Application of Optical Multilevel Transmission Technique in WDM/OCDM-Based Core Networks

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ABSTRACT

In this article, we present a new scheme to improve the performance of multiservice WDM/OCDM-based core networks. The idea is based on utilizing optical multilevel transmission technique (MLTT) to mitigate the multiple access interference (MAI) effect of OCDM. In this multilevel-multiclass network, users of each class are divided into multiple groups and users of each group are allowed to transmit at a specific power level. We demonstrate that, the proposed multilevel-multiservice scheme outperforms previously introduced multiservice WDM/OCDM based networks. This is due to the interference reduction property of MLTT, and this superiority can be further enhanced by using advanced optical logic gates. The proposed scheme is a modification implemented at the data plane by upgrading the intermediate optical routers to support MLTT. In the proposed network model, data and control planes are separated and can be designed independently. However, our results reveal that a data-plane-aware controlling approach, which considers the information of the data plane, outperforms a data-plane-unaware algorithm in terms of average error probability.

INTRODUCTION

Ever since the invention of laser transmitters and fiber optic transmission with terahertz of bandwidth, fiber optic communication systems were introduced as viable transmission techniques in local and global communication networks. Furthermore, recent advances in optical devices such as optical cross-connect (OXC), optical add-drop (OAD), and optical logic gates (OLGs) have highlighted the role of optical networks in next generation data networks.

Wavelength routing (WR) is a conventional method employed to transport data traffic in optical core networks [1]. In WR, the wavelength of an input signal is considered as the identifying label; and by changing the wavelength, data are forwarded toward the destination. Although WR helps us obtain all-optical transmission, the coarseness of the bandwidth granularity and the scarcity of the number of available labels are the main shortcomings of this scheme. Recently, optical code-division multiplexing (OCDM) has been employed in each wavelength to multiplex data of multiple paths in a wavelength-division multiplexing (WDM) window [2–5]. By employing hybrid WDM/OCDM, a thinner bandwidth granularity and adequate number of labels are acquired. It should be noted that OCDM used in these scenarios is conceptually different from the optical code-division multiple access (OCDMA) technique employed in local area networks such as passive optical networks (PONs). In fact, in PONs the purpose of using optical codes is to share common optical resources between multiple asynchronous users, whereas in core networks, OCDM multiplexes data traffic of different paths, and optical code is also considered as the path identifier.

Multiservice transmission capability is an important issue that should be addressed in WDM/OCDM based core networks. In [4, 5], we presented two approaches to support multiservice transmission in WDM/OCDM-based core networks. In the first approach, multi-length variable-weight optical orthogonal codes (MLVW-OOCs) are used as signature sequences and identifying labels [4]. To support the requested class of services, the code length and code weight are designed based on the characteristics of the class of services. In the second approach, the fiber bandwidth is classified, and wavelengths of each class are considered for a specific class of service applying the corresponding OOCs as the signature sequences and identifying labels [5].

In this article, a new scheme is introduced to improve the performance of multiservice WDM/OCDM-based core networks. To this aim, we inspire the optical multilevel transmission technique (MLTT), which was originally introduced in order to improve the performance of a typical OCDMA-based local area network [6, 7]. In a multilevel OCDMA, users are divided into multiple groups, and users of each group transmit at a specific power level. In this multilevel system, by employing a new receiver structure, referred to as a multistage structure, interferences at different power levels are distinguishable and can be suppressed [6]. The multistage

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receiver utilizes optical logic gates operating based on the power level of input signals. Our numerical results indicate that by employing MLTT, the performance of multiservice WDM/OCDM-based network is substantially improved. Furthermore, in order to achieve more performance improvement, we propose to adapt the corresponding control plane so that the resource management and allocation are performed based on the information of the data plane. Our results reveal that data-plane-aware resource allocation outperforms data-plane-unaware resource allocation in terms of average error probability.

Multilevel Transmission Technique in an OCDMA System

Multi-Length Variable-Weight OCDMA System

The OCDMA system was primarily introduced as a viable technique to share fiber optic bandwidth among many asynchronous users in access networks [8]. This is mainly due to the distinct properties of OCDMA such as bandwidth sharing among temporally asynchronous users without any central controller and providing differentiated quality of service (QoS) at the physical layer. Generally, OCDMA is divided into two classes: incoherent and coherent. In a coherent OCDMA system, the phase of the optical signal is encoded with bipolar codes; in an incoherent OCDMA system, the intensity of optical signal is encoded with unipolar codes such as OOCs. OOCs are a family of binary sequences specified by (L, w, I_c), where L denotes the code length, w indicates the code weight (the total number of ones in each code), and I_c is the maximum value of the cross-correlation and shifted auto-correlation [8]. In this article, due to its simplicity and ease of implementation, we focus on incoherent OCDMA. In incoherent OOC-based OCDMA, the QoS depends on the code properties and the number of transmitting users. It has been demonstrated that if the code weight increases, reasonable QoS is obtained [4]. Evidently, in this system all users have the same code parameters (code length and code weight); hence, all users have the same transmission rate and the same QoS. However, in order to provide multi-rate and differentiated QoS, *multi-length variable-weight* OOCs (MLVW-OOCs) have been introduced [4]. MLVW-OOCs are characterized by $(\{L_1, L_2, \ldots, L_Q\}, \{w_1, w_2, \ldots, w_Q\}, \{N_{C(1)}, N_{C(2)}, \ldots, N_{C(Q)}\}, Q, I)$, where L_i and w_i denote the code length and code weight of class i, respectively. $N_{C(i)}$ indicates the number of available codes in class i; Q is the number of classes; and I denotes the cross-correlation matrix [4]. In MLVW-OOC-based OCDMA, the code length and code weight are designed based on the requested class of services. In both OOC- and MLVW-OOC-based systems, the throughput limitation is a challenging issue that should be resolved. Hence, a novel transmission technique based on optical logic gates, optical multilevel transmission technique (MLTT), was proposed in [6, 7] to improve the throughput of incoherent OCDMA. In MLTT, users are divided into multiple groups, and users of each group are allowed to transmit at a specific power level. Furthermore, at the receiver front-end, an interference remover utilizing optical logic gates is employed to mitigate the interference contributed by users of other groups (i.e., users with different power levels).

Optical Multilevel Transmission Technique and Interference Remover

In MLTT, users are divided into multiple groups, and users of each group transmit at a specific power level. Two receiver structures can be used in a multilevel system, asymmetric and symmetric structures. In an asymmetric structure, the receiver is an ordinary AND logic gate in which the power threshold of an input hard-limiter is equal to the power level of the corresponding user. In a symmetric structure, an interference remover based on optical logic gates is used instead of the input hard-limiter. In Fig. 1, the asymmetric and symmetric receivers for a *two-level* system are compared. It can be observed that in an asymmetric structure, the low-power (P_1) interfering pulses can be suppressed at the receiver of high-power (P_2) users, while at the receiver of low-power users, both low-power and high-power pulses have the same effect. Consequently, the performance of the high-power users is improved, while the low-power users have the same performance as the ordinary *one-level* OCDMA system. On the other hand, in a symmetric receiver, high-power interfering pulses can be removed at the low-power receiver. Hence in this structure, the performance of both low-power and high-power users are improved.

In a symmetric structure, instead of an input hard-limiter, an interference remover is employed (Fig. 1b). The interference remover is designed by utilizing optical logic gates such as optical AND, OR, and XNOR elements, in which the level of interference cancellation can be increased by using more optical logic gates. This structure is further referred to as multistage interference remover [6]. In Fig. 1c, two-stage interference removers of a typical two-level OCMDA are illustrated.

Generally, OCDMA is divided into two classes: incoherent and coherent. In a coherent OCDMA system, the phase of the optical signal is encoded with bipolar codes; in an incoherent OCDMA system, the intensity of optical signal is encoded with unipolar codes such as optical orthogonal codes.

Multiservice WDM/OCDM-Based Core Networks

Network Model

In a WDM/OCDM-based network, data traffic is forwarded by label switching where the established path between source and destination (s, d) is referred to as a label switched path (LSP). In order to exploit WDM/OCDM multiplexing, we propose to separate the data and control planes. The data plane contains optical multiplexing, all-optical signal processing, and traffic forwarding at the intermediate routers, while the control plane executes all the signaling, controlling, and resource provisioning algorithms such as routing, code and wavelength assignment, path protection and restoration, and quality of service differentiation.

Figure 2a illustrates the network model considered for WDM/OCDM-based networks. As

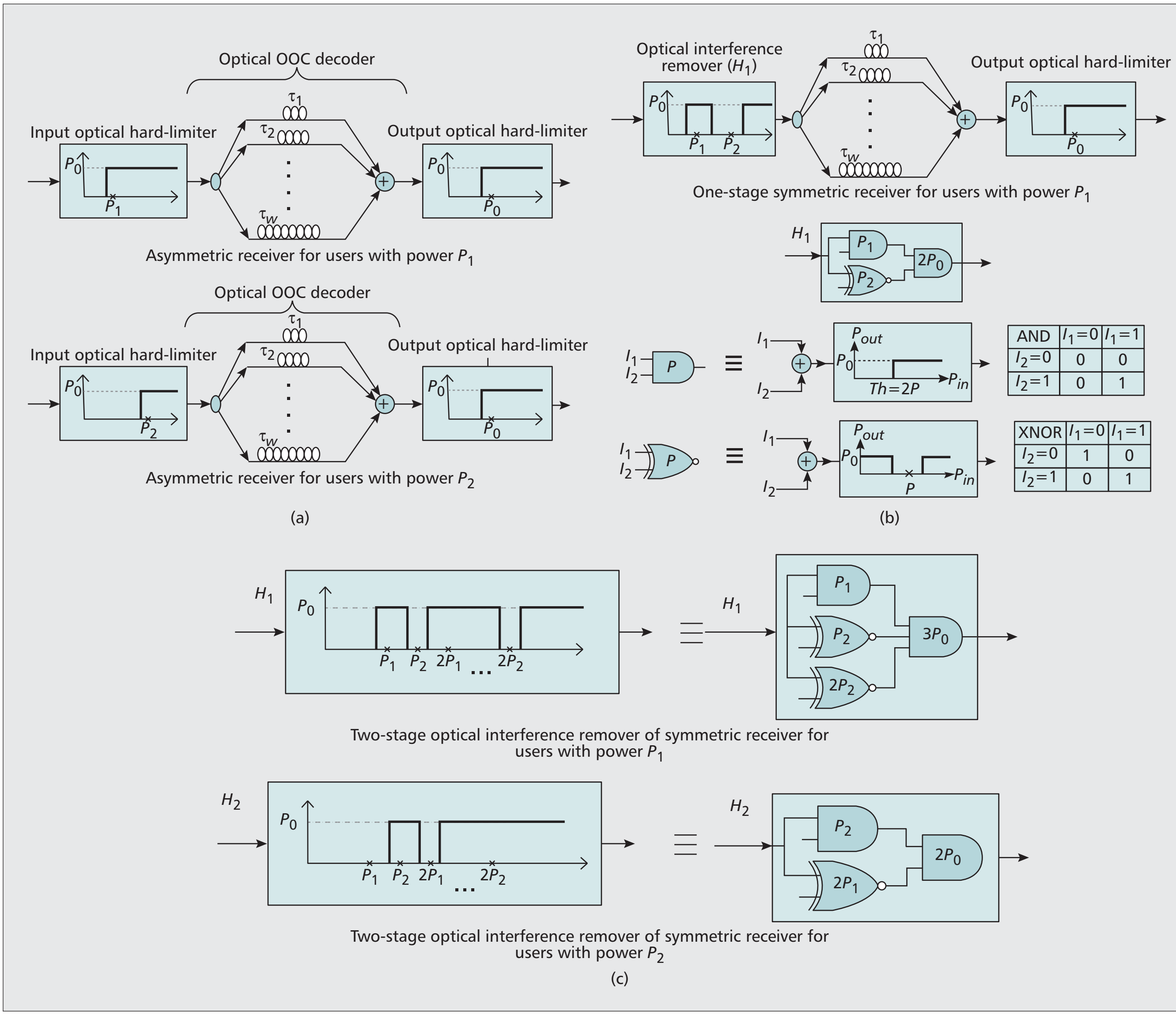

Figure 1. a) Asymmetric receiver in two-level signaling; b) one-stage symmetric receiver in two-level signaling; c) two-stage interference remover in two-level signaling.

can be seen, data of different LPSs are multiplexed in a WDM window using optical codes, and each wavelength and code pair, (λ, C) is considered as the path indentifying label. Figure 2b shows the WDM/OCDM labeling in a simple network. By employing hybrid WDM/OCDM as the multiplexing technique, instead of ordinary WDM, the number of available channels increases to $N_w \times N_C$, where N_w is the number of WDM channels and N_C denotes the number of optical codes used in each WDM window. Hence, in this new architecture, the number of available channels, and equivalently available labels, are multiplied by a factor of N_C. Evidently, the increase of available channels leads to the decrease of blocking probability and improvement of the overall network performance as well [4].

Router Architecture

In a WDM/OCDM-based intermediate router, first, the wavelength and code of the input optical signal, (λ_{in}, C_{in}), are all-optically distinguished; then input signals are encoded and forwarded to the output port determined based on the information of the forwarding table. Figure 2c illustrates the basic building block of a WDM/OCDM router. As shown in the figure, each router has a forwarding table that maps the input (label/port#) to the output (label/port#). At the input of a router, wavelength demultiplexers and optical decoders are employed to detect the incoming label, (λ_{in}, C_{in}). The OXC switches the decoded signal to the input of the corresponding encoder of the output label (λ_{out}, C_{out}). If $\lambda_{in} \neq \lambda_{out}$, wavelength conversion should be performed at the OXC prior to switching the decoded signal. In Fig. 2c, the bandwidth classifications of input and output ports are also depicted. By comparing the input and output bandwidth classifications, we can envision the router's operation. As can be observed, the code and wavelength of LSP1 were switched, LSP7 was forwarded after fiber switching (space switching), and the other LSPs were forwarded to output ports without any change. It should be noted that an OXC is configured by a manage-

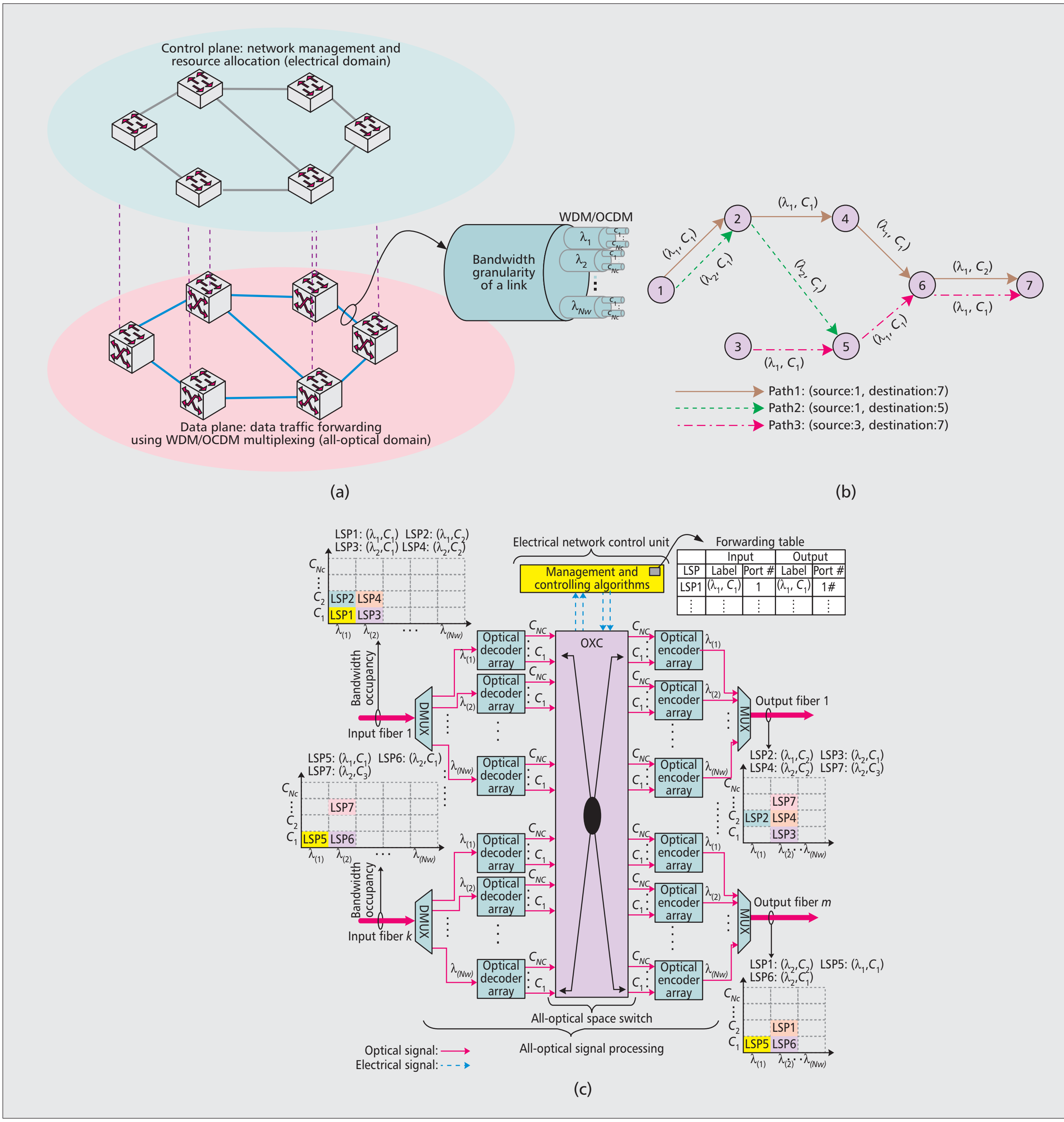

Figure 2. a) Network architecture; b) path labeling; c) router architecture in WDM/OCDM core network.

ment and controlling unit based on the recorded labels in the forwarding table. This configuration is performed in the path establishment period prior to the arrival of data traffic. Therefore, although OXC is configured by electrical signals in the path establishment phase, it switches data traffic optically in a transparent manner.

As multiservice transmission is an essential requirement for next generation optical networks, in [4, 5] we introduced two approaches to support multiservice transmission in WDM/OCDM based networks. In [4], MLVW-OOCs are employed as the coding sequences, and in [5], we classified fiber bandwidth into the number of wavebands and used each waveband for a specific class of service. In this article, we refer to the first scheme as a MLVW-OOC-based network (MBN) and the second as a bandwidth classified network (BCN).

Control Plane Issues

As mentioned earlier, the routing, signaling, and other management protocols are handled at the control plane. The Open Shortest Path First (OSPF) protocol finds the shortest path of a given (s, d), and the Label Distribution Protocol (LDP) determines the necessary labels of the intermediate routers along the designated path.

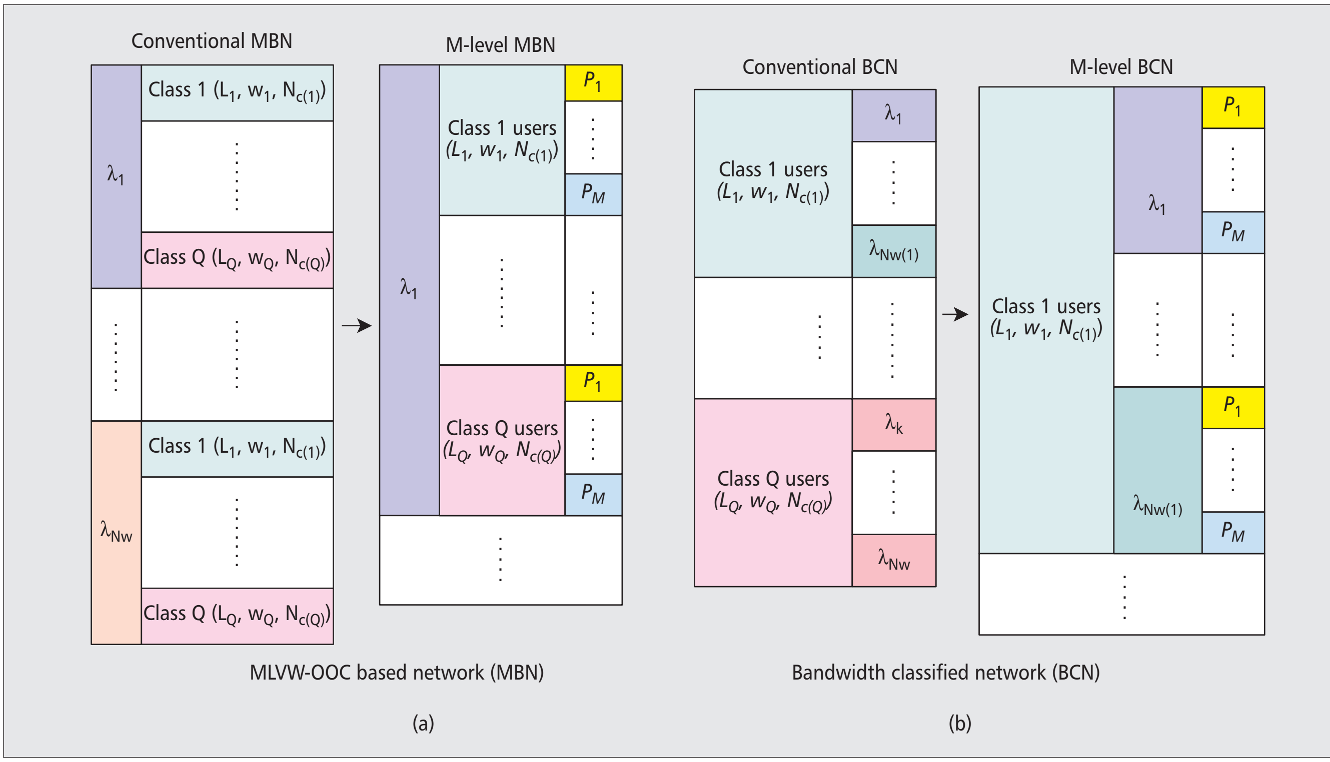

Figure 3. Bandwidth classification in: a) conventional MBN and multilevel-MBN; b) conventional BCN and multilevel-BCN.

Generally, due to the separation of data and control planes, there is no restriction for the management protocols. However, we propose to employ generalized multiprotocol label switching (GMPLS) to execute management and control issues such as traffic engineering, path protection and restoration, QoS differentiation, and resource reservation. GMPLS is preferred due to the fact that it is a protocol suite extending MPLS to manage further classes of interfaces and switching technologies. The switching capabilities supported by GMPLS are packet switching, layer 2 switching, time slot switching, and fiber switching [1]. Hence, GMPLS is a promising candidate for the control plane of WDM/OCDM. To this aim, GMPLS should be modified in order to manage the code switching capability, and new Type-Length-Values (TLVs), which is a common way to encode variable-sized information, should be defined for the WDM/OCDM parameters. In future studies, similar approaches introduced in [9, 10] can be utilized to modify the GMPLS protocol suite in order to support the WDM/OCDM data plane.

Multilevel-Multiservice WDM/OCDM-Based Core Networks

Data Plane

In order to increase the throughput of a multiservice WDM/OCDM network, we propose a new scheme based on the optical MLTT. This technique improves the efficiency of both MBNs and BCNs. In an MBN, we can provide Q classes of services in each wavelength, and the total number of available labels in *class q* ($N_{L(q)}$) is $N_{C(q)} \times N_w$ where $N_{C(q)}$ denotes the number of available MLVW-OOC codes in class q, and N_w indicates the number of wavelengths in a fiber. To employ MLTT in MBNs, users of each class are divided into M groups, and users of each group transmit at a specific power level. Let P_1, P_2, …, P_M denote the power levels of M groups, and $P_1 < P_2 < \ldots < P_M$. Figure 3a illustrates the bandwidth classification of a conventional MBN and the proposed multilevel-MBN. In a multilevel-MBN, Q classes of service are available in each wavelength, and users of each class are divided into M groups.

Similarly, in order to apply MLTT in a BCN, users of each class are divided into M groups. Figure 3b represents the bandwidth classification of a conventional BCN and the proposed multilevel-BCN. In a BCN, $N_{L(q)}$ is $N_{C(q)} \times N_{w(q)}$, where $N_{w(q)}$ denotes the number of assigned wavelengths to *class q* users. It should be noted that in the wavelengths assigned to *class q*, OOCs with the same parameters (L_q, w_q, $N_{C(q)}$) are employed. By comparing Figs. 3a and 3b, it can be observed that in an MBN, Q classes of service are provided in each wavelength, while in a BCN, only one class of service is provided in $N_w(q)$ wavelengths. In an MBN, the performance of all classes are related to one another, whereas in a BCN, signals of each class are transmitted in separate wavelengths, and users of different classes do not affect the performance of each other.

Figure 4 illustrates the architecture of the proposed multilevel WDM/OCDM router. In the figure, H_i is the multistage interference remover of the ith power group, A_{in} represents the input optical amplifier; A_i indicates the out-

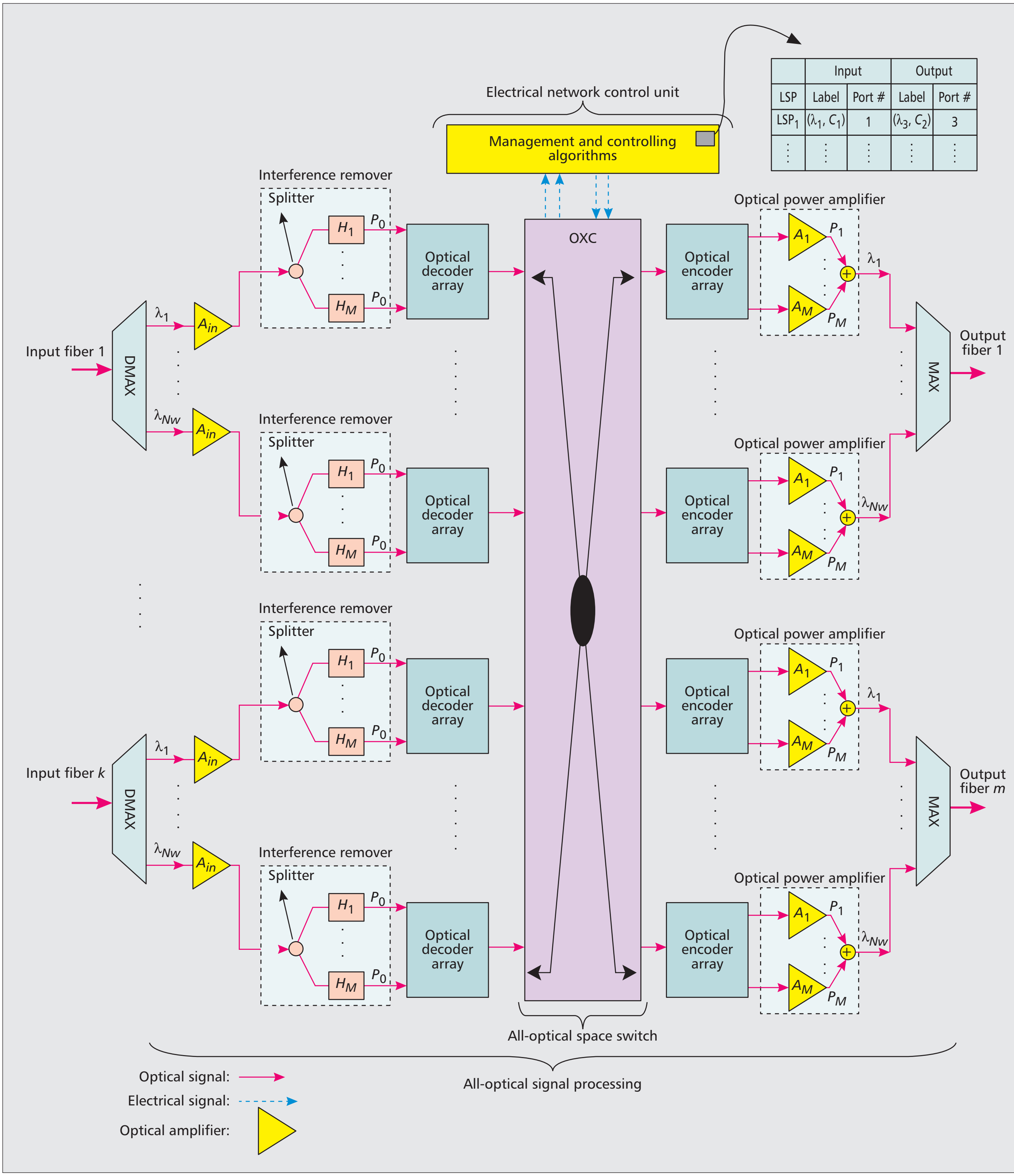

Figure 4. Multilevel-multiservice WDM/OCDM-based router.

put optical amplifier used for power group i; and P_o denotes the optical power level at the output of the interference remover. The input optical amplifiers are employed to compensate for the fiber attenuation and splitter loss, while the output optical amplifier of group i is used to increase the optical power level of the output signal to P_i, where P_i denotes the optical power level of group i.

Control Plane

In a multilevel-multiservice WDM/OCDM, due to the separation of the data and control planes, the data plane does not impose any restriction on the management and controlling algorithms of the control plane. However, as we show in the next section, by exploiting the data plane information such as the number of active codes in

DPA-RA exploits dynamic information of active paths to track the network status and assign the most appropriate channel minimizing multiple access interference (MAI). This information can be obtained by updating the forwarding table of the intermediate router after each path establishment and termination.

each WDM window and power group, the performance of the data plane in terms of error probability is improved.

In a cross-layer approach, optical resources (wavelength, code, and power) should be allocated in such a way that data traffic is evenly distributed along available bandwidth, and the interference among active paths is reduced. To this aim, we propose data-plane-aware resource allocation (DPA-RA), which considers the number of occupied codes of WDM windows and selects a WDM window with maximum free codes. Then it chooses one free codes of the designated WDM window and determines the power level so that different power groups have the same number of active channels (to this aim, it selects a power group with minimum active users). A common alternate for DPA-RA is data-plane-unaware resource allocation (DPU-RA) in which the wavelength, code, and power of paths are allocated randomly by considering the available free channels.

It should be noted that DPA-RA exploits dynamic information of active paths to track the network status and assign the most appropriate channel minimizing multiple access interference (MAI). This information can be obtained by updating the forwarding table of the intermediate router after each path establishment and termination.

Comparison and Numerical Results

In this section, in order to highlight the superiority of the proposed multilevel-multiservice WDM/OCDM scheme, we evaluate the probability of outage (P_{out}) and blocking probability (BP), where P_{out} represents the probability that the error probability (P_e) exceeds a predetermined value, and BP indicates the probability that all channels are occupied and an arrived connection request is blocked. Furthermore, the average error probability ($P_{e(avr)}$) in each link is computed for both introduced resource allocation algorithms (i.e., DPA-RA and DPU-RA).

Probability of Outage

First, we evaluate the probability of outage for the MBN scheme, P_{out}^{MBN}. In an MBN, P_e is a function of the code parameters and the number of transmitting users. Evidently, in order to have a specific P_e ($P_{e(\max)}$), the number of interfering users should be less than a threshold, which hereafter is referred to as the degradation threshold (d_{th}). In other words, if the number of interfering users in *class q* ($N_{I(q)}$) exceeds $d_{th(q)}$ (d_{th} of class q), the specified QoS is declined. Furthermore, $P_{e(i)}$ depends on the number of class i interfering users and the number of interfering users at the other classes as well. Therefore, P_{out}^{MBN} is computed as follows:

$$P_{out}^{MBN} = 1 - \Pr(N_{I(1,1)} < d_{th(1,1)}, N_{I(1,2)} < d_{th(1,2)}, \ldots, N_{I(Q,2)} < d_{th(Q,2)}) \quad (1)$$

where $N_{I(q,j)}$ and $d_{th(q,j)}$ are the number of users and the degradation threshold of the class q users in the power group j, respectively. This probability can be obtained by considering the probability density function (pdf) of active LSPs in each class. Furthermore, $d_{th(i)}$ for the given $P_{e(max)}$ is computed using the error probability relation derived for multilevel-multiservice OCDMA [7].

In a BCN, users of different classes transmit on separate wavelengths; hence, the QoS of different classes is independent. Therefore, the probability of outage for class i, $P_{out(i)}^{BCN}$, only depends on the number of class i users transmitting at different power groups, and it can be evaluated as follows:

$$P_{out(i)}^{BCN} = 1 - \Pr(N_{I(i,1)} < d_{th(i,1)}, N_{I(i,2)} < d_{th(i,2)}). \quad (2)$$

In what follows, a typical *two-class two-level* WDM/OCDM scheme is investigated by considering a Poisson traffic model and link-based performance analysis. The employed optical codes in MBNs and BCNs are characterized by (L = {400, 600}, w = {16, 14}, N_C = {20, 20}, $Q = 2$, $I = [I(i,j) = 2$ for $i, j = 1,2]$) and (class 1: {$L_1 = 400$, $w_1 = 18$, $N_{C1} = 32$, $I_1 = 2$}, class 2: {$L_2 = 600$, $w_2 = 20$, $N_{C2} = 52$, $I_2 = 2$}), respectively. Furthermore, the maximum allowable P_e for both classes is $P_{e(max-1)} = 10^{-12}$. It should be noted that the codes' parameters are chosen to provide a two-rate class of services, where the transmission rate of class 1 is higher than that of class 2, because $L_1 < L_2$.

Figure 5a represents P_e vs. the number of interfering users for an MBN and a BCN, respectively. In Fig. 5a, for a *one-level* system, x denotes the number of interfering users of class 1 and class 2 (i.e., $x = N_{I(1)} = N_{I(2)}$); for a *two-level* system, $x = (N_{I(1,1)} + N_{I(1,2)}) = (N_{I(2,1)} + N_{I(2,2)})$ where $N_{I(1,1)} = N_{I(1,2)}$ and $N_{I(2,1)} = N_{I(2,2)}$. Furthermore, the terms *two-level one-stage* and *two-level three-stage* represent two-level MLTTs that have receivers capable of one and three stages of interference cancellation, respectively.

From the figures, the degradation thresholds for $P_{e(max)} = 10^{-12}$ are obtained as follows:

- MBN: one-level WDM/OCDM: $d_{th(1)} = 9$, $d_{th(2)} = 6$, two-level one-stage WDM/OCDM: $d_{th(1,1)} = 7$, $d_{th(1,2)} = 7$, $d_{th(2,1)} = 5$, $d_{th(2,2)} = 5$, and two-level two-stage WDM/OCDM: $d_{th(1,1)} = 9$, $d_{th(1,2)} = 9$, $d_{th(2,1)} = 7$, $d_{th(2,2)} = 7$.
- BCN: one-level WDM/OCDM: $d_{th(1)} = 13$, $d_{th(2)} = 19$, two-level one-stage WDM/OCDM: $d_{th(1,1)} = 9$, $d_{th(1,2)} = 9$, $d_{th(2,1)} = 13$, $d_{th(2,2)} = 13$, and two-level two-stage WDM/OCDM: $d_{th(1,1)} = 12$, $d_{th(1,2)} = 12$, $d_{th(2,1)} = 17$, $d_{th(2,2)} = 17$.

The obtained values for different scenarios reveal that by using MLTT, the degradation threshold is increased, and as a result, more paths can be served simultaneously.

In Fig. 5b, the probability of outage of the MBN and BCN is plotted vs. the offered load, r. We have assumed that the number of wavelengths is $N_w = 20$, and the activity coefficient of the connected LSP is $\rho = 0.5$. Results show that for both schemes, MBN and BCN, the probability of outage is reduced by using a multilevel signaling technique. Furthermore, by increasing the stages of the interference remover, more improvement is achieved.

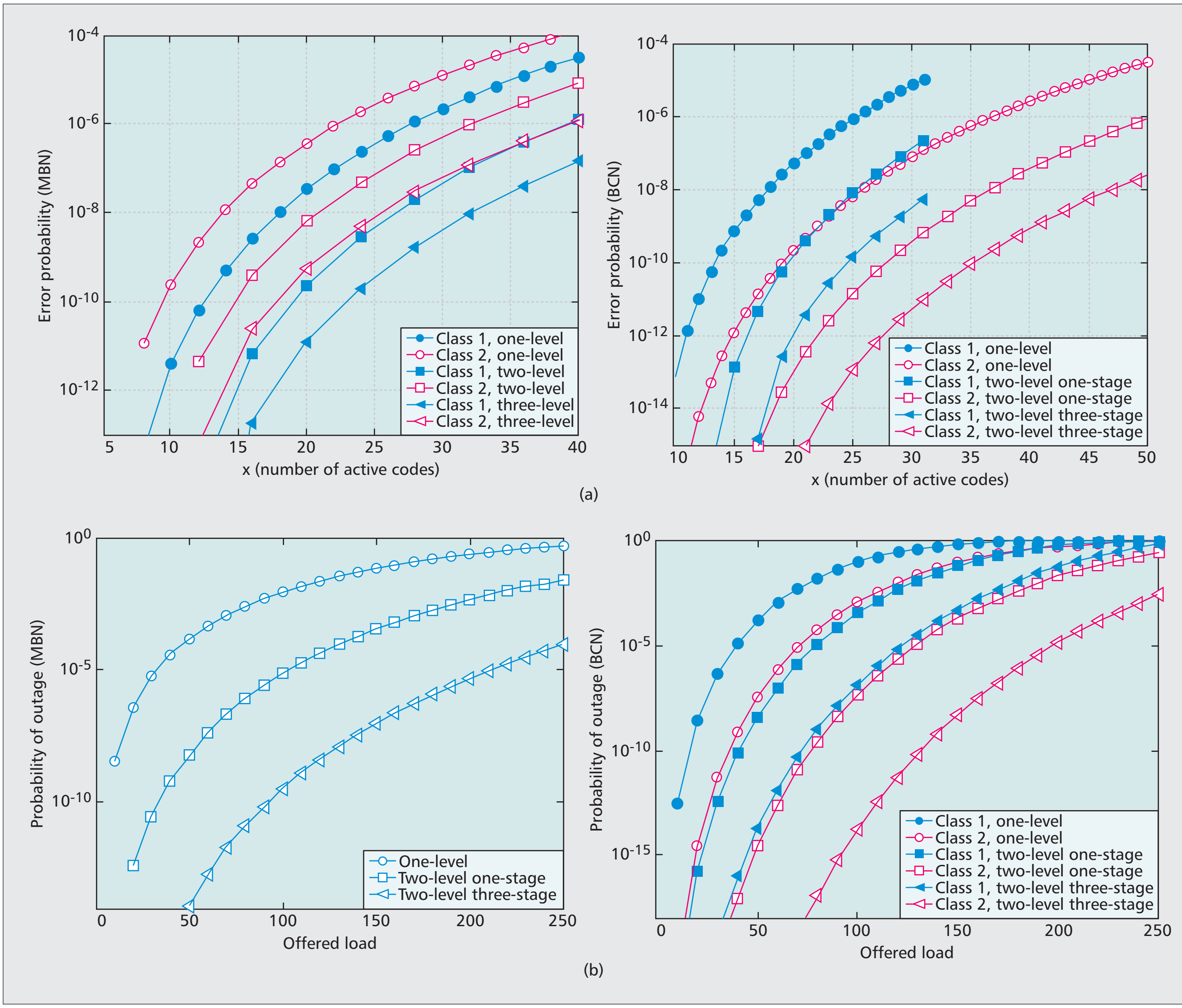

Figure 5. a) The error probability; b) probability of outage for both MBN and BCN.

It should be noted that due to the separation of different classes in multilevel-BCN, a two-class two-level BCN outperforms a two-class two-level MBN. In both schemes the total number of available labels are the same; however, they have different numbers of *class 1* or *class 2* labels in a single wavelength. Furthermore, the d_{th} of multilevel-BCN is greater than that of multilevel-MBN.

Blocking Probability

The blocking probability (BP) is evaluated using the pdf of the number of occupied channels, $P_A(a)$, as follows:

$$BP = 1 - \Pr(a < N_A) = 1 - \Sigma_{a=0}^{N_A - 1} P_A(a), \qquad (3)$$

where N_A is the number of available channels.

It should be noted that Eq. 3 can be computed for different scenarios by using the corresponding $P_A(a)$ given in [5], which was obtained using a Poisson traffic model and the Erlang loss formula. Figure 6a compares the *BP* of different scenarios. As can be observed, by using WDM/OCDM instead of WDM, BP is reduced. Moreover, by employing MLTT, the number of available channels is increased, and hence *BP* is further reduced.

Data-Plane-Aware vs. Data-Plane-Unaware Resource Allocation

In order to investigate the effect of resource allocation (RA) algorithms on the data plane performance, we have simulated one-level and two-level WDM/OCDM under the control of DPA-RA and DPU-RA approaches, and computed the corresponding average error probabilities ($P_{e(avr)}$). It should be noted that $P_{e(avr)}$ is computed by averaging over the P_e of WDM windows.

Figure 6b compares the $P_{e(ave)}$ of an MBN and a BCN controlled by DPA-RA and DPU-RA. Results reveal that for both MBNs and BCNs, DPA-RA outperforms DPU-RA; this is due to the fact that DPA-RA distributes active paths uniformly among WDM windows, whereas DPU-RA only considers the available channels,

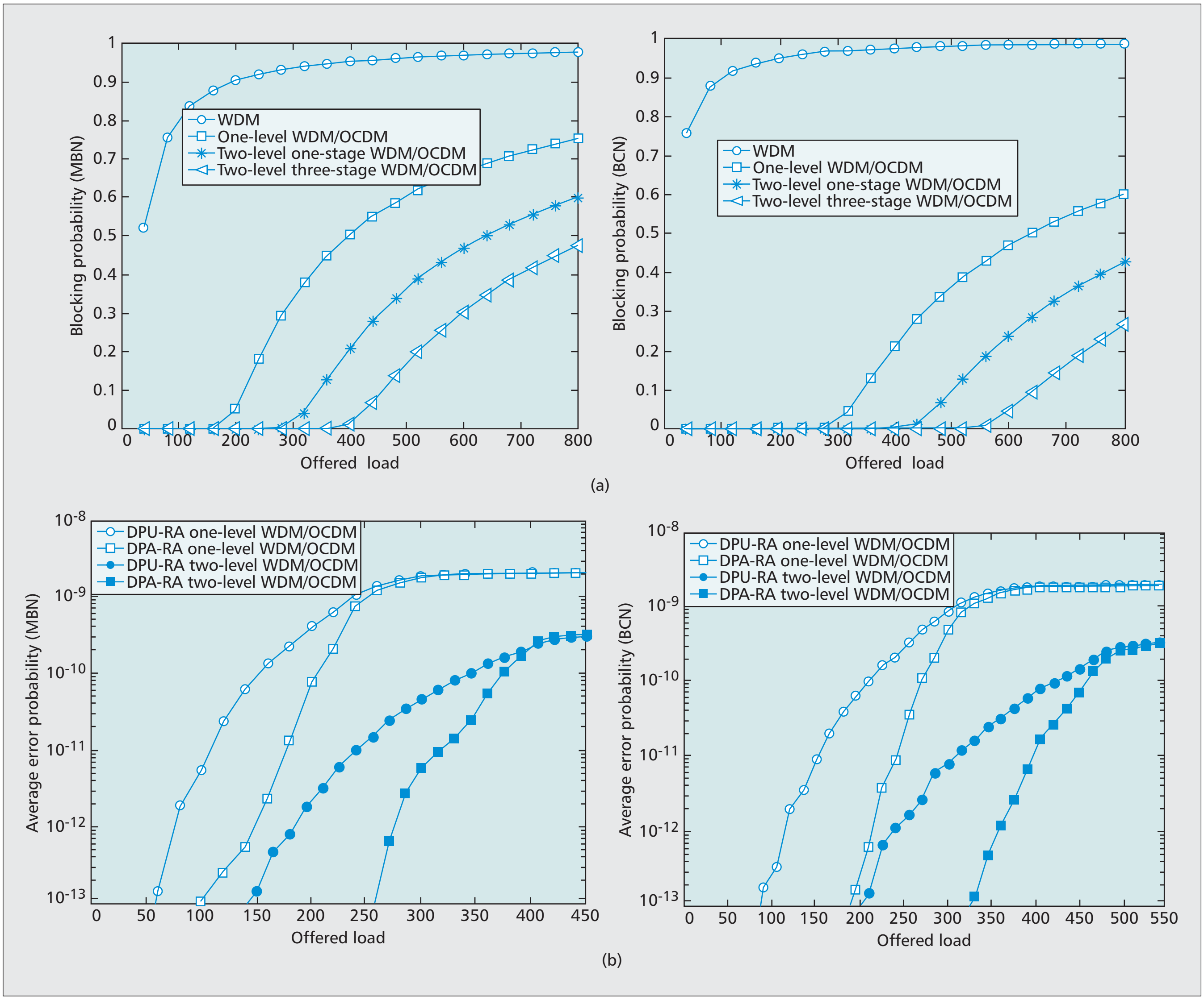

Figure 6. a) The blocking probability; b) average error probability for both MBNs and BCNs.

and as a result active paths are randomly distributed among WDM windows, and average error probability is degraded. Furthermore, as offered load increases, both RA algorithms have the same performance. This is basically due to the fact that in high offered load all available channels are occupied and the RA methods can not affect the data-plane performance.

Conclusion

In this article, we have proposed a new scheme to improve the performance of multiservice WDM/OCDM-based core networks. The idea is based on using optical multilevel transmission technique in which users of each class are divided into multiple groups, and users of each group transmit at a specific power level. We began by describing the network model, router architecture, and control issues of a one-level WDM/OCDM network; then we introduced the proposed optical multilevel WDM/OCDM scheme. The network model is based on the separation of data and control planes, which causes the controlling algorithm to be selected without any restriction imposed by the data plane. However, we propose to employ GMPLS as the control plane to execute management and control issues such as traffic engineering, path protection and restoration, QoS differentiation, and resource reservation. GMPLS is preferred due to the fact that it is a protocol suite extending MPLS to manage further classes of interfaces and switching technologies; hence, it is a suitable protocol suite to control the proposed optical multilevel WDM/OCDM-based data plane.

In this article, a simple two-class two-level network has been investigated. The results reveal that using WDM/OCDM instead of WDM improves the blocking probability. Furthermore, the use of optical multilevel transmission technique enhances the performance of both MBNs and BCNs in terms of probability of outage, blocking probability, and average error probability. Finally, we have shown that the resource allocation algorithm executed at the control plane can affect the data plane performance. The comparison of the introduced data-plane-aware and data-plane-unaware resource allocation methods reveals that the DPA-RA improves the performance of data plane in terms of average error probability.

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GMPLS is preferred due to the fact that it is a protocol suite extending MPLS to manage further classes of interfaces and switching technologies, hence it is a suitable protocol suite to control the proposed optical multilevel WDM/OCDM based data plane.