12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

13P-8

Optimum Placement of Dispersion Compensating Unit for Transparent DWDM Ring Network

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Abstract

This paper first time introduces an optimal algorithm for placing the dispersion compensating unit (DCU) in DWDM ring network. Our proposed algorithm can be applied for both non-slope-compensated and slope-compensated DCUs.

1. Introduction

SONET/SDH-based optical ring network has a widespread of adoption as metro-area networks (MANs) due to its reliability and outstanding restoration scheme [1]. The exponential growth in data traffic leads to the requirement of upgrading the incumbent SONET/SDH ring to support transparent DWDM technologies, where the multi-wavelength signal remains in optical domain during transmission in the network [1]. For such a network that involves with long links, the fiber attenuation and the fiber dispersion become the serious problems that limit the transmission performance. The optimal amplifier placement method for the long-haul DWDM ring network has been already developed [2], while no any attempt has been made on the dispersion compensation although the dispersion compensation is also a serious issue that has to be taken into account in practical design of the transparent DWDM ring network.

In this paper, we propose, for the first time in our knowledge, an algorithm for optimal placement of DCUs in the transparent DWDM ring network. Our algorithm can support both non-slope-compensated (NS) and slope-compensated (SC) DCUs, and can ensure the minimum number of DCUs. We assign a part of the optical pan-European network (OPEN) with the total length of 1,882 km as a 4-ring-intersected sample network, as shown in Fig. 1. By applying our algorithm, we show that for the channel spacing range of 0.2 nm - 1.0 nm, the required total number of DCUs for 9-channel signal is 44 for both NSC-and SC-DCUs.

2. Optimum DCU placement algorithm

Our algorithm consists of 4 steps as follows:

Step1: Communication light paths between any two nodes.

Let the communication between any two nodes can be bidirectional, in this step, the possible light paths between any two nodes are generated, and finally only the shortest paths are selected for signal transmission

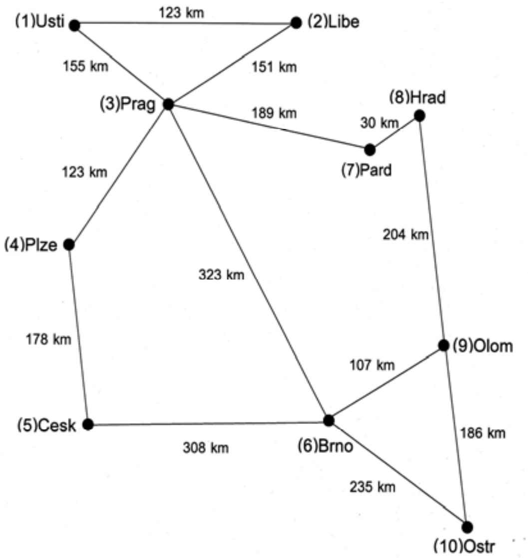

Fig.1: Part of OPEN [3] that is used as sample network.

Step 2: Generate the constraints.

First, we assign a group of wavelengths which will be used in the network. The number of wavelength can be larger, smaller, or equivalent to the number of node. Then, the following constraints are generated.

(A) Path Constraints

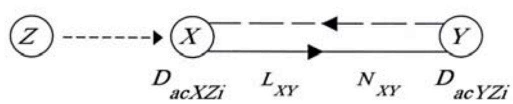

Fig.2: Light path between adjacent nodes

The path constraint for optimum DCU placement is

$$D_{acXZi} + (D_i \times L_{XY}) + (D_{COMPi} \times N_{XY}) = D_{acYZi} \qquad (1)$$

According to Eq. (1), for a path started from node X to node Y with the length of $L_{XY}(X \neq Y)$, the accumulated dispersion (D_{acXZi}) from node Z of signal at wavelength i (λ_i) will increase with the amount of $D_i \times L_{XY}$, where D_i is the dispersion at λ_i of the transmission fiber of the path. At the same time, the accumulated dispersion will be compensated by the amount of $D_{COMPi} \times N_{XY}$ where D_{COMPi} is the dispersion of DCU at λ_i and N_{XY} is the number of DCU on path XY. Finally, we obtain the total accumulated dispersion at the output of node Y equals to D_{acYZi}.

(B) Maximum dispersion constraints.

For each wavelength, it is required that the accumulated dispersion at any point in the network should not exceed the maximum acceptable accumulated dispersion $D_{\max}$ [4]. Therefore, we have the constraint,

$$-D_{\max} \le D_{acYZi} \le D_{\max} \qquad (2)$$

(C) Integrality constraints

For each path XY, N_{XY} must be an integer.

(D) Objective function

$$Minimize(N) \qquad (3)$$

Where N is total number of DCU in the network

Step 3: Solve the constraint equations.

Since our problem is a type of mixed-integer linear programming (MILP), this optimization problem can be solved by the soft wares such as X-Press.MP and C-plex. As a result from solving the problem, the number of DCU in each link and the accumulated dispersion at every node is obtained.

Step 4: Place the DCUs.

The DCUs are placed in the network at a position where at least one wavelength exhibits the accumulated dispersion that reaches $D_{\max}$.

3. Optimal DCUs placement in sample network

For demonstrating our algorithm in really existing network, we use part of OPEN as a sample network as shown in Fig. 1. Our sample network is assumed to operate as ring topology and is consisted of 4-intersected rings with 10 nodes, 13 links, and has the total length of 1,882 km. For transmission fiber, the standard single-mode fiber (SMF, G.652), which exhibits the dispersion (D) of 16.5 $ps/nm/km$ and the dispersion slope (D') of 0.05 $ps/nm^2/km$ at 1,550 nm [5]. We employ 2 types of DCUs: the NS-DCU that has D of $(-82)ps/nm/km$ with D' of 0.25 $ps/nm^2/km$ both at 1,550 nm, and the length of the NS-DCU can perfectly compensate for the accumulated dispersion of the 100-km-transmitted length of G.652 fiber, and the SC-DCUs that has same characteristics as the NS-DCU except the reverse sign of the dispersion slope [5]. Next, we assign the group of 9 wavelengths with the center wavelength located at 1,550.12 nm. Following the procedures described in section 2, we obtain the minimum number of DCU and the appropriate location of DCUs in the network. By varying the channel spacing ($\Delta\lambda$) from 0.2 nm to 1.4 nm, we compare the total number of both types of DCUs that requires in the sample network in Table 1. From Table 1, the total number of DCUs equals to 44 for both types of DCUs although $\Delta\lambda$ increases from 0.2 nm to 1.0 nm. These results indicate that we can use the NS-DCU to obtain the same network performance as using the SC-DCU. This significantly helps reducing the cost of the network because the NS-DCU is usually less expensive than the SC-DCU. For $\Delta\lambda$ = 1.2-1.4 nm, the number of NS-DCU necessary for the network becomes greater than that of SC-DCU due to large over- and under-compensation.

4. Conclusion

In this paper, an optimal DCU placement algorithm that gives the minimum number of DCU for transparent DWDM ring network was presented. By applying the algorithm to the sample network based on part of OPEN, we obtained equivalent number of DCUs for both SC-DCU and NS-DCU for $\Delta\lambda$ = 0.2 nm up to 1.0 nm.

Acknowledgement

This work is supported by the cooperation project between the Department of Electrical Engineering and private sector for research and development.

Table.1: Comparison of number of DCU between NS-DCU and SC-DCU

Type Of DCU	$\Delta\lambda$ 0.2 nm	$\Delta\lambda$ 0.4 nm	$\Delta\lambda$ 0.8 nm	$\Delta\lambda$ 1.0 nm	$\Delta\lambda$ 1.2 nm	$\Delta\lambda$ 1.4 nm
NS-DCU	44	44	44	44	46	46
SC-DCU	44	44	44	44	44	44

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