FLEXIBLE OADM NETWORK

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Abstract: The use of Optical Add and Drop Multiplexing (OADM) in submarine systems allows the design of complex networks, which are cost effective, offer an optimised bandwidth allocation, and permit increased connectivity. Various solutions can be offered, by locating the OADM function either in the land station, or in a sub-sea Branching Unit (BU). New generation of BUs bring a new step in the conception of such networks, by adding extra flexibility and robustness in the design.

1. OADM IMPLEMENTATION SOLUTIONS

Network design for systems having multiple landings is challenging. The requirements of such networks are multiple: capacity demand not constant over the network, cost effectiveness, flexibility of the traffic allocation, robustness to faults, and independence of segments against faults. The implementation of the OADM function in a submarine network is a good way to address such challenges. Thanks to the recent developments in BU designs, more flexibility can now be achieved in systems using such technology.

Two main strategies are considered when designing systems with high connectivity (i.e. multiple landings with increased connectivity between landings), and with different capacity demand per connection.

The use of an OADM SLTE in intermediate stations is the first solutions. The through traffic is routed directly, while the dropped traffic is terminated in the station. This solution brings flexibility, since the ratio between through and dropped traffic can be adjusted over the system life. However, it still requires the direct traffic to physically pass through the land station (Figure 1, top).

The second solution is provided by the use of OADM Branching Units inserted into the system main trunk. The impact of shore end cable cuts on the direct traffic is drastically reduced, in that case. This is particularly true, when the BU location can be chosen beyond the continental shelf (Figure 1, bottom).[1]

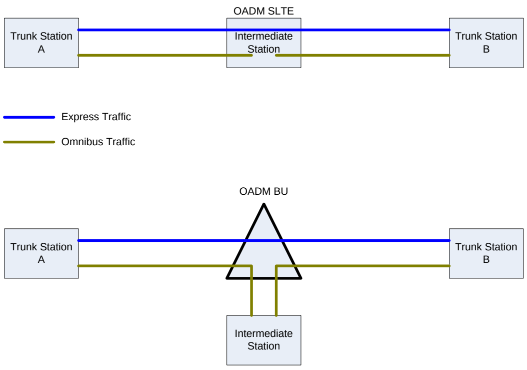

Figure 1: OADM implementation

The OADM BU solution has been implemented for a long time, starting with 8x2.5Gbit/s systems in the late 90's [2]. The first systems, because of the bandwidth limitation, implemented single or dual channel drop.

Then, because of the repeater bandwidth extension, wide band add/drop have been implemented, allowing a significant percentage of the total capacity to be dropped.

In parallel, more specific designs for scientific applications, or Oil&Gaz applications have been developed. These designs are based on non-wavelength re-use topology, which is again permitted by wide bandwidth amplifiers.

2. COMPARED BENEFITS OF OADM IMPLEMENTATION SOLUTIONS

Both OADM function implementation solution faces both common challenges, plus specific aspects that will drive the choice for one or the other solution.

Bandwith allocation:

OADM SLTE offers a wavelength allocation granularity and flexibility over the system life. Pass-through traffic can be partly or entirely converted into omnibus traffic, and vice-versa.

Concerning OADM BU, the bandwidth allocation flexibility will depend on the type of OADM BU implemented. Wavelength re-use BU allow a high level of bandwidth allocation flexibility, but at the cost of express traffic bandwidth. On the other hand, no wavelength re-use OADM BU dropped capacity is defined at system design. Although the change of direct/dropped traffic ratio could theoretically be achieved by replacing the BU, this solution would in real life be complex to implement.

System Design:

The design of a system including OADM SLTE will have to be based on the longest DLS (Digital Line Segment). Most of the time, the direct traffic going through intermediate stations will be the one running the longest path. Depending on the system topology, this could significantly increase the length, compared to a direct cable running between the extremity stations. Therefore this solution would require an extra quantity of repeaters in order to reach the optical power budget requirements

OADM BUs, on the other hand, will let the direct traffic to go along a shorter path, hence reducing the required repeater quantity.

Robustness:

A fault occurring in any part of a network should not impair the parts of the network not directly impacted by the fault. This is a key requirement of such multi-DLS network.

It is well known that the removal of part of the WDM spectrum in a repeatered link has an impact on the remaining channels, due to the distortion of the amplified link gain profile.

With OADM SLTE, the direct traffic has to go through the intermediate station. The distortion induced by a fault in a part of the network can be overcome by replacing the missing traffic by loading channels [1].

With OADM BU, the impact of the distortion can be overcome by taking benefit of extra margin available for the shorter DLS, which are often the omnibus DLS [1]. In this case, the ratio between the express and the dropped traffic is a key point to take into consideration for the robustness.

3. NEW OADM BU REQUIREMENT

Taking into account the aspects previously described, and the respective system advantages of each solution, new BU design and development can be considered.

The requirements of such a BU are:

- Robustness of the system that would not require extra-margin availability.
- Higher degree of flexibility of bandwidth allocation than with current no-wavelength re-use OADM BU. Higher bandwidth availability than with wavelength re-use BU.

- High reliability to allow undersea deployment without impairing the system reliability.
- Improved flexibility with regard to electrical re-configuration

The basic functionality of the BU, and its implementation in a network is described in Figure 2 below. It is similar to the no-wavelength re-use BU.

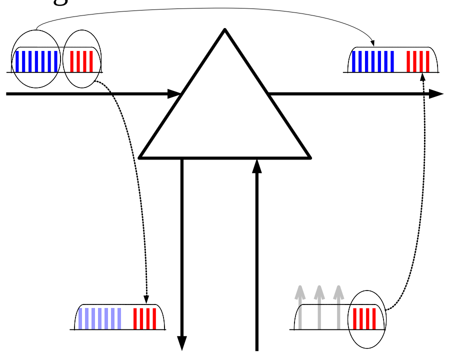

Figure 2 : OADM implementation in BU

4. SYSTEM ROBUSTNESS

The robustness of the OADM implementation solutions described above is reached, either by extra design margin (No-wavelength Re-use BU), or by inserting loading channels when required (OADM SLTE, wavelength re-use BU).
The new BU design approach presented in this paper is based on the use of a switching engine inside the BU, which allows the filtering stage of the BU to be by-passed. In case a fault occurs in the trunk (Figure 3b), the traffic added from the branch suffers an increase of power that can result in an impact on transmission performance due to high Non-Linear Effects (NLE). The switching engine will divert the whole branch spectrum, including the loading channel, therefore restoring proper transmission for the added channels (Figure 3c).

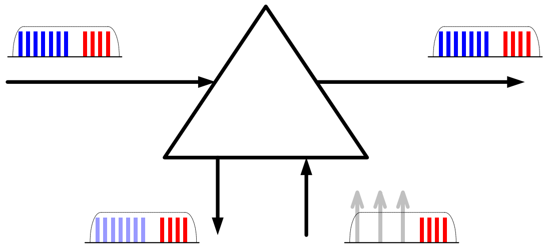

Figure 3a : Fault Free BU system

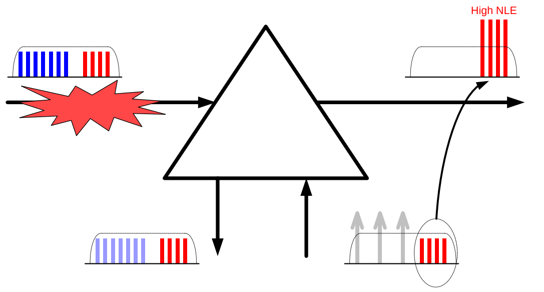

Figure 3b : Trunk fault

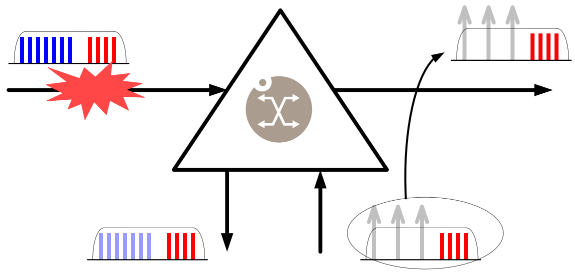

Figure 3c : Trunk fault recovery

Symmetrically, the same will apply in case of branch fault. The switching engine will let all the trunk traffic to go through, restoring proper transmission for the express traffic.

5. BANDWIDTH ALLOCATION

The use of a switching engine inside the BU opens the door to new possibilities for extra flexibility in the bandwidth management of OADM BU systems. Unlike the traditional no-wavelength re-use BU, the new OADM BU will have the capacity to accommodate different express/omnibus traffic ratio. These ratios will have to be chosen at system design time, but will bring extra bandwidth management flexibility during the system life. For example, at start of life (Figure 4 top), the number of channels dropped is lower than the number of channels of the express path. Then, during system life, the required drop capacity demand is higher, while the express capacity is less than initially planned (Figure 4 bottom). The switching engine will dynamically commute between the two configurations to allow easy modification of the express/drop capacity ratio.

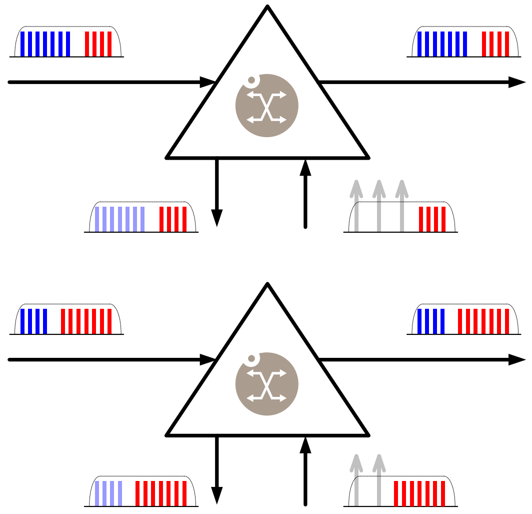

Figure 4 : Top : OADM BU configuration 1. Bottom : OADM BU configuration 2

6. RELIABILITY

Simplicity and reliability of undersea components have been key in the fantastic development of transoceanic communication. The introduction of a switching engine, while bringing new features, adds complexity to the BU. This point has to be carefully addressed, and reliability of the engine has to be specifically taken into account at the development stage.

7. CONCLUSION

The insertion of OADM function in a network brings obvious benefits to the operators implementing a complex network. Various solutions exist, with different advantages and constraints. The advantages can be maximized, while constraints reduced to the minimum, by considering new switching facilities inside a BU unit.

8. REFERENCES

[1] S. Dupont, V. Letellier, P. Marmier "Design Robustness of Submarine Networks using Optical Add and Drop Multiplexing", Suboptic 2010, Yokohama, Japan

[2] O. Gautheron, G. Bassier, V. Letellier, G. Grandpierre, P. Bollaert "8 x 2.5Gbit/s WDM transmission over 6000 km with wavelength add/drop multiplexing", Electron. Letters, 1996, **32**, (11), pp1019-1020