way approaches for optimizing the performance of OBS network by controlling the Burst Loss Ratio. The two approaches are providing closed loop feedback technique from the destination node and providing link protection and restoration mechanism.

The feedback control technique provides differentiated services and support quality of service (QoS) for different class of bursts. Feedback control approach computes accurate burstification rate (i.e., rate by which the bursts are injected into the network) for each class of bursts. Burstification rates are computed at each burst manager controller for each class based on the previous measured value of the burst loss rate and the desired burst loss rate. Based on the above computed burstification rates the maximum delay is calculated and the delay is guaranteed to the deterministic level.The user receives an absolute service profile such asbandwidth, loss and delay. It also guarantees that no starvationoccurs, i.e. lower priority classes will not get zero service inorder to satisfy higher order classes service requirements.

Several feedback control schemes have been proposed to improve the OBS performance [12], [13], [14], [15], [16], [17].Performance parameters for each burst flow are exchanged by a feedback message to the edge/ingress nodes. According to the information contained in the message, the edge nodes dynamically adjust its parameters needed to achieve a defined QoS parameter. The adjusted parameters are the offset times [16], [14], the burst assembly parameters [15], [16] or theburstification rate [18], [12], [13].Jin et al. [15] used feedback control to achieve the required loss rate for a burst flow by adjusting the burst assembly process, specifically the burst assembly timer. Farahmand et al. [18] proposed a feed-back technique which adjusts the burstification rate at source nodes. The model controls the network congestion by controlling the load at each link. Every core node sends a feedback to the edge nodes containing a reduction request of the burstification rate. However, this model is not able to control the BLR. This paper is an extension of the work done in [12], [13] to manage the OBS network in order to guarantee a relative QoS.

The link protection and restoration mechanismdeals with the issue of a protection and restoration in OBS networks [3–5]. Oh et al. [3] validated that their proposed recovery scheme has a high scalability to cope with a wavelength (or channel), link and node failures as well. In traditional circuit based protection and restoration an unique property of the OBS, called tell-and-go was not considered. In the OBS, especially, a common just-enough-time (JET) scheme, the changes in a data path or offset time in a core router easily result in serious and contiguous burst losses. In the OBS ingress router, the offset time between the control packet and data burst is determined based on the end-to end path determined by a source routing and network load distribution, which includes a control packet processing time in each core router, the number of hops and quality of service (QoS) requirement levels. Thus, if unexpected changes occur in some parts of the path, bursts are discarded without exceptions until the ingress node handles that and controls burst transmission, even though bursts can be temporarily deflected in a local area. Thus, a single recovery easily results in contiguous burst losses in neighboring links, because of the increase in the contentions of channel reservation. simultaneously[3, 6]. At the same time, in order to achieve high throughput, the statistical burst multiplexing property of the OBS has to be considered enough in resource reservation for backup links and paths. In this paper, we deal with the design issues of the link and path protection in the OBS networks.

This protection scheme adjusts the number of protection channels according to the changes in the traffic load of the working link and QoS[7–10], and always reserves the optimal number of back channels by using burst multiplexing and label stacking.

The remainder of the paper is organized as follows: SectionII provides abrief introduction on feedback control theory when applied toOBS. Section III describes the operation principles and design issues of 1:1 protection mechanism.Section IV deals with the proposed work. Simulation results are shown in Section V.Concluding remarks are given in Section VI.

II. CLOSED LOOP AND FEEDBACK CONTROL

A linear control system implementing closed loop feedback control is shown in Fig. 1. At first *ingess (source) node* generates bursts by aggregating a number of IP packets directed towards the same *egress (destination) node*. The burst manager controller(BMC) controls the Burstification rate which resides at every edge node of the network. The target system to be controlled *is the OBS network*. The *burstification rate* is the tuning parameter which decides the congestion of the network. Congestion leads to dropping of bursts. The BLR is the system's controlled output parameter which represents a metric of the OBS network's performance.

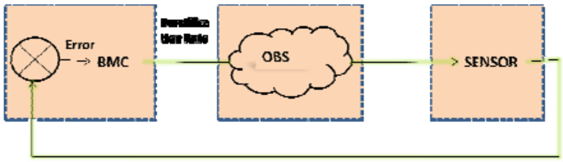

Figure 1: Closed Loop Feedback Control

The *sensor* reads the value of the controlled output parameter (*measured BLR*) at each egress node and provides this value as a feedback to the ingress nodes. The *reference BLR* is a reference value that the controlled output parameter should be restrained in the network. The *error* is the difference between the reference BLR and the measured BLR read by the sensor. The *burst manager controller* (BMC) takes the error value as an input and generates a burstification rate accordingly based on a control law. Classical controller design methodology consists of two phases. The first phase is *the system identification* where aconstruction of a transfer function which relates input values to output values. The second phase is *the controller design* to find the controller's parameters.

III. 1:1 PROTECTION MECHANISM

A. *Principles of 1:1 protection scheme:*

This proposed link protection consists of a local link protection between nodes end-to-end path deflection. The local protection helps in recovering a failed link with sequential handshaking using several messages: link-liveness, restoration-request, restoration-confirm and failureadvertisement. The internal logical operations of the 1:1 local link protection and end-to-end path deflection are shown in Fig. 2.

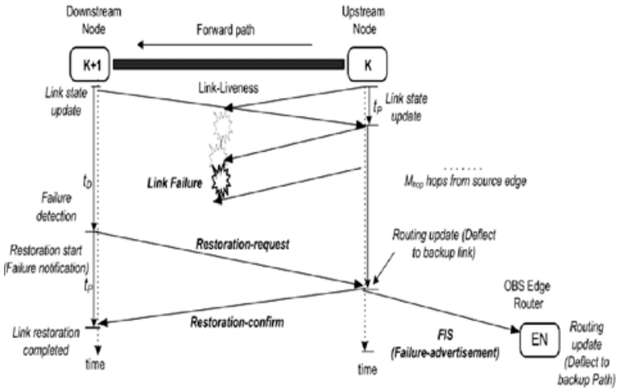

Figure 2: 1:1 Link protection

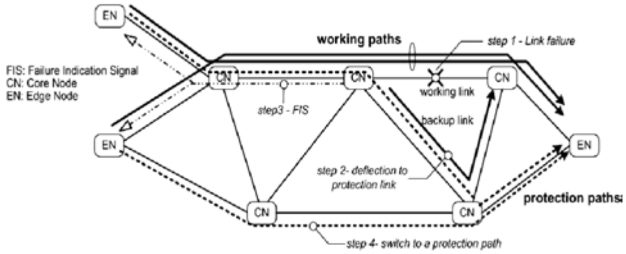

Figure 3: Working of End-to-End path deflection

Here, we assume a bi-directional link with a pair of unidirectional fibres, and a unidirectional link failure by a single fibre cut in the forward direction from the upstream node K to the downstream node K+1 is dealt with. The sequential handshaking using several messages as beforementioned are transmitted by the control channel group (CCG) of a working link. The CCG control packets are optical–electric–optical (O/E/O) converted at every intermediate OBS core router,whereas data bursts are transmitted through the channels of a burst channel group (BCG) without O/E/O conversion in the optical layer. Sequential protection procedures of the introduced link protection mechanism are as follows:

1. Link-state monitoring: Link-liveness messages are transmitted between the nodes at interval (tP) in order to observe the link-state.
2. Link-failure detection: When a link failure occurs, the link liveness message is not delivered to the node K+1. The node K+1 waits for the message during the fault detection time (tD), and then goes into the link restoration state. It transmits the restoration-request message to the node K by the CCG as shown in Fig. 1a
3. Restoration and link deflection: The node K now deflects incoming control packetsand data bursts to the pre-determined backup link without the permission from the ingress router to minimise burst lossesand the node K confirms restoration by transmitting the restoration-confirmed message to the node K+1.
4. Path deflection: The node K notifies edge ingress routers of the link failure by transmitting the failure-indication message using failure indication signalling (FIS). Correspondingly, the edge routers deflect the bursts of working paths to backup paths as shown in Fig.3. The proposed protection is the 1:1 protection that can minimise burst losses by localising the effect of a link failure.

B. Issues in the 1:1 protection mechanism

The performance of 1:1 mechanism in terms of survivability is dependent upon the tD and tP values. If tD and tP has a low value burst loss ratio is less. However there is a chance of wrong restoration.Hence an optimal tradeoff is needed in deciding the values of tD and tP. The earlier mechanisms [3, 5,11] tried to guarantee bursts without using statistical burst multiplexing property of OBS.We note that the condition that the number of backup channels in the backup link has to be the same as that of a working link in an optical circuit switched network is not a mandatory requirement in the OBS networks because of the statistical burst multiplexing property in the OBS. If the bursts can be effectively multiplexed in the backup link without loss in the QoS level, it is possible to optimally provision backup channels according to the changes in the traffic load of a working link. This statistical multiplexing improves utilisation and throughput because remaining channels can be allocated to other neighbouring links.

IV. PROPOSED WORK

The proposed work firsts start with discussion of feedback control model for OBS networks and then proceeds with discussion of link protection and restoration mechanism that support QoS. The model has n ingress nodes, m egress nodes, k core nodes and w classes of service . Each ingress node s_i has a burst manager controller ($BMC_{s_id_jc_k}$) for each egress node d_j and class of service c_k. Thus, there are m*c burst manager controllers at each ingress node. Each egress node d_j has a sensor ($Sensor_{s_id_jc_k}$) for each ingress node s_i and class of service c_k. The sensor measures the BLR of the class c_k ($BLR_{s_id_jc_k}$) periodically and sends it as a feedback to the $BMC_{s_id_jc_k}$at the ingress node s_i. The error value ($E_{s_id_jc_k}$) is computed as the difference between the reference BLR ($REF_{s_id_jc_k}$) and the measured BLR ($BLR_{s_id_jc_k}$). The $BMC_{s_id_jc_k}$ computes the burstification rate ($BR_{s_id_jc_k}$) based on the error. The burstification rate is used as an admission control parameter to the OBS network. Once the value of the burstification rate is exceeded, no more bursts will be injected into the network.

A. *Identifying the System*

Controllers use defined relationships between inputs and outputs of the system. This work uses autoregressive moving average (ARMA) empirical approach, to relate inputs and outputs. The general form of the ARMA model is given by:

$$y(t) = \sum_{i=1}^{p} a_i y(t-i) + \sum_{j=0}^{q} b_j x(t-j) \qquad (1)$$

The input, x(t), of the ARMA model represents a tuning parameter and the output, y(t), represents a controlled output parameter. The parameters p and q are the order of the model, and the a_i, and $b_j$are constants that are estimated from data using *least squares regression* [19]. Transfer functions are converted from time to frequency domain (the z-domain). The z-transform [20] of y(t) is given by :

$$Y(z) = \sum_{t=0}^{\infty} y(t) z^{-t} \qquad (2)$$

Where, z is a complex number. These principles are applied to Eq.(1) to obtain the ARMA model in the frequency domain given by:

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{j=0}^{q} b_j z^{q-j}}{z^q - (\sum_{i=1}^{p} a_i z^{q-i})} \qquad (3)$$

Simulations show that the ARMA model is a good fit to model the *OBS network* from each ingress node s_i to each egress node d_j. That is, if y(t) is set to the burst loss ratio ($blr_{s_id_jc_k}(t)$) from source s_i to destination d_j for bursts of class c_k, the input x(t) is set to the burstification rate ($br_{s_id_jc_k}(t)$) from s_i to $d_j$for bursts of class c_k. Then,

$$OBS_{s_id_jc_k}(z) = \frac{BLR_{s_id_jc_k}(z)}{BR_{s_id_jc_k}(z)} = \frac{zb_0}{z - a_1} \qquad (4)$$

where$OBS_{s_id_jc_k}(z)$ models the network for each ingress node (s_i) and each egress node (d_j) and class c of bursts. First order ARMA model is used with p = 1 and q = 0 and the ARMA model parameters are estimated to $a_1 = 1.3$ and $b_0 = -1.03$. This model gives a fraction of variability (goodness of the model) [19] of no lower than 75%.

B. *Designing the Controller*

A control law is needed to be described for how the controller changes the value of a tuning parameter, for designing controller. *Integral control law* is used in this paper for its simplicity and efficiency [20]. The *integral controller* produces a control action that increases its corrective effect as long as the error persists. If the error is small, the integral controller increases the correction slowly. If the error is large, the integral action increases the correction more rapidly [20]. The integral controller has the following general time domain formula:

$$br_{s_id_jc_k}(t) = br_{s_id_jc_k}(t-1) + K_{s_id_jc_k}\ e_{s_id_jc_k}(t-1) \qquad (5)$$

Where, $b_{s_id_jc_k}(t)$ is the burstification rate from ingress node s_i towards egress node d_j for bursts of class c_k. $K_{s_id_jc_k}$ is the integral gain associated with each burst manager, and $e_{s_id_jc_k}(t)$ is its associated error value that the controller's goal is to eliminate. A classical control theory technique called *root locus* can be applied to calculate the value of $K_{s_id_jc_k}$. Further details for this methods is available in [12], [13].

C. *Link Restoration and Protection Mechanism*

The proposed protection mechanism reserves protection channels in a backup link based on the incoming load and their QoS requirements. This protection mechanism provides efficient resource sharing in the network-wide as well as local protection and restoration, by achieving optimal statistical burst multiplexing, while strictly guaranteeing QoS and the survivability of 1:1 protection. It is impossible to avoid burst collision and data drop in OBS networks. Because data bursts are transmitted by source routing and one-way channel reservation in

OBS networks, it is nearly impossible to guarantee blocking-free transmission in a high traffic load condition. Intelligent control mechanism can increase the efficiency of protection and restoration and also increases the reliability of the network, since load balancing in paths affects blocking loss probabilities in a link backup. However, a protection and restoration mechanism is still needed in every core router to minimise burst losses independent of transmission reliability in a working link. The blocking probabilities of classes are determined by the incoming traffic load and its distribution over classes [10].Thus, if the blocking probabilities of class bursts are much lower than requirements in a given traffic load condition, that is, bandwidth over-provisioning occurs in a working link, it is possible to effectively protect bursts being transmitted in a working link in the case of a link failure by using statistical burst multiplexing and consolidating voids,which is a promising advantage of the OBS networks over other optical circuit switched networks.

D. Providing burst guarantee by label stacking and burst multiplexing

This mechanism manages the number of backup channels N_{BC} based on the changes in the traffic load of r and its distribution in a working link. It is assumed that data traffic are categorised into C priority classes in an ingress edge node, and class bursts are transmitted by the JET scheme using different QoS offset times. In this protection scheme, the upstream node in a link observes potential blocking loss probabilities of class bursts by using the traffic load information referenced from the switching reservation fields of the control packets. Two kinds of mechanisms are utilized for link protection, which are statistical burst multiplexing and label stacking. First, control packets whose bursts are scheduled to pass through the same backup channel are merged into a single protection control packet by using a label stacking method as shown in Fig. 4. Wavelength reservation information in the backup link is written in the dedicated field of the protection control packet, and is recovered as an individual control packet in the K+1 node if a link failure occurs. Correspondently, if a link failure occurs, the bursts are statistically multiplexed based on the stacked control packet, which is coordinated by the control agent in advance, and transmitted by the reserved backup channels as shown in Fig. 4. Also in this method instead of deflecting the bursts through a single backup channel, they are routed via more than one backup channel. As a result the load is distributed over many channels. This prevents further loss occurring due to the backup restoration. It is possible to introduce fixed FDL banks to core routes in order to improve link utilization and achieve more reliable protection. However, considering the complexity needed in FDL bank control resulting from the large granularity of fixed FDLs as discussed in [8, 9] the proposed link protection solution is a more effective in OBS networks.

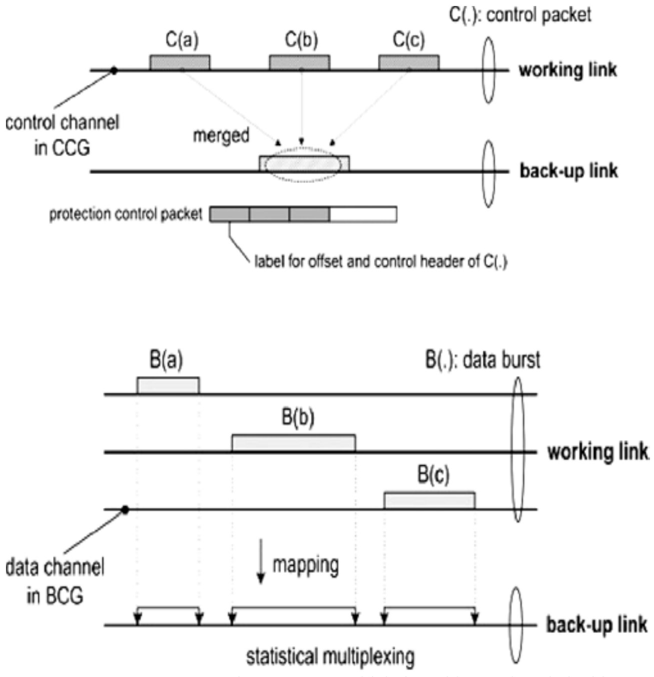

Figure 4: Control label stacking and statistical burst multiplexing in a backup channel

E. *Selection of backup channels*

We define $P_{BG}(k)$ and $P_B(k)$ as the contracted blocking probability and observedblocking probability of class k in a working link, respectively, where r_k is the traffic load. The control agent coordinates the number of backup channels such that the blocking rate metric (P_B) in a backup link channel satisfies the contracted blocking loss rate metric (P_{BG}) in this mechanism. Thus, blocking metrics should satisfy the following requirements

$$P_{\mathrm{B}} = \{[P_{\mathrm{B}}(1), P_{\mathrm{B}}(2), \ldots, P_{\mathrm{B}}(C)] | 0 \le P_{\mathrm{B}}(1), \times P_{\mathrm{B}}(2), \ldots, P_{\mathrm{B}}(C) \le 1\} \quad (1)$$

$$P_{\mathrm{BG}} = \{[P_{\mathrm{BG}}(1), P_{\mathrm{BG}}(2), \ldots, P_{\mathrm{BG}}(C)] | 0 \le P_{\mathrm{BG}}(1), \times P_{\mathrm{BG}}(2), \ldots, P_{\mathrm{BG}}(C) \le 1\} \quad (2)$$

$$P_{\mathrm{B}}(i) \le P_{\mathrm{BG}}(i), 1 \le i \le C \quad \text{for given } N_{\mathrm{BC}} \text{ and } \rho \quad (3)$$

Based on the status of blocking probabilities of classes, the upstream node coordinates N_{BC} adaptively, while the monitoring blockobserves the offered load and its distribution. By the result of comparison, the number of backup channels is adjusted from 1 (a single backup channel) to N_{WC} (entire1:1 protection) in the outer iteration. We note that N_{BC}does not exceed N_{WC} in any case in the proposed resource sharing scheme.

To analyse a feasible blocking loss probability in both links, a Poisson burst arrival model is assumed in this paper. The total traffic load is assumed to be r ¼

PCi¼1 r_i, and is serviced by N_{WC} wavelengths in a single fibre. First, the burst blocking probability in a classless system can be derived by the Erlang loss formula used in the M/M/k/k queue as follows

$$P_{\mathrm{B}} = B(N_{\mathrm{WC}}, \rho) = \frac{\rho^{N_{\mathrm{WC}}}/N_{\mathrm{WC}}!}{\sum_{i=0}^{N_{\mathrm{WC}}} \rho^i/i!} \quad (4)$$

In the case of class-based service differentiation, the average blocking probabilities of classes are affected by a traffic load distribution over classes. If the JET-based loss differentiation is effectively exploited, the blocking probability of the highest class C is achieved as

$$P_{\mathrm{B}}(C) = B(N_{\mathrm{WC}}, \rho_C) = \frac{\rho_C^{N_{\mathrm{WC}}}/N_{\mathrm{WC}}!}{\sum_{i=0}^{N_{\mathrm{WC}}} \rho_C^i/i!} \quad (5)$$

by pre-emptive link bandwidth provisioning. Meanwhile, the blocking probability of a low-priority class is affected by its own load and the cumulative load of high-priority classes. By the result of wavelength reservation is successfully exploited in acore router, the amount of load that affects the blocking probability of class k þ 1, $r_{ekþ1}$, is the same as the sum of $r_{kþ1}$ and the cascaded blocked loads of high-priority classesas [5, 10]

$$\rho_{k+1}^e = \rho_{k+1} + \rho_C \cdot P_{\mathrm{B}}(C) \cdot \ldots \cdot P_{\mathrm{B}}(k+2) + \rho_{C-1} \cdot P_{\mathrm{B}}(C-1) \cdot \ldots \cdot P_{\mathrm{B}}(k+2) + \ldots + \rho_{k+2} \cdot P_{\mathrm{B}}(k+2) \quad (6)$$

The decrease in the amount of allocable bandwidth in the backup link, which can be provided to the class k þ 1, has to be considered as well. In this protection, voids can be minimised by the statistical burst multiplexing of the OBS. Thus, the normal blocking loss probability models can be applied for a backup link without changes. The blocking loss probability of the class j (1 _ j ,C) is derived as

$$P_{\mathrm{B}}(j) = B(N_{\mathrm{W,E}}(j), \rho_j^e) = B\left(N_{\mathrm{W,E}}(j), \rho_j + \sum_{i=j+1}^{C} (\rho_i \cdot \prod_{k=j+1}^{i} P_{\mathrm{B}}(k))\right) \quad (7)$$

Where $N_{W,E}(j)$ is the number of effective wavelengths allocable for the channel reservation of the class j burst. Because a high-priority class burst is rarely affected by low class bursts in the JET service differentiation, even if a reservation contention occurs, $N_{W,E}(j)$ is determined by target blocking probabilities and the offered loads of high priority classes. Optimal provisioning of system parameters, especially thenumber of backup channels and sharing efficiency in the DRS, can be formulated by using monitored blocking loss probabilities. The optimal number of wavelengths whichhave to be provisioned as a backup link for a working link l with given [r, P_{BG}], N_{BC} (l), is derived as

$$N_{\mathrm{BC}}(l) = \min\{N | P_{\mathrm{B}} \le P_{\mathrm{BG}}\} = \min\left\{N | B\left(N, \rho_j + \sum_{i=j+1}^{C} (\rho_i \cdot \prod_{k=j+1}^{i} P_{\mathrm{B}}(k))\right) \le P_{\mathrm{BG}}, \text{for} 1 \le j \le C\right\} \quad (8)$$

Thus, if the offered loads of working links are low, a single link can support a number of working links as their backup link, while guaranteeing the contracted blocking loss probabilities based on coordination using (7) and

(8). It is expected that the effect of blocked high-priority bursts decreases by reducing P_{BG}s or deploying a strict service management using an admission control mechanism [11, 12].In addition, to support service differentiation in blocking probabilities, the control agent has to guarantee the blocking loss rates of the relative ratio values of classes,which are determined by the ingress router. If the contracted blocking probability is guaranteed in everyclass, the overall probability can be subdivided by Thus, the blocking loss probability in the selection of class n backup channels has to be coordinated as [5]

$$B\left(N_{\mathrm{W,E}}(j), \rho_j + \sum_{i=j+1}^{C} (\rho_i \cdot \prod_{k=j+1}^{i} P_{\mathrm{B}}(k))\right) \leq \frac{P_{\mathrm{BG}}(j)}{P_{\mathrm{BG}}(j-1)} \tag{9}$$

The control agent can provide effective protection and service differentiation simultaneously by applying (8) and (9) to the selection of backup channels recursively. This protection mechanism achieves optimal backup channel reservation for the given burst traffic load by using a recursive blocking probability comparison, and the upstream node of the protection adaptively coordinates backup channel provisioning every T_P. We note that this multiplexing-based protection can efficiently be deployed because of the unique property of the OBS network by which control packets arrive at the core routers in advance.

The proposed mechanism uses statistical multiplexing in order to minimise channel voids (i.e. unused parts in a backuplink), while guaranteeing the same QoS performance achievable in a working link at least. It is expectable that channel utilisation and efficiency in resource allocation will increase in a backup link, since an optimal amount of resource is reserved for protection in a given load condition. It is expected that the entire network utilisation can also be improved, since link utilisation increases in every hop. However, in order to achieve optimal performance in terms of survivability and utilisation at the same time in an entire network wherein a number of paths comprising cascaded links are connected, optimal path protection to guarantee high survivability as well as maximum resource-sharing in an entire network have to be achieved.

V. SIMULATION RESULTS

In order to evaluate the proposed technique, we have implemented a new module for the controller and then integrated it to the OBS module in ns-2. NSFNET network used in the simulations is shown in Fig. 5.

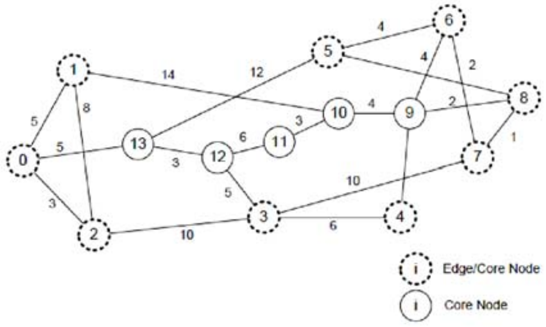

Figure 5: NSFNET Network

It consists of 14 nodes and 21 bi-directional links. The figure shows the propagation delay of each link expressed in milliseconds. Nodes with dotted line act as edge and core nodes. The others are only core nodes. Each ingress node s_i generates bursts following *Poisson distribution* towards each egress node d_j. There are three classes of bursts, namely class c_0, c_1, and c_2. Class c_0 has the highest priority. The average burst rate for classes c_0, c_1 and c_2 are 35000, 65000, and 115000 bursts per second respectively. Pre-emption for wavelength reservation is used i.e. higher priority classes of bursts preempt lower priority classes of bursts. The maximum burst size is 120 Kbyte. The processing delay for the control packet is 10µs. The same offset time is set to 1 ms. The nodes support wavelength conversion but there is no buffering. Fixed shortest path is used for routing. Each link has 70 channels operating at 10 Gbps, 15 of which are used as control channels and the rest are data channels. The reservation scheme is the Just-Enough-Time (JET) protocol [6]. The reference burst loss ratios for classes c_0, c_1 and c_2 are 0, 0.001 and 0.005 respectively. The root locus technique provides a gain $K_{s_id_jc_k}$ equal to 0.3. Simulations were performed to compare between using the proposed model and not using it.

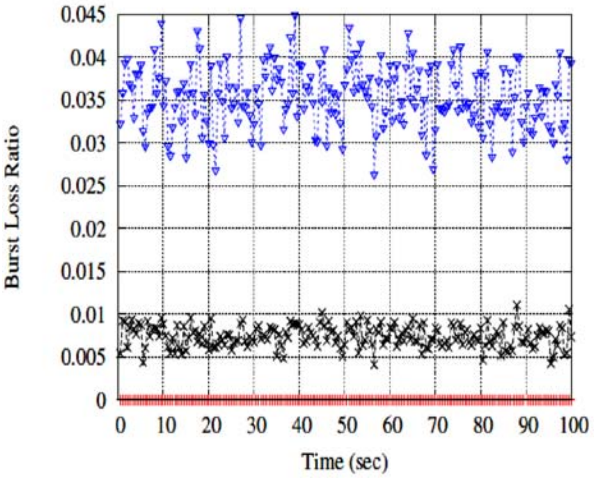

Figure 6: Burst Loss Ratio from source to destination

VI. CONCLUSION

In this paper, we propose an approach based on closed loop feedback control to provide relative QoS differentiation in OBS networks. The practical issues of a link protection and restoration in the OBS networks have been dealt with. The approach guarantees quality of service in terms of burst loss ratio for each class. Simulations showed that the proposed technique allows a better control of the burst loss ratio for each class by controlling the burstification rate at each source node. Without feedback control, the desired BLR is not guaranteed. The proposed link protection improves the efficiency of network resource allocation and the link utilisation of a backup link, while guaranteeing the QoS requirements of classes by the optimal backup link selection using label merging and statistical burst multiplexing.

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