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An Algorithm and a Tool for Wavelength Allocation in OMS-SP Ring Architecture

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***Abstract*—OMS-SP ring is one of the well known architectures in Wavelength Division Multiplexing based optical fiber networks. The architecture supports a restorable full mesh in an optical fiber ring using multiple light wavelengths. The paper presents an algorithm to allocate wavelengths in the OMS-SP ring architecture. A tool is also introduced which implements the algorithm and assigns wavelengths. The proposed algorithm uses fewer number of wavelengths than the classical allocation method. The algorithm is described and results are presented.**

***Index Terms*—Communication Network Topology & Planning, Next Generation Networks, OMS-SP ring, WDM Architectures, Wavelength Allocation**

I. Introduction

In recent years the interest in optical communication has increased in many folds. This is primarily due to the exponentially increasing traffic, and to lower the cost of the networks. The optical network is the only known technology which promises virtually unlimited capacity. Today optical networks are about to be deployed directly to the end users. The deployment of new optical fiber based access networks, commonly known as Fiber to the Home (FTTH), is comparatively faster than the backbone networks. In the backbone networks, the replacement of copper based networks with optical fiber networks was completed already decades ago.

The traffic increase in access networks will put a huge load on the backbone networks. The capacity in backbone networks is upgraded by adding new electronic switching equipment, adding new fiber lines or wavelengths. Using the Wavelength Division Multiplexing (WDM) technology, it has become practical to increase the capacity by the multitude of adding new wavelengths in the same fiber. The use of more wavelengths in the same fiber leads to many advantages, such as savings on the amount of fiber, amplifiers and repeaters. To some extent WDM reduces the maintenance cost as well, i.e. if a fiber failure occurs due to a fiber cut the repair would be faster compared to multiple fibers with only one wavelength. However, a weak side is the loss of multiple wavelengths with a single fiber cut. Today WDM technology has become the preferred technology in the transmission networks and long-haul operators [1]. In the early days of WDM the optical layer was only able to perform multiplexing and de-multiplexing. Later, the development of Optical Add Drop Multiplexers (OADMs) and Optical Cross Connects (OXCs) introduced it as an independent layer, enabling the optical layer to terminate signals on individual wavelengths and replace it with their signal transparently passing through the other remaining wavelengths. Different architectures have been proposed within the WDM domain, which are capable of routing and restoring the wavelengths independently with the help of OXCs and OADMs. Most of the WDM architectures are based on the ring topology. The reason for using the ring topology is mainly its simplicity of routing and restoration. The mesh architectures are also supported using OXCs. Among the ring architectures the most interesting is Optical Multiplex Section - Shared Protection (OMS-SP) ring. The OMS-SP ring has shown better cost-performance compared to other ring based architectures [2] [3] [4].

In this paper we propose an algorithm, and a tool which implements the algorithm to allocate the wavelengths in the OMS-SP ring. The algorithm is based on our proposed method which less wavelengths compared to the method described in [5]. The algorithm allocates wavelengths for the full mesh at the optical layer on a simple physical ring. The algorithm supports the optical layer to be adaptive, in case of any arbitrary link failure all wavelengths can be restored. The tool is able to show different wavelengths by using different colors on a display-board. The tool could be very useful for planning and analysis of WDM networks using OMS-SP ring architecture.

The structure of the paper is as follows: The paper starts with a general introduction to the optical networks and its evolution. Therein some of the most interesting WDM technologies are discussed. In section II, the architecture of the OMS-SP ring is described. Routing and protection schemes for the OMS-SP ring are described in sub section A. The design and algorithm for the tool are presented in section IV. The results are given in V. The last section presents the conclusion of the work.

II. OMS-SP Ring

Several ring architectures exist today for WDM networks, among them the most used are Color Section (CS-Ring), Optical Mulitiplex Section Dedicated Protection (OMS-DP), and Optical Multisection Share Protection (OMS-SP) [1]. The concept of the OMS-SP ring was introduced for the first time in [6]. The OMS-SP architecture uses two fiber rings, each fiber ring supports both working and protection wavelengths. In OMS-SP, routing and protection are implemented in the optical layer, and in principle it can handle a generic and large optical demand pattern. The protection scheme in the OMS-SP ring allows simultaneous protection of all optical channels, which provides a considerable simplification of equipment. This also gives an advantage of protection in the OMS-SP ring, and therefore it should be more useful to use in high-capacity WDM systems where all channels must be protected [7].

A. Wavelengths Allocation in OMS-SP ring

In the OMS-SP ring routing and protection are implemented at the optical layer. The capacity of each fiber is shared between working and protection wavelengths. For example, in the clockwise fiber the first half of the wavelength spectrum is used for working traffic, while the second half is used for protection of the working channels in the counter-clockwise fibers. In the counter-clockwise fibers things are inverted: the first half of the spectrum is used for protection of the working channels in the clockwise fiber, while the second half is used for working traffic [7].

In case of link or node failure, the adjacent nodes reroute the traffic to the complementary arc of the ring; the working wavelengths of the clockwise fibers are re-routed to the protection wavelengths of the counter-clockwise fibers, and the service wavelengths of the counter-clockwise fibers are re-routed to the protection wavelengths of the clockwise fiber [7]. It is important to note that bidirectional or fullduplex traffic should use different sets of wavelengths in order to avoid conversion [5].

III. Proposed Method

In section A, a method for wavelength allocation is described. According to the method different wavelengths are used for the full duplex connections. This is in order to avoid the conflict or conversion caused by overlap of the same wavelength during the restoration.

In our proposed method, different wavelengths are not used in all the cases, the same wavelengths are used for the fullduplex where connection span on fiber is one. If the connection span is one then the same wavelength can be utilized for the duplex connection, and if a link fails the protection wavelength can be restored without causing any conversion on either side of the ring. In all the other cases we keep the classical approach.

A. Algorithm

Let $G = (V, E)$ be a connected undirected graph with vertex set $V = \{v_0, ..., v_n\}$ and edge set $E = \{e_0, ..., e_n\}$. Then the OMS-SP ring can be defined with vertices connected to edges as $(v_i, v_{i+1}(mod\ n))$ where $0 \le i \le n-1$.

In the algorithm, q is used for connection (v_i, v_{i+q}). The variable c is used for the colors. The list l_c contains elements $e(v_i, v_j)$. We also use W_s for the list l_c that yields the same color of wavelengths and conversely different color for W_d. The matrix $M_{i,j}$ is used for visited links, where $M_{i,j} = 0$ for unvisited and $M_{i,j} = 1$ for visited links. The wavelength allocation is implemented by Algorithm 1.

IV. Design of Tool

One of the goals was to design a tool which implements the proposed wavelength allocation algorithm. However, the tool also implements the classical method for wavelength allocation. The tool should be useful for network

Algorithm 1 OMS-SP Wavelength Allocation Algorithm

```
W ← ∅, c ← color, l_c ← ∅, count ← 0
for i ← 0, n − 1 do
    for q ← 1, n/2 do
        for j = i, n − 1 do
            if j + q < n and M_{j,j+q} = 0 then
                M_{j,j+q} = 1
                insert e(j, j + q) into l_c
                count ← count + 1
            else
                if i + q − p ≤ k and M_{i,i+q−p} = 0 then
                    M_{j,i+q−p} = 1
                    insert e(j, j + q) into l_c
                    count ← count + 1
                end if
                i = i − q + 1
            end if
        end for
        if count = 1 then
            same W_s(l_c) for duplex connection
        else
            if count ≠ 0 then
                different W_d(l_c) for duplex connection
            end if
        end if
        c ← new color
        count ← 0
    end for
end for
```

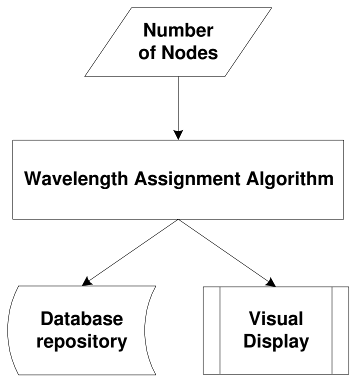

Fig. 1. The functional flow diagram for the tool.

planners to visually analyze the wavelength allocation. The basic functionality of the tool is as follows:

- Take an input as a number of nodes in the ring
- Perform calculations for wavelength allocation
- Display statistical results of the allocation
- Show the allocation on the display-board
- Save the allocation details in the database repository

In Figure 1 the flow diagram for the main functions of the tool is shown. The algorithm takes input as number of nodes. The output of the results goes to the database repository and is visually displayed as well.

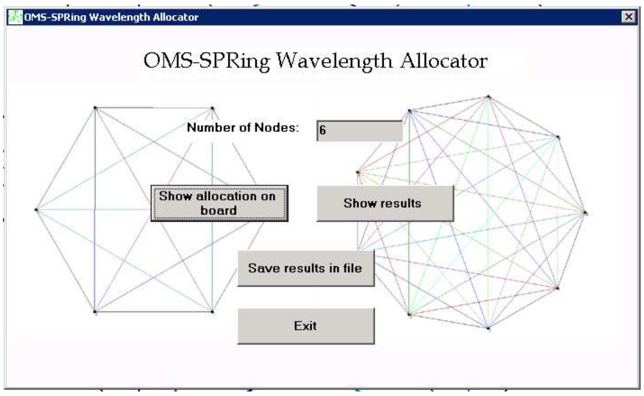

Fig. 2. The main window of the tool.

A. Implementation

The implementation of the tool was done in MS Visual Basic (VB) Studio. VB was chosen for an easier integration with the existing Geographic Information System (GIS) based Network planning tools. MS Access database system was used to store the results of wavelength allocation. It is, however, possible to export data to other database systems like Oracle, MySQL etc.

V. Results

Calculations have been performed both for the classical and the proposed methods. Figure 4 shows the required number of wavelengths needed for the OMS-SP ring using both methods. The results are shown only for 40 nodes. Usually, the rings are not deployed for such a large number of nodes, this is mainly due to getting a large diameter of the ring which decreases the overall performance of the network. Furthermore, the number of wavelengths increases as the number of nodes. Figure 5 shows the distribution of the same and different wavelengths from the total number of required wavelengths.

It can be seen from Figure 4 that the proposed method uses less wavelengths than the classical method. In Figure 2 and Figure 3 the screen-shots of the tool are shown.

Considering the maximum number of wavelengths on a single lines is not reduced, however it still reduces the total number of wavelengths used in the OMS-SP ring.

VI. Conclusion

We have proposed a method and algorithm in this paper. The implementation of the algorithm and the tool have been presented. The algorithm used for the allocation is described in detail. The proposed method uses less wavelengths in comparison with the classical approach. The allocation tool can be very useful for fast design of OMS-Ring architectures with minimal overall number of wavelengths. In our allocation method we did not consider the distribution of the number wavelengths in the links. Further research is needed to minimize the number of wavelengths in the individual links and then overall minimize the number of wavelengths. Only full mesh was supported in the

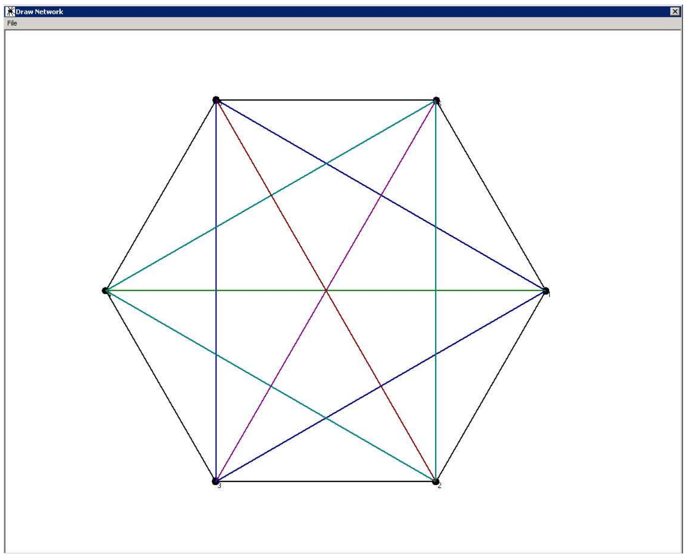

Fig. 3. The display-board for displaying wavelengths.

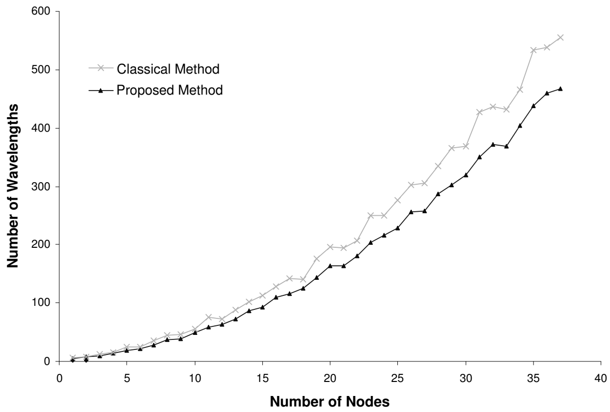

Fig. 4. Results from wavelength allocation.

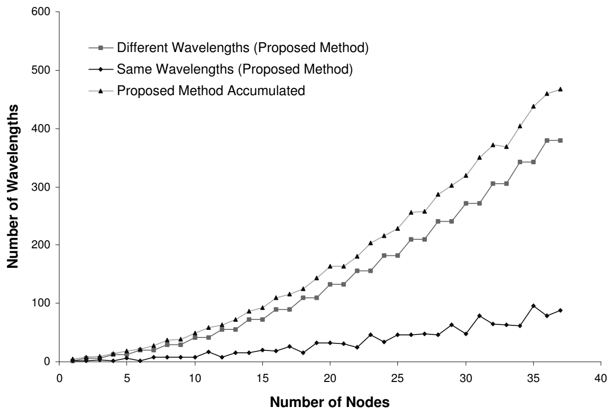

Fig. 5. Distribution of the same and the different wavelengths.

optical level. Recently, different structures were proposed for largescale networks in [8] [9]. The largescale networks are mostly implemented as ring structures. It would be interesting to implement these structures in a OMS-SP ring.

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