Cross - Connection Management Specialisation for WDM - OTN's

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1. Introduction

Future WDM Optical Transport Networks (WDM-OTN) will use new all-optical nodes that will perform functions such as routing, restoration and protection directly in the optical domain, using wavelength as a new network resource. They will require new levels of management and supervision to ensure its proper operation and the quality of payload delivery. A key word in future OTN's is evolution, both in terms of traffic growth and technology availability. Hence, networks' topology and nodes' architecture will need careful design in order to meet operator's requirements regarding adaptability, scalability, modularity and transparency. Several European funded projects such as MEPHISTO and MOON have addressed the needs for OTN Management Systems Support, proposing layered management object information models for standardisation [1], [2]. This paper presents a new approach for the Optical Cross-connect (OXC) routing operation that takes into account a diminished connection capability.

2. New class definition

Connection capability of an OXC may be diminished mainly for three reasons. The first one is external to the OXC and comes from the impossibility of certain output optical links to carry specific client signals due to e.g. PMD. The second reason is internal and arises from a component's failure thus precluding a number of connections. The third reason is also internal and results from the connection nature of the OXC structure, which is not strictly non-blocking (strictly non-blocking means that an input channel can always reach any output channel).

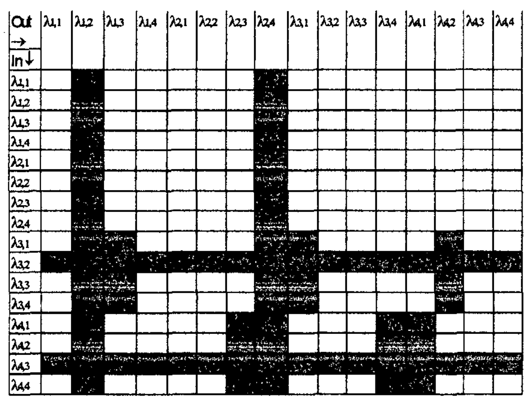

Figure 1. NSM example of a 4x4 OXC with 4 channels per fibre showing occupied and unavailable connections.

When managing an OXC with diminished connection capability, attainable output ports depend on both the number and the way the existing connections have been established. Hence an updated list with idle/available connections between input/output ports becomes necessary, which can be represented in a matrix format, and shall be called Node Status Matrix (NSM) from where the real internal OXC capabilities can be clearly and easily seen. Figure 1 shows an example where two connections have been established in a 4x4 OXC with 4 channels per fibre. The first sub-index indicates the input fibre and the second the input wavelength number. The NSM depicted in Figure 1 shows a connection between $\lambda_{3,2} \rightarrow \lambda_{2,4}$ precluding any connection between $\lambda_{3,1}$, $\lambda_{3,3}$, $\lambda_{3,4} \rightarrow \lambda_{1,3}$, $\lambda_{3,1}$, $\lambda_{4,2}$. An analogous case is shown for connection between $\lambda_{4,3} \rightarrow \lambda_{1,2}$. To manage this matrix we propose a specialisation of the cross-connection fragment (set of related object classes) in the Generic Network Information Model [3] adding a new object class named *wdmfabricR1* with a new attribute called *statusMatrix*. This new class is derived from the generic object class *fabricR1*, which itself derives from *fabric*.

3. OXC routing functional description

Relation between input/output channels can be described through the Wavelength Transfer Matrix (WTM) [4]. The knowledge of the WTM allows the systematic and simple resolution of the controls and their operation to establish any connection. The list of these controls can be written in a matrix format, which we call Routing Control Matrix (RCM). It is architecture dependent showing all physical paths from any input to any output port. Since there may exist more than one path between input/output ports, each RCM element is a vector every element of which is one out of n possible routing paths between input and output (i.e. $[P_1, P_2, \dots, P_n]$). In general, the dimension of all vectors in the RCM will be the same. However, there are cases where the OXC architecture may not be symmetric for every input channel and thus vector dimensions might be different.

The network node agent uses the RCM to efficiently perform dynamic routing, connection rearrangement, and Node Status Matrix (NSM) updates. NSM is an abstraction of the RCM and, while the latter is implementation dependent, the NSM is implementation independent.

4. Example of RCM and NSM usage

The OXC structure depicted in Figure 2 is link modular where the routing mechanism consists of Wavelength Converters (W-C) followed by Arrayed Waveguide Gratings (AWG). Different modules are then interconnected through Star Couplers (SC) to the output fibres. This structure is rearrangeably non-blocking, (i.e. any connection can be established re-configuring pre-established connections), therefore some connection requests may be rejected because pre-established connections cannot be interrupted unless for protection purposes.

Connection requests are considered successfully established when the input channel can be routed to the requested output fibre no matter at which wavelength. Blocking probability is defined as the ratio between rejected and total requests. To demonstrate the usage and show the usefulness of the RCM and NSM, we evaluate the blocking probability as a function of active channels. We will compare the blocking probability applying two different routing algorithms. The input traffic is considered uniformly distributed.

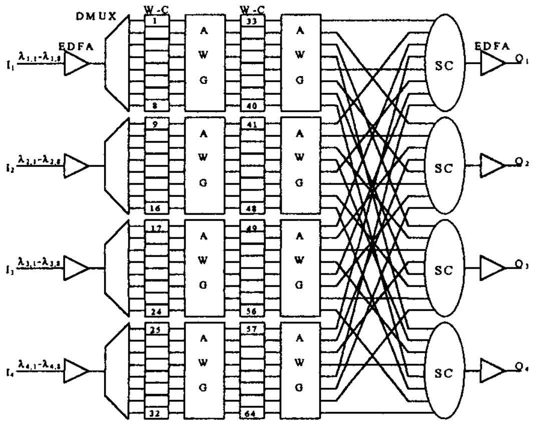

Figure 2. 4x4 OXC arch. with 8 wavelengths per fibre.

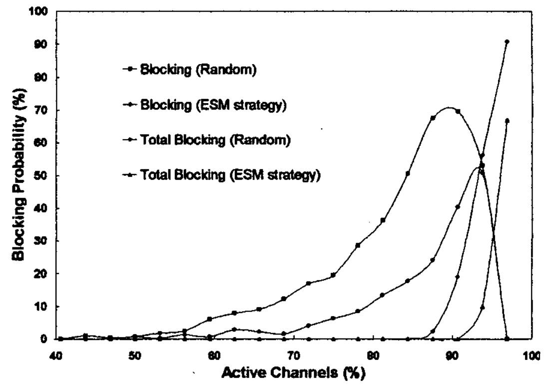

Figure 3. Block probability using two routing approaches.

To simulate the OXC operation, we randomly generate connection requests, with equal probability, from a list of idle input/output OXC channels. If the connection is not available it is blocked and registered, and then we generate a different request. Otherwise, we look at the RCM to find all possible paths and the controls to be operated. Following a routing algorithm, we choose one path, update the NSM and then register the connection. The blocking probability is calculated and another request can be processed. When the NSM is full (no more connections are available) it is reset and a new iteration begins. This process is continued until the blocking probability value is stabilised for each active channel.

Simulations address two different routing approaches. The first approach randomly chooses an available path from the RCM. The second approach applies a routing strategy we call Emptiest Status Matrix (ESM). This strategy evaluates every NSM after each possible path is tried, and chooses that precluding less unused connections, which is the option that leaves more free elements in the matrix. If there are more than one most effective option, the choice is made at random.

Results are drawn in Figure 3 showing a sensible improvement when the ESM has been applied. A blocking of 10% is reached for 66% and 80% of active channels with and without routing strategy respectively. The peak values are 70% and 50% reached at 90% and 94% of active channels respectively. A drawback of this structure is that it becomes completely blocked, i.e. no more connections are possible even when there are idle input/output OXC ports and the NSM becomes completely full. Usable OXC without total blocking is 88% of active channels and 94% when ESM has been applied. Besides, the peak total blocking is 91% and 67% respectively (see Figure 3).

NSM is an abstraction of the RCM and hence the node element agent must update it. Nonetheless, the implementation independence and the binary nature of the NSM ease the OXC manageability what represents a clear advantage for the Configuration and Protection Manager. Moreover, new threshold parameters can be defined in the NSM to deal with traffic capacity exhaust, what can be used by the Performance Manager.

5. Discussion

A new object class has been proposed for the cross-connection fragment of the Information Model what represents a specialisation for routing sub-networks in WDM transport networks. This class allows the manager to operate cross-connecting nodes with diminished connection capabilities. Using a new notation methodology to describe an OXC routing functionality (WTM), the Routing Control matrix (RCM) can be found. WTM and RCM are a clear way to describe completely the architecture and operation of the cross-connecting sub-network.

A new matrix called Node Status Matrix has been defined from a Management point of view that relaxes the processing and memory requirements and minimises messaging information. This Matrix along with the RCM allows a pro-active management approach from the Network Element Level. To demonstrate all these advantages, we have evaluated the internal blocking probability (as a function of active channels) of an OXC structure used as an example, which is not strictly non-blocking. Definition of the NSM has allowed us to apply a simple routing strategy that has lead to a sensible decrease in the OXC internal blocking probability.

6. References

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