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Packet Loss Rate Differentiation in slotted Optical Packet Switching OCDM/WDM

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Abstract

We propose a multi-class mechanism for Optical Code Division Multiplexing (OCDM), Wavelength Division Multiplexing (WDM) Optical Packet Switch (OPS) architecture capable of supporting Quality of Service (QoS) transmission. OCDM/WDM has been proposed as a competitive hybrid switching technology to support the next generation optical Internet. This paper addresses performance issues in the slotted OPS networks and proposed four differentiation schemes to support Quality of Service. In addition, we present a comparison between the proposed schemes as well as, a simulation scheduler design which can be suitable for the core switch node in OPS networks. Using software simulations the performance of our algorithm in terms of losing probability, the packet delay, and scalability is evaluated.

Keywords: *Quality of Service (QoS), Slotted Optical Packet Switching, Packet Loss Probability (PLP), shared Fiber Delay Line (FDL).*

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1. Introduction

Upcoming optical networks are expected to support many numbers of users with multiple bit rate transmissions, finer granularity capacity and quality of service (QoS) demands in a flexible manner [1].The growth of interactive application and multimedia, such as video-on-demand, teleconferencing and digital video broadcasting depend on the Internet to exchange data traffic. Consequently, Optical Packet Switching (OPS) is supposed to be among one of the greatest candidates to be implemented in future optical backbone network [2], [3], it is fundamental to develop new QoS differentiation mechanisms that consider the OPS network characteristics.

Over years, plenty of different switching technologies such as optical code division multiplexing (OCDM), and wavelength division multiplexing (WDM) have been investigated in optical fiber communication [4],[5]. These technologies, OCDM constitutes a potential candidate for the next generation optical networks particularly due to features like synchronous and asynchronous operation simplified network control the easy addition of new users and the possibility of differentiated quality of service QoS at the physical. Nowadays, there has been an increasing demand for new multimedia applications, for instance, e-learning e-health high-data-capacity 3-D full-HD (high-definition) the video, multiplayer games, video-on-demand, etc., as a consequence, these new applications will require differentiated QoS and multiple rates transmission which are becoming a challenge for future optical networks.

However, wavelength division multiplexing, Optical code-division multiplexing (OCDM/WDM) is a technic, which can use for the future generation of the Internet [6]. In WDM technology, the optical media spectrum divided into a number of wavelength bands, which arent overlapping and each wavelength can provide a large amount of raw bandwidth. Moreover, WDM can support a multi-coded communication channels operating at high data ratio. Presently, WDM technology supports the multiplexing of hundreds of spectrum into a single optical fiber, at a transmission rate of 10s Gb/s per spectrum channel [7]. In optical code-division, multiplexing (OCDM) can provide flexible, heterogeneous, and synchronous multiple bit-rate transmissions at a sub-wavelength level to connections with enhanced security and network scalability [8]. In addition, OCDM can

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provide QoS differentiation at the physical layer level. Moreover, optical code generation, processing, and decoding are performed entirely in the optical domain [1].

This article is organized as the following sections. In Section II, we describe the related work. The differentiated contention resolution in photonic packet switching networks is discussed in Section III. In Section IV, we discuss the simulation performance. The conclusion has been explaining in Section V.

2. Related Work

Actually, high bandwidth does not solve the QoS issue; therefore, new schemes for supporting QoS in an optical background are needed. Currently, there is different service differentiation have been proposed to support multi-rate services provision in OCDM networks such as employing codes with different lengths [9]. A different approach is to use the multi-cored technique, where the number of simultaneously assigned codewords to each user is a function of the data rate of the service class, while QoS differentiation is realized by variable-weight codewords for each service class [10].

Adapting the number of allocated codes according to the requested transmission rate, so as to support time-variant data rates and multiservice transmissions by employing a multi-code variable-weight two-dimensional (2D) one coincidence frequency hopping code, optical orthogonal code (OCFHC/OOC) as the signature code [1]. However, the author proposed dynamic changes in the requested rate by means of allocating/de-allocating encoders/decoders to the existing connections. Two multicode assignment methods, used, random multicode assignment (RMA) policy and uniform multicode assignment (UMA) policy. Consequently, the result shows that blocking probability observe worse end-to-end blocking probability. Furthermore, RMA and UMA policies have the same blocking probability.

On the other hand, utilizing multilength variable-weight (MLVW) codes [9, 11], and multicode variable-weight (MCVW) codes [10], both multi-rate and multi-QoS transmission are supported simultaneously, as a comparison is carried out between using MCVW codes and MLVW codes in [10]. In the article [9], the idea was based on OCDM scheme in generalized multi-protocol label switching (GMPLS) network using multilength variable-weight optical, orthogonal codes (MLVW-OOC) as signature sequences. The weight and the length of codes were designed based on the service characteristics, with limitation the number of connections based on the activity number of the connected users to guarantee the desired service. Moreover, multi-length variable-weight, optical orthogonal codes (MLVW-OOC) is used as signature sequences of a hybrid WDM/OCDM system, the code length and code weight of MLVW-OOCs are designed based on the characteristics of the demanded classes of service [11]. In [12] an overall technique of constructing ML-OOCs, with arbitrary correlation value λ for multi-rate OCDM networks have been introduced to construct a variable-length mapping sequence with unparalleled λ positions, with which map short-length OOCs into long-length OOCs to realize the general construction of ML-OOCs with correlation value λ with high efficiency.

Furthermore, the author in, [13, 14] have proposed formalisms can be successfully applied to 1-D and 2-D MWML-OOC OCDM networks with any number of user classes. In [13], the bit error rate (BER) and packet correct probability expressions were derived, considering the multiple-access interference as binomially distributed. On the other hand, Packet throughput expressions were derived considering Poisson, binomial, and Markov chain approaches for the composite packet arrivals distributions, with the latter defined as a benchmark. Numerical results show that the Poisson approach underestimates the throughput performance in unacceptable levels and incorrectly predicts the number of successfully received packets for most offered load values even in favorable conditions, such as for the 2-D MWML OOC OCDM network with a considerably large number of simultaneous users.

The authors in [15] have proposed to categorize the fiber wavelength spectrum into a number of wavebands and allocate the spectrum of each waveband for a particular class of service and the corresponding codes were designed based on the characteristics of the class of service. They have suggested two scenarios: path establishment with traffic management and path establishment without traffic management. In the first scenario, a controlling mechanism manages the distribution of the connected paths so that all wavelengths have the same number of connected paths; whereas, in the second scenario, connected paths are divided among wavelengths randomly. Moreover, in [16] an oriented path length based wavelength assignment strategy for wavelength-routed WDM networks was purposed which assign the wavelength to the connection request according to the path length. In their scheme, the connection requests with shorter light path were assigned the wavelengths having higher dispersion and the wavelengths having lesser dispersion were assigned to the light paths with longer distance. Additionally, wavelength assignment has been used in [17, 18] , and wavelength reservation with shared buffers in [19]. In [19], the authors divided the wavelengths to sets, therefore regarding to the reservation scheme, the high priority packets (level 1) can be shifted to any sets of available wavelengths, in decreasing order from L1 to L4, where the rest packets of other QoS levels were consequently shifted to their own sets.

3. Differentiated Contention Resolution in Photonic Packet Switching Networks

QoS differentiation framework supports OPS networks to provide multiple service classes. Efficient and fair resource categorization between the classes of service increases the total network efficiency and utilization [20]. In this article, the control and data planes of the proposed WDM/OCDM-based OPS scheme is designed considering QoS requirements. The measurement criteria of QoS are PLP and, FDL delay. Furthermore, we provide a switch architecture and channel allocation scheme implementation for supporting differentiated buffering and differentiated wavelength converters in photonic packet-switched networks.

Generally, absolute levels can be specified for each QoS metric [20, 21]. However, without loss of principle, two classes are considered for every metric, to be specific, high priority (HP) and low priority (LP) classes. Considering HP and LP classes for the characterized four channel allocation schemes, there are feasible. In any case, all possible combinations of allocation schemes are simulated. We then discuss the various parameters for providing differentiated service in photonic packet-switched networks.

3.1. Node architecture

In the recent work [22], we have proposed hybrid OCDM/WDM combined with shared FDL as it is demonstrated in Figurer 1. The advantages of the hybrid system [22] were to improve the performance of the node and, in [23] was to optimize the ultimate number of FDL to reduce the cost and to keep the performance high. The proposed algorithm, initially tries to eliminate the contention by means of optical code by assigning the packet to available code and, if there is no free channel code in that particular wavelength, the algorithm tries to shift the packet to another wavelength in the same out fiber link using the wavelength converter from the shared wavelength converter pool, then, if there is no free wavelength converter, the algorithm sends the packet to either FW buffers or FB buffers regarding to their availability. The only cases where the packets would be dropped are if there is no free FB buffer is available.

In the switch assumption, we assumed that all switch matrix is function synchronously with constant length packets received at N ingress optical link in the fitted time slot. The matrix of core switch has $((N*M*F)+K)*((N*M*F)+R+D+K)$ switching matrix. It has N Input/output fiber ports (IF/OF), K FB, R wavelength converter, D FW FDLs. Moreover, every fiber supports M wavelengths, and every wavelength can hold up to F packets coded along, by using Optical Code. Means that, each input and output channel is recognized by the three variable $(i, \lambda j, OC_k)$.

The proposed scheduling algorithm is executed at each slot time of the multiservice OCDM/WDM optical packet switch. The proposed scheduling algorithm has been modified from [22, 23], in order to support multiservice transmission [24]. In this paper, the multiservice differentiation is assisted by a number of technologies such as code conversion, wavelength conversion, and Fiber Delay Lines (FW and FB) buffering [25]. The multiservice OCDM/WDM packet switch shown in Figure 1 performs the following operations: (1) incoming packets on each input fiber are wavelength demultiplexed and code decoded by means of M WDM demultiplexer and $M.F$

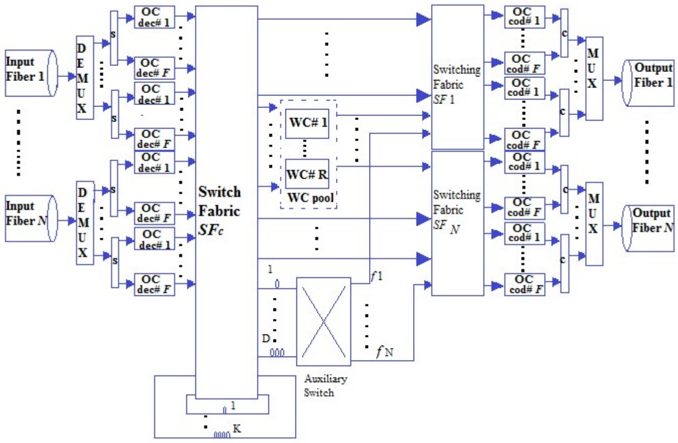

Figure 1. Architecture of OCDM/WDM with shared FDL.

code decoders; (2) the control unit processes and check for all High priority packets in entire input for a time slot and give them the priority to use resource first, resolves packet contentions, and directs packets either to codeword, wavelength converted or buffered based on the rules of the scheduling algorithm, for HP packets, when a packet arrives at ingress first try to transmit it immediately to desired out wavelength through free code channel, if contention occurs, then, try to solve the problem using wavelength converter, if there is no free converter, then, send the packet to FW buffers, if there are no free FW buffers and no guarantee of successful transmit later on, at that time, the HP packet will be dropped, this scenario runs up to finish all HP packets, same scenario goes with LP packets accept that, if it is not successfully sent to FW buffers then, send it to FB buffers unless all FB buffers are occupied, at that moment, the LP packet will be dropped; (3) all successful packets routed either direct codeword packets, wavelength converted packets and buffered packets are directed to SF_i switches based on decisions taken by the control unit; (4) finally, packets are routed towards to desired output channel after been coded and multiplexed [24]. Once again, there are only three possible places where the packet could be dropped; first place, if HP or LP packet did not get free FW buffer and no guarantee of output reservation; second place, if LP packet did not get free FB buffer; third place, if LP packet exceed four round in FB buffer and no chance to leave the node.

Moreover, the packet losses are the main concern in the switch consideration, and packet delay which is effected factor by both lacks of wavelength converters and contentions at an output port [26]. Hence, in this article, we concentrate on the Packet Loss Probability (PLP) and packet delay as the main QoS parameters, which means that the variety service classes will be differentiated from each other based on different PLP and packet delay. PLP is defined as the average number of dropping packets per unit time. However, for the sake of performance evaluation of the switching node under different traffic load, PLP is defined as ratio of the total number of losing packets to the total number of arriving packets; as well as throughput is defined as ratio of the total number of successful departure packets to the total number of arriving packets. The average packet delay is defined as the number of time slots a packet has waited since its arrival into the input buffer till it is transmitted to its output port.

$$PLP = \frac{\sum Lossingpackets}{\sum arrivingpackets} \tag{1}$$

$$Through = \frac{\sum departurepackets}{\sum arrivingpackets} \tag{2}$$

$$Delay = \frac{\sum waitedslots}{\sum bufferdpackets} \tag{3}$$

3.2. Channel Allocation Schemes

Basically, ports restriction based QoS differentiation scheme, the optical code allocation algorithm (OCAA), has been studied. In the optical code allocation, which provides QoS differentiation in synchronous buffered OPS networks with (full range and limited number) of shared wavelength converters, certain allocation strategies have been simulated in order to obtain QoS. Furthermore, the algorithm has been adapted from our previous work [22, 23] however, four mechanisms have been simulated for the single node based QoS differentiation: shared input, shared output (SSM); shared input, privet output (SPM); privet input, shared output (PSM); and privet input, privet output (PPM) [25].

In the OCAA, the total available codes (F) at an input/output wavelengths are divided into two pools according to priority, i.e. a class HP pool with FH codes and a class LP pool with FL codes. Incoming packets can access these codes only if they have the necessary priority level. This means that at share mechanism phase, both classes are sharing the ports with the priority service (i.e. WC, FW) to HP packets. On the other hand, at privet mechanism phase, class HP traffic can access only codes from the class FH pool, as well as class LP traffic can access only codes from the class LP pool, where is the total of $FH + FL = F$ codes on one wavelength. By adjusting the variable FH and FL, we achieve any desired level of the PLR for class HP traffic, which is important in order to provide QoS to the core network nodes [27]. For incoming packets which fail to acquire any services (FW buffer for HP and FB buffer for LP) are immediately dropped at the node.

In order to obtain simulation results for the PLP for both priority classes, we have built the OCAA algorithm. The first algorithm is PPM, where the coded channels are divided into two sets FH and FL for in/out ports. All packets arrived at the inputs are serviced regarding their priority class. Therefore, the HP packets are serviced at first, and they have the priority to use nodes resource. Furthermore, each class packets are separated by channels in use (i.e. each class has its own channels in/out). In this phase, the initial value of HP set is (FH =2, 4, 6, and 8) channels, in the same time, the initial value of FL is (FL= 8, 6, 4, and 2) channels. The second algorithm is PSM, where the input coded channels are divided into two sets FH and FL, at the same time the output ports are shared among all packets, depend on the channel availability. For instance, the HP packets reach the input node in privet coded channels and leaving the node using sharing channels with FL packets. The third algorithm is SPM, where the input coded channels are shared by all the different classes, but the output is privet each class has its own channel to use. The fourth algorithm is SSM, where all ports are shared in use for all different classes.

4. Simulation Performance

In this section, we evaluate the performance of one node based QoS mechanisms for OPS networks with offered (0.8) traffic load, to this end, we consider OCAA QoS differentiation mechanisms as explained early section. The simulation results are obtained using Scilab. In the simulations, it is assumed that time slots are fitted to packet boundary and all are equal length duration. The proposed differentiation schemes algorithm has involved fixed-length packets, simplifying the algorithm and operation of the switching node. In another word, it is assumed that all packets entered the switch are synchronized with respect to their boundaries, consequently that all packets are fitted to their timeslot. The simulation environment that been used is run for a paired of 5000-time slots.

In simulation experiment, the switch node size is $N = 32$, wavelength $M = 16$, optical code $F = 10$, and with shared pool wavelength converter $R = 24$. A simulation runs enough time with the purpose of differentiation mechanism. The packets arrive according to Bernoulli distribution new slot. Traffic is equally distributed to all output of switch $1/N$ and it is considered that packet duration is fit to time cell. In the experiments, during each time slot execution, the HP packets have given the priority to be serviced first, for instance, occupies free output channels, use available wavelength converters, and FW buffers over LP packets. On another word, the HP packets cant use FB buffers to reduce the delay.

In Figure 2 shows the result of an experimental simulation of PPM. The packet loss prob-

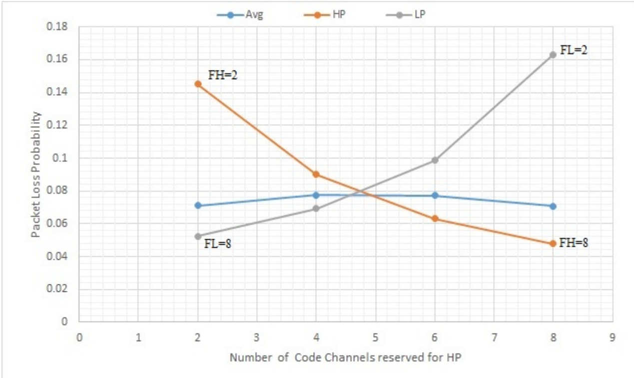

Figure 2. Packet Loss Probability of hybrid OCDM/WDM system at different numbers of code channel, privet input privet output mechanism.

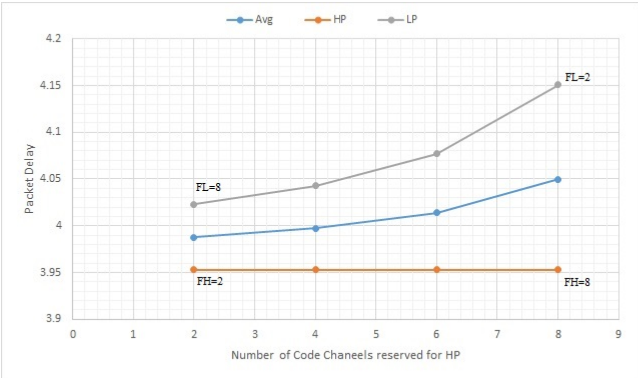

Figure 3. Packet Delay of hybrid OCDM/WDM system at different numbers of code channel, privet input privet output mechanism.

ability and packet delay of hybrid OCDM/WDM system with different numbers of reserved code channels for HP under (0.8) total traffic load. The result of the algorithm performance shows that, when FH increases, the PLP decreases, take note that $FH + FL = 10$ is the total number of coded channels in the single wavelength. Its obvious that when the small number of FH used the probability of losing packets is higher and reduced when increasing the number of FH, because of the contention is reduced by increasing the number of out channels. On another hand, Figure 3 shows the performance of the packet delay for HP is almost flat for all number of the channels, as a consequence of high traffic directed from the same number of input channels to the same number of output channels.

Figure 4 and Figure 5 illustrated the performance of PSM. The number of input coded channels which been reserved to class HP is FL=2, 4, 6, 8, at each wavelength, and where the output channels are shared among all classes. The algorithm policy receives the HP packets class from privet channels and sends them through shared channels with the priority service for HP class. The result of the algorithm performance displays that, PLP for HP almost is $zero$ for up to 6 channels, and for 8 channels the PLP is 10^{-4}, the explanation is that the HP packets are served first as they have more out channels than inputs. **Note**, even that the PLP of LH packets has performed better than PPM and SPM. The delay performance of this algorithm for HP class is almost $zero$ when reserved channels less than 6 channels, then starts to rise up due to the heavy traffic flowing from the increased number of reserved channels.

The performance of algorithm SPM is presented in Figure 6 and Figure 7. The experiment tested all the probability of input traffic for a different number of reserved output channels.

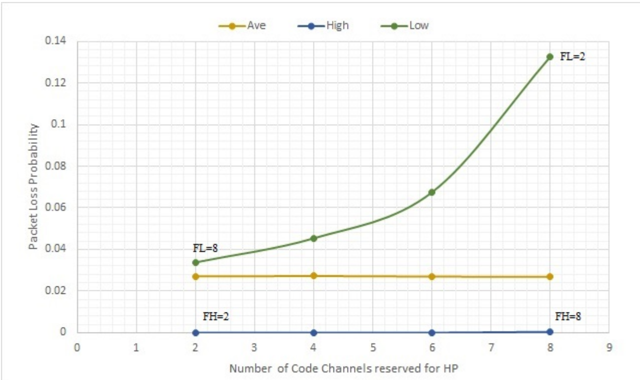

Figure 4. Packet Loss Probability of hybrid OCDM/WDM system at different numbers of code channel, privet input shared output mechanism.

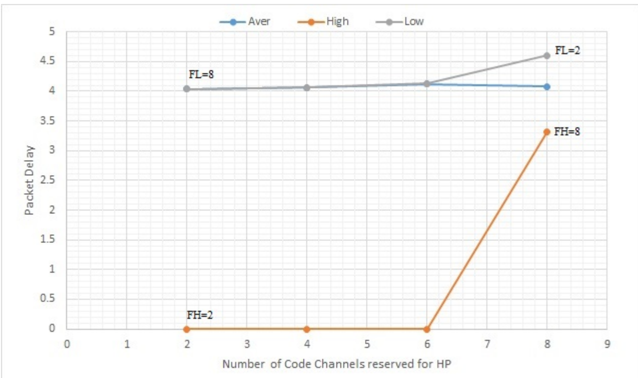

Figure 5. Packet Delay of hybrid OCDM/WDM system at different numbers of code channel, privet input shared output mechanism.

Figure 6. Packet Loss Probability of HP hybrid OCDM/WDM system versus a variety of HP traffic from total traffic 0.8, for different numbers of channels reserved to HP, shared input privet output mechanism.

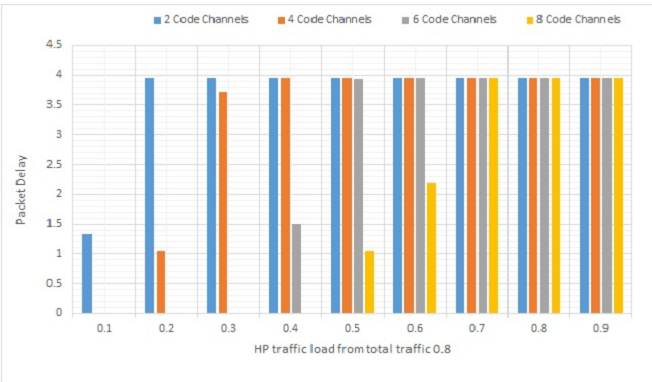

Figure 7. Packet Delay of HP hybrid OCDM/WDM system versus a variety of HP traffic from total traffic 0.8, for different numbers of channels reserved to HP, shared input privet output mechanism.

The result is drowned with three verbal, which are PLP, traffic load, and a number of reserved channels, the chart shows the PLP only for HP class. The SPM algorithm performs high packet loss probability comparing with the other three proposed algorithms, due to the limited available output channels. Furthermore, Figure 7 shows the packet delay performance, where it performs very high delay, due to very high traffic flows to FW buffers. In general, this algorithm did not perform well in both PLP and delay, due to limited available output channels.

In Figure 8 and Figure 9 demonstrate the results of an experimental simulation of SSM, where the input and output are shared among the classes with the respect of the priority. The Figure 8 plotted the PLP versus the HP traffic load from total traffic (0.8). From the plot drawn in Figure 8, obvious that the SSM algorithm performance significance, with the consideration, that the node is working in hybrid networks. The SSM algorithm performs very low packet loss probability comparing with the other three proposed algorithms, due to the variety of available channels. Note that the PLP of HP class at heavy traffic is starting to rise up as a result of HP packets cant use FB buffers where dropping packets are increased. On the other hand, the performance of packet delay is plotted in Figure 9. The HP class performed no delay at low traffic and tolerable delay at heavy traffic. The reason behind this is at high traffic more contention occurs with limited wavelength converters.

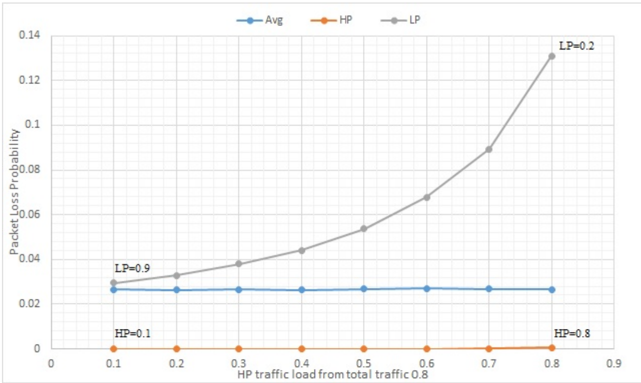

Figure 8. Packet Loss Probability of hybrid OCDM/WDM system versus a variety of HP traffic from total traffic 0.8, shared input shared output mechanism.

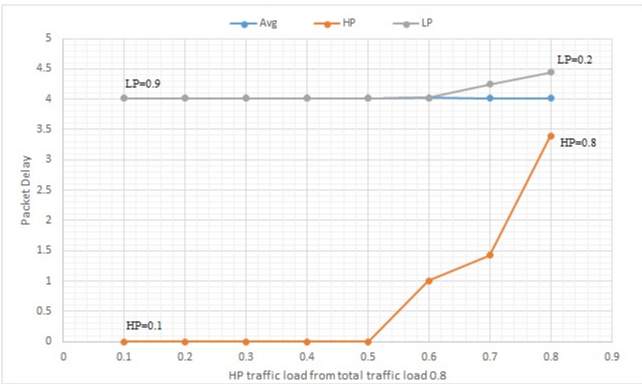

Figure 9. Packet Delay of hybrid OCDM/WDM system versus a variety of HP traffic from total traffic 0.8, shared input shared output mechanism.

5. Conclusion

This research aims at reducing packet loss probability of HP hybrid OCDM/WDM system in which a huge amount of data is being transmitted through high-speed optical links. In order to do so, our objective is to make QoS differentiation and resource utilization proportional to each other. Four differentiation algorithms called PPM, PSM, SPM, and SSM was proposed in order to differentiate between the classes. Simulation results indicate the fact that the proposed algorithms PSM and SSM yield a significant packet loss probability with an acceptable level of packet delay compared with PPM and SPM algorithms. Moreover, since that the switch node is a part of hybrid networks connected to each other and therefore if we use PSM algorithm, the next node must use privet input mechanism, where the performance of the network may suffer from high contention. The simulations show that SSP method has very high performance efficiency, it can approach the Raddo bound. Consequently, it is clear that the SSP algorithm is a significant algorithm for such hybrid networks.

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