SMART WAVELENGTH ROUTING ASSIGNMENT: A WDM INTELLIGENT TRANSPORT NETWORK SOLUTION

A. Podcameni, M. M. Mosso and E. S. da Silva

Telecommunications Studies Center, CETUC, Catholic University of Rio de Janeiro
Rua Marques de Sao Vicente 225 / PUC-Rio, 22453-900, Brazil
Fax: +(5521) 3114-1154; Phone +(55-21) 3114-1685
Email: abelardo@cetuc.puc-rio.br

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Abstract: Conventional optical WDM networks calls for optoelectronic conversion for each wavelength in every node plus a large management effort for proper packet routing. All-optical networks are still unavailable. Here, a new architecture is described where the optical transport is done without conversions (except at extreme nodes), and with minimal routing management effort. The present basic mechanism is, firstly, to gather (at any source node) the packets demanding for a certain destination node K. Secondly, all these packets are modulated onto wavelength λ_K. Next, the wavelength is routed towards node K by passive directional devices. As other source nodes reuse wavelength λ_K, an anti-collision mechanism is presented. This mechanism uses very economic and widely available components. The present arrangement seems to be *pre-wired*, conveying packets from source to destination nodes almost automatically. The present arrangement is simpler and far more economical than (G)MPL(λ)S arrangements, for instance. Additionally, the present system does not demand for expensive wavelength conversions or central protocols. The disadvantage over (G)MPL(λ)S is that the present arrangement limits its maximum number of operational nodes to the number of wavelenghts WDM is able to support.

1. INTRODUCTION

When using the packet-switching mode, present transport WDM optical networks need to convert data from the optical to the electric domain in order to read headers for proper packet routing [1]. This is done in every node and for every wavelength. Optoelectronic converters at speeds of per instance 10 Gbit/s are expensive, and they are required in all nodes and all wavelengths. Additionally, the above mentioned routing operations are backed-up by a network management driven by software, sometimes UNIX or even Windows NT, meaning that it operates at relatively low speeds; typically at the μs to ms range [2].

There are future expectations for all-optical-networks [3], however they are not yet operational. Engineers are eager to see wavelengths reaching a node and cleverly choosing their precise way, without any conversion, or yet, dropping out if this is the correct choice. This paper will show that these last operations —so desirable—are possible to done and, to be done now, with widely available components, and in a quite economical way.

The present architecture is called as *Smart Wavelength Routing Assignment* (SWRA), and presents the following features:

(a) – At each *source node* entrance there is a router that groups packets according to their *destination node*.
(b) – If data is going to node K, than it should mandatory be modulated onto wavelength λ_K. Packets aiming at node K, coming from all other nodes, will use wavelength λ_K.
(c) – In each node, throughout the transport network, there is a cluster of Optical Add and Drop Multiplexers (OADM) that provides for proper wavelength routing to their respective destinations.
(d) – It would seem that the entire network has been *pre-wired* in order to route a wavelength λ_K to node K.
(e) – The above mentioned routing follows either a minimum delay path or a minimal-node path, according to an algorithm chosen by the network designer.

Observe that the capacity may be reused inside each wavelength. For instance, for launching packets to a certain node K, all nodes (except K) use the same wavelength λ_K to reach this given node. This fact has two basic implications. The first is that the whole network is served with a small number of wavelengths. For N nodes, it is sufficient to have N wavelengths. The second implication is that data-collision may occur, meaning that a certain node may attempt to inject into a backbone sector a certain wavelength while the same wavelength is already present in that backbone sector. Consequently, a data-collision avoidance mechanism must be present. However, this mechanism may be extremely simple and quite low-cost. Additionally, the data-collision avoidance mechanism does not depend upon central network management. It only performs local operations, like detecting if the backbone is free at a certain link and, at a certain wavelength. Consequently, this mechanism is far faster than centralized network management. In other words, all nodes may have *their own local intelligence* for dealing with collisions, without any further external help.

At this point, the reader is referred to a previous paper already presented by one of the authors, [4], where SWRA has been described. However, that work had an important simplification with respect to the present one.

The previous simplification was that the network should be a ring. It is clear that in a node ring, any entering wavelength, in any node, has only two options. The first is to follow to the next node and, the second option is to drop out. Now in the present work, we are dealing with mesh networks. A wavelength entering a node may have several path options including the possibility of dropping out. The description of the SWRA for mesh transport networks will be given now.

2. SWRA Description

Consider a seven-node optical transport network. The SWRA is obtained with the aid of graph theory [5]. A *connectivity matrix* where each node is successively considered as source node defines the wavelengths that are passing through each link. The software support tool is the very simple Maple as explained elsewhere [6]. In Fig. 1, the result for minimal delay criteria is shown.

In Fig. 2 it is shown the result for minimal number of nodes per connection. Observe that the results in Fig. 1 and Fig. 2 present some differences between them, as far as wavelengths passing through sectors is concerned.

It is apparent that an OADM cluster may be put in each node for proper routing. As an illustration, Fig. 3 shows how that cluster would be when node 1 is using a minimal delay arrangement.

The ADD shadowed circles denote the points where data-collision is possible. However, data collision is easily avoided by means of simple electronic circuitry like very simple photodetectors and contention electric buffers, as already described previously [4]. All the collision-avoiding circuits are done with widely available and economical circuitry. An example showing the simplicity of the collision avoidance mechanism is schematically shown in Fig. 4.

In this way, any entering wavelength is able to find its own way, through the transport network section, reaching its destination node without any optoelectronic conversion, or network management intervention.

Therefore, the transport portion of the network needs almost no external management and uses neither tunable transmitters (meaning tunable lasers) nor tunable receivers. Additionally, no wavelength conversions are necessary. The presented arrangement is economical, efficient, and robust.

3. Conclusions

Most of the present conventional transport portion of WDM optical networks works using successive O/E/O conversions. These conversions must be done in every node and for every wavelength, with some packets being dropped out and others being reconverted to the optical domain to be properly routed.

This paper central contribution is to demonstrate that only wavelenghts reaching their destination-node need to be converted to the electrical domain and dropped. All the others are kept in the optical domain and properly routed by successive clusters of optical directional devices.

The cost saving, as far as equipment is concerned, is extremely significant. The cost saving, as far as diminishing the routing management steps and costs, is also extremely significant. Furthermore, latency time is also diminished. This last assertion is easily understood, by comparing the delay of routing management driven by software with a minute light propagation delay through directional devices.

The present arrangement compares favorably with MPLS and MPλS [7], being far simpler and more economic. However, MPLS and MPλS may use wavelength conversions. Consequently, they are able to serve networks with an extremely large number of nodes. Here, the maximum number of network nodes is equal to the maximum number of wavelengths the WDM technology is able to handle.

The suggestive outcome is that the arrangement described in this paper is easily and immediately accomplished with widely available components.

It is understood that the present paper is limited to introduce the basics of a new architecture concept. A discussion on how to implement features such as protection, restoration, flow control, rerouting, and scalability in this new architecture is still an open issue. A possible solution is using OXCs for implementing those operational functions and, in this last case, a management for the routing array (although relatively small) will be needed for performing those operational issues.

For concluding, it is expected that the future is pointing towards the introduction of more intelligence and functionality within the optical physical layer. It seems that managing optical routing with solutions, which depend upon software utilization, is becoming expensive and complex. Although MPL(λ)S and GMPLS are powerful network solutions, emphasizing the optical layer, their complexity is apparent. This article is, tentatively, launching a new paradigm. In the past, bandwidth was expensive. That time, the paradigm was to carefully manage the traffic for saving bandwidth. Nowadays, after extensive use of WDM, the paradigm may be rephrased. Bandwidth is cheap and optical routing management must not be expensive and/or complex. The future for All-Optical Networking will endorse solutions where the optical layer seems to be *pre-wired*, in order to conduct wavelenghts, from source to destination nodes with minimal external action; almost automatically, almost passively. It is believed that this paper copes with this new paradigm.

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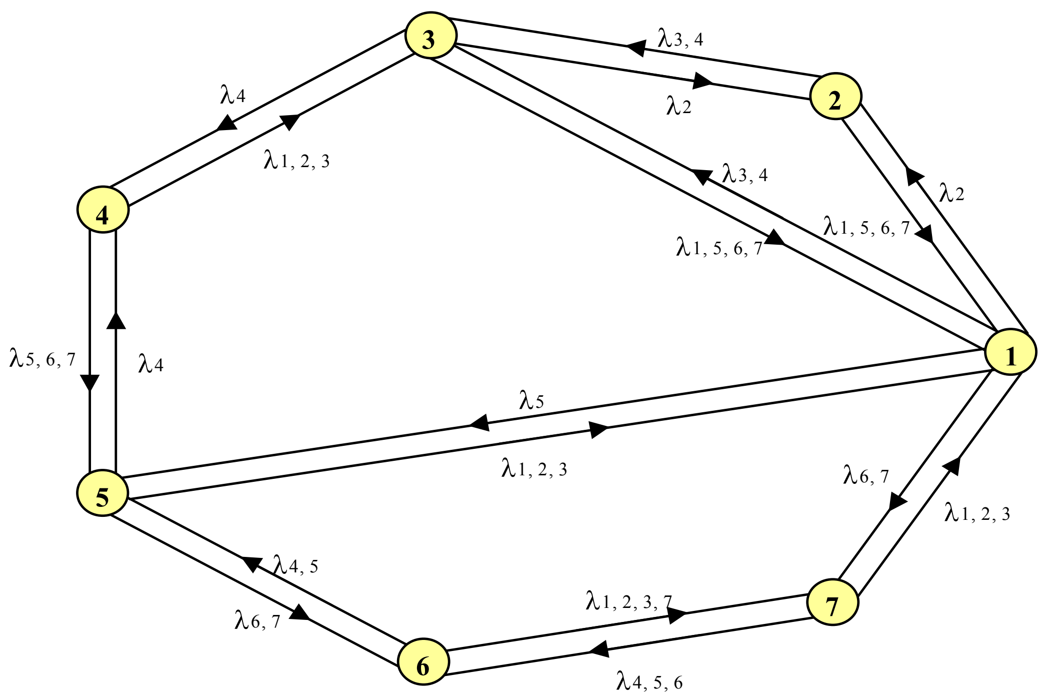

Figure 1 – Wavelength Routing in a seven-node optical network according to the criteria of minimal delay.

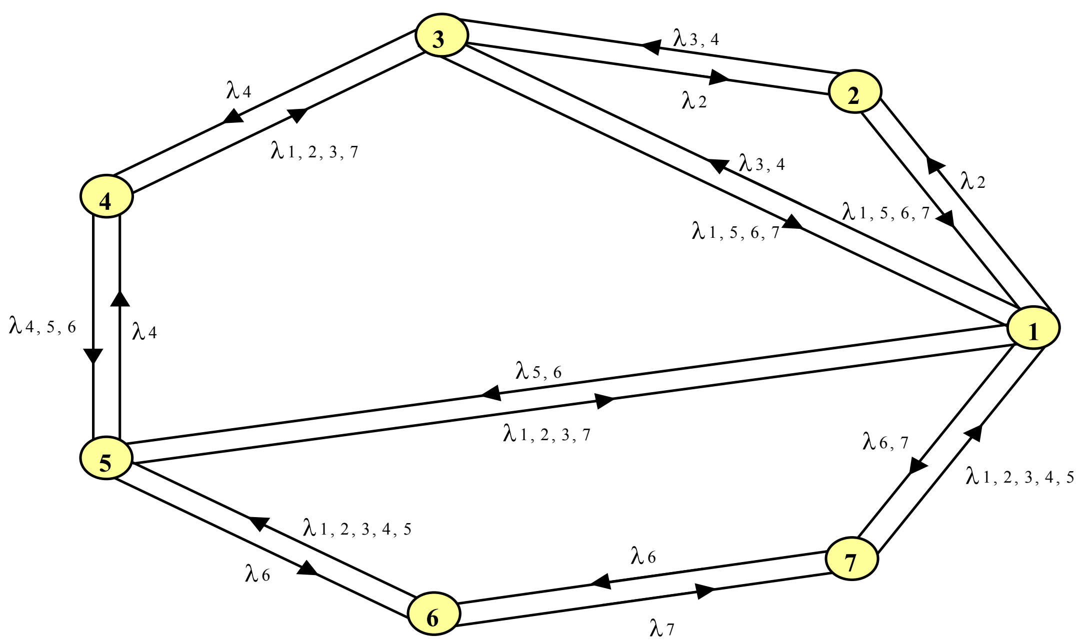

Figure 2 - Wavelength Routing in a seven-node optical network according to the criteria of minimal number of nodes per connection.

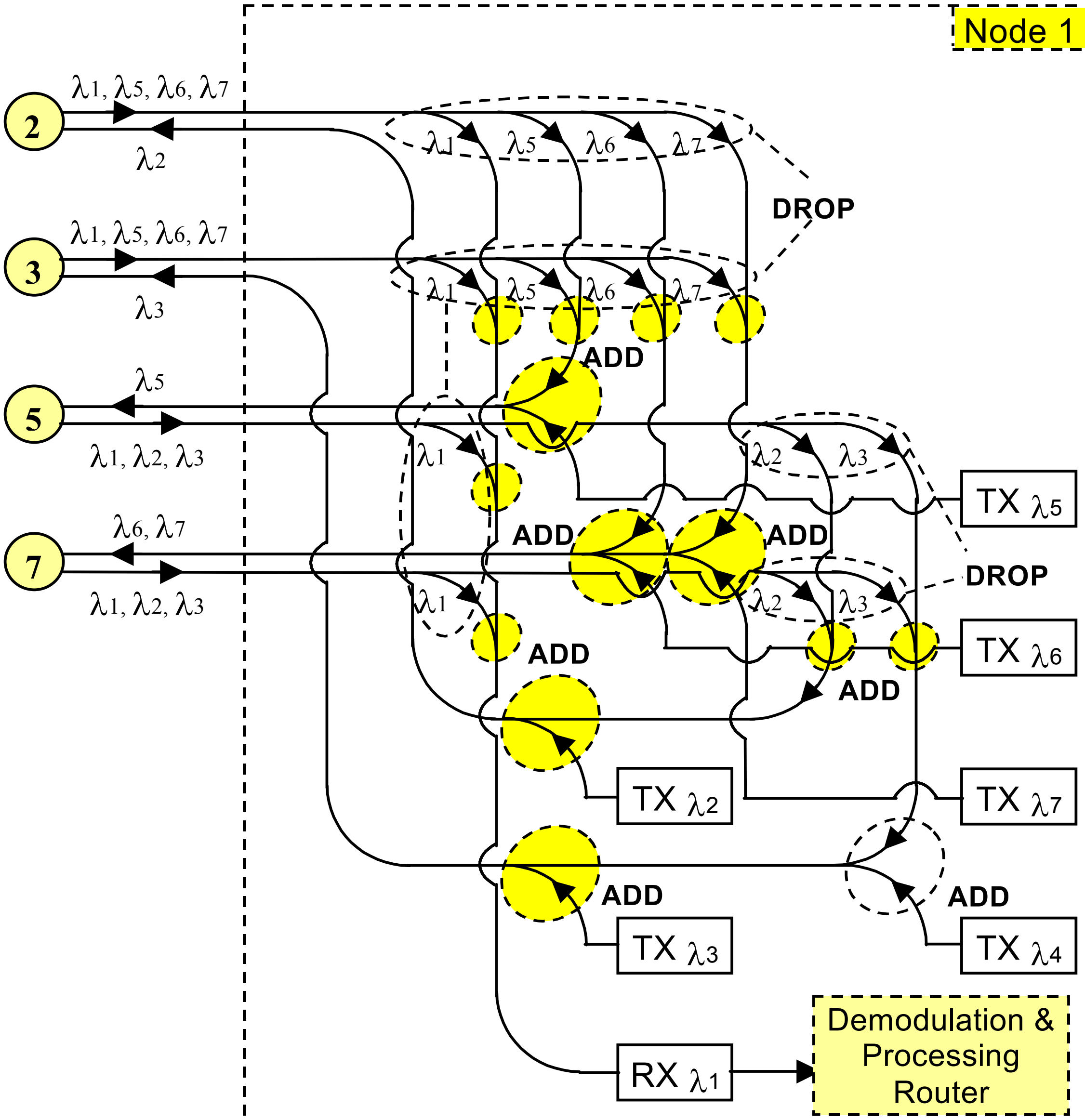

Figure 3 – A cluster of Optical ADD-and-DROP Multiplexers for being used in node 1.

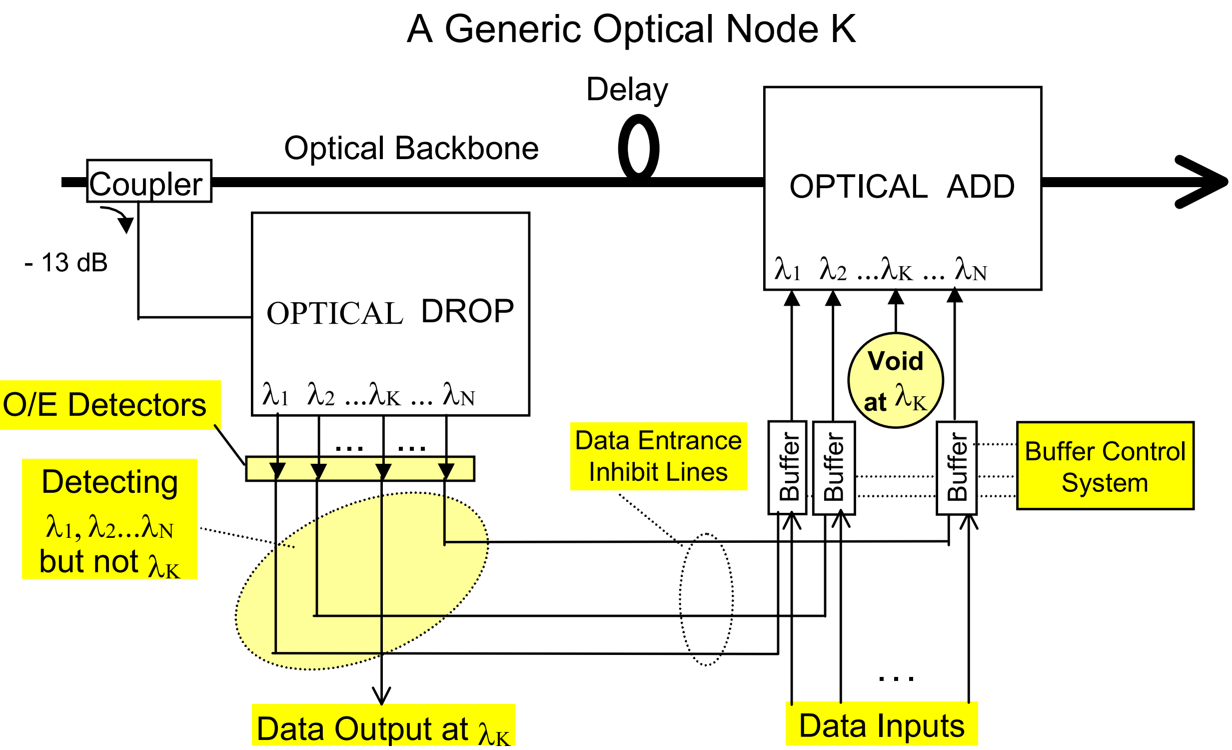

Figure 4 - A generic network node K, where the OADM functions are split. Inhibit signals avoid collision for a given wavelength. Buffers are only erased after all its data has successfully entered the optical backbone.