NESTED NETWORK TOPOLOGY FOR FLEXIBLE EXTENSION

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Abstract: This paper introduce a flexible nested network topology in submarine cable communication system. In the preliminary stage of project construction, a series of adjacent BU pairs can be reserved in the system main trunk. The future extended submarine cable can be connected to the reserved BU pairs to form an Ω-type configuration. Multiple landing points can be connected to the system via the newly-added BUs on the Ω-type configuration. Moreover, a 2nd BU pairs can be reserved for further extension, which can achieve continuous extension in theory. The extension will have no disruption to the existing traffic. This network topology is especially suitable for the uncertain oil & gas platforms or inter-island submarine cable project.
Due to uncertainties over the location and start-up dates of the future extension, the nested network topology has much better flexibility and extensibility. Furthermore, it can greatly reduce the CAPEX and OPEX of the initial system. The nested network topology is suitable for both unrepeatered and repeatered system.

1. INTRODUCTION

In the years since the introduction of submarine cable system, a wide variety of alternative applications have emerged in response to Oil and Gas industrial, many small island interconnection, military, and scientific needs.

For these applications, design trade-offs differ from traditional telecommunication systems. Maximizing the bandwidth is rarely the most important factor, features such as flexibility, geographic extension may take precedence.

In this paper, we present the traditional ways and a nested network topology to achieve flexible network extension capability.

2. TRADITIONAL WAYS OF EXTENSION

The simplest network topology is point-to-point connection. However, submarine cable system demand topologies that are always more complex than that. In order to meet this demand, a Branch Unit (BU) which has the capability to interconnect three cables is usually deployed to interconnect multiple landing points.

BU can support the following functions.

From electrical domain:

- ✧ Passive: the power feeding state of BU is fixed.
- ✧ Power switch: the power feeding state of BU can be reconfigured in case of cable faults to recover some traffic.

From optical domain:

- ✧ Fiber drop
- ✧ Fiber drop with optical switch
- ✧ Optical Add/Drop Multiplexer (OADM) based on fixed filter technology, the add/drop ratio is fixed, it cannot be adjusted once manufactured.
- ✧ Reconfigurable OADM based on Wavelength Selective Switch (WSS) technology, the add/drop ratio can be adjusted according to traffic demand in future.

For different system application, different electrical and optical functions can be integrated into BU to offer the most cost-effective solution, as shown in Figure 1.

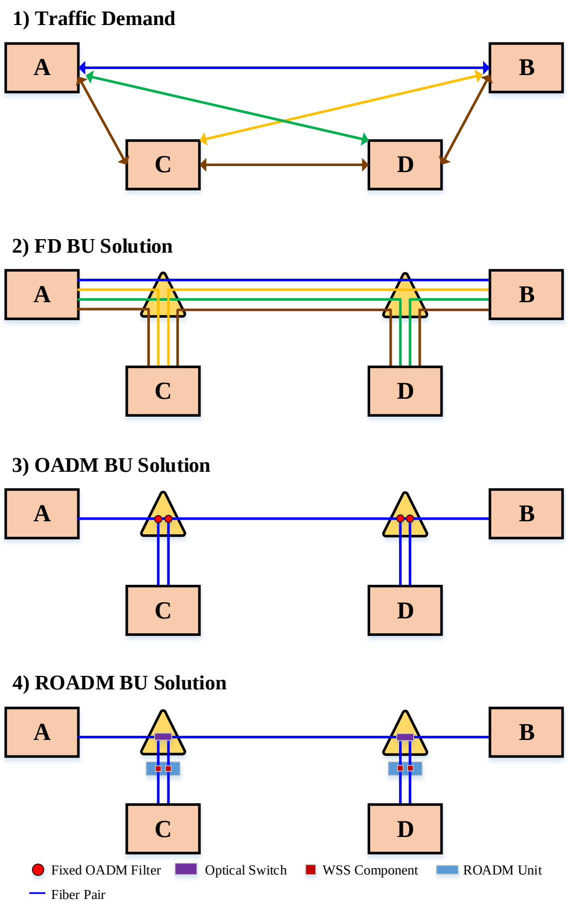

Figure 1: Different Kinds of BU Application for Same Traffic Demand

Compared to fiber drop BU solution, the main benefit of OADM and ROADM BU is to share capacity carried on one fiber pair between several cable stations, so it could reduce the number of fiber pairs in the trunk. As shown in Figure 1, for the same traffic demand, 4 fiber pairs in the trunk is required, but for OADM and ROADM solution, 1 fiber pair is sufficient. This will help to save the cost for trunk construction. OADM BU solution is the most cost effective solution for branch stations which do not need too much capacity, such as Oil and Gas platform or islands with limited populations.

At the planning stage, due to financing or permitting issues, some branches may not be able to construct. In the interest of allowing the potential landing sites to be connected into the system in future, the following ways are usually adopted.

1) Stubbed BU Solution

For traditional submarine cable system, reserving stubbed BU solution is the simplest way. At the construction stage, due to some reasons, the branch to Station D could not be implemented. However, the owner of the system still want to keep the possibility for future extension to Station D considering the traffic demand. In this case, a stubbed BU can be reserved, as shown in Figure 2. The stubbed BU could be fiber drop or OADM or ROADM based on the requirement. Loop Fiber End Seal (LFES) is used at the end of BU stub cable for fiber loop, sealing, testing and future easy recovery.

When constructing the branch, LFES will be recovered and replaced by UJ to connect the stubbed cable and branch cable.

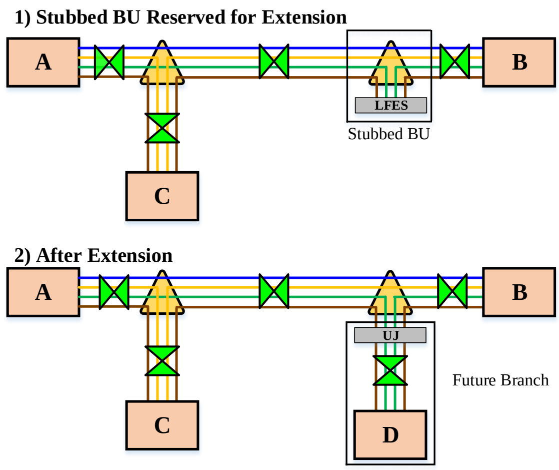

Figure 2: Stubbed BU Solution Before and After Extension to Station D

For telecommunication cable system, Power Feeding Equipment (PFE) can be installed at Station D. Repeater can be deployed into branch if required, so there is no limitation on the length of branch.

After installation of branch, the power feeding configuration will be dual end feeding for trunk and single end feeding for the branches, as given in Figure 3.

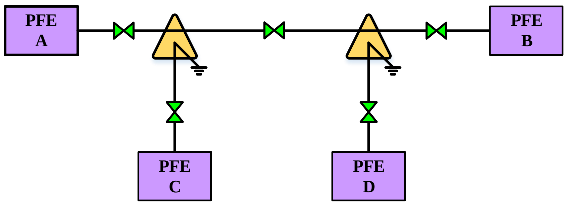

Figure 3: Power Feeding Configuration After the Extension to Station D

One advantage of stubbed BU solution is that it will not affect the traffic on the trunk express fiber pair when constructing the branch.

2) Loss Equalizer Solution (LEQ)

At the construction stage of main trunk, it is not sure whether to construct the branch or not, but want to keep the extension capability by using a cheap way other than using stubbed BU. In this case, LEQ could be inserted into the main trunk at the most possible point to extension, as shown in Figure 4.

At the later stage, when need to construct the branch, it can use BU to replace the LEQ. The attenuation of LEQ shall be equal to the attenuation of branch unit and extra cable needed when installing the BU. In this way, after replacement, it will not affect the transmission quality of traffic on trunk.

When doing replacement, it need to turn off the power feeding, cut the main trunk, recover the LEQ, and lay down the newly-added BU and branch cable. During this period, the traffic on the trunk will lost for approximately one week.

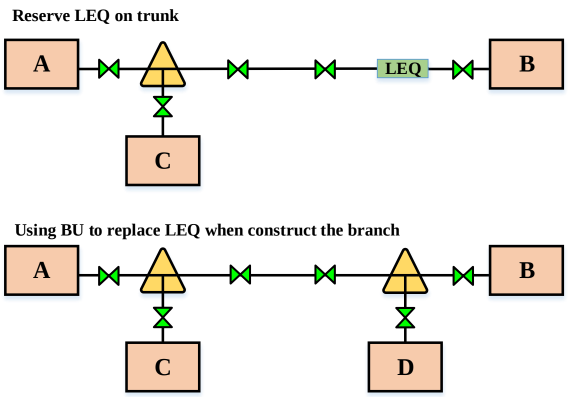

Figure 4: LEQ Solution Before and After Branch Installation

The type of BU could be fiber drop, OADM or ROADM according to the actual requirements of the system.

3. NETWORK TOPOLOGY IN OIL&GAS APPLICATION

The usage of optical fiber to provide communications to oil and gas platforms began in the 1990s. Traditionally, offshore oil and gas platforms have relied on satellite or microwave communications. With increasing size and sophistication of offshore platforms, the requirement for higher bandwidth, lower latency, and higher reliability communications has prompted a shift to submarine optical fiber system.

3.1 Typical Network Topology

1) Optical Perspective

Considering that there are lots of platforms need to be connected to one submarine cable system, and one or two wavelengths (100Gbit/s or even higher capacity per wavelength) is sufficient for each platform. One main trunk between two Oil & Gas Terminals with ‘No wavelength reuse’ OADM BU solution are usually adopted in Oil & Gas Network architecture, as shown in Figure 5.

Through using OADM BU, the traffics between platform and two terminals could be achieved, which could form two diverse routes protection to improve the reliability. Also, OADM solution could minimize the fibre pair quantity in the trunk and save the cost.

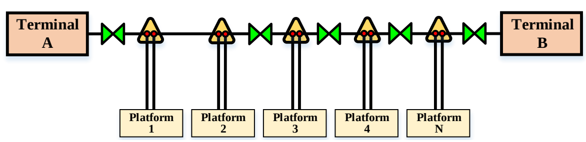

Figure 5: OADM BU Solution for Oil & Gas Platform Application

2) Electrical Perspective

Electrical power safety is a major concern for offshore oil and gas platforms where even a slightest discharge can cause disastrous consequence. It is common practice to earth the cable conductor in the wet plant before reaching the platform. This is the case even the platform is connected via a branch cable which does not normally carry power feed current.

The power feeding configuration will be dual end feeding for the main trunk, all the branches will be unrepeatered branch.

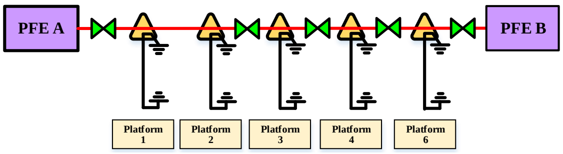

Figure 6: Power Feeding for OADM BU Solution for Oil & Gas Platform Application

In this case, Repeater cannot be used in the branch due to the absence of PFE. As shown in Figure 7, the loss between the platform and adjacent RPTs shall meet the following equations:

- $L_1+L_3+L_{BU} \leqslant G$
- $L_2+L_3+ L_{BU} \leqslant G$

Where,

- L_1: the loss between RPT1 and BU
- L_2: the loss between RPT2 and BU
- L_3: the loss between BU and platform
- L_{BU}: the insertion loss of BU
- G: gain of RPT
- Span length=G/Attenuation of Fibre.

According to the recommendations of ICPC, the distance between two submersible plants shall be minimum three times the water depth. Thus, the length of branch is limited less than one span length.

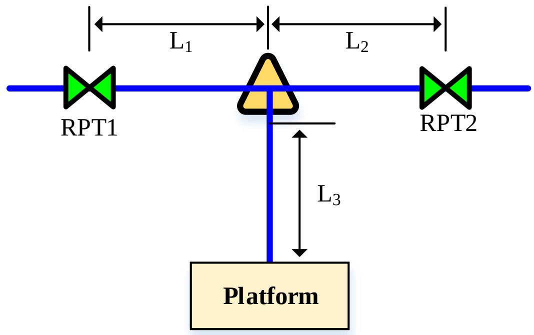

Figure 7: Unrepeatered Branch to Platform

The turret system is adopted for some Floated, Production, Storage, and Offloading (FPSO) to facilitate the rotation of the FPSO to weather vane in response to the prevailing wind, waves and dominating ocean conditions while the risers are still connected to the fixed part on the seabed.

The major component used in turret system for optical connection is FORJ (Fiber Optical Rotary Joint). The FORJ has a specific set of optical characteristics, namely insertion loss and maximum input power limitation. Those two parameters need to be carefully considered when doing the optical power budget for the branch, and it will further reduce the length between the BU and platform as well.

As shown in the Figure 8, the platform located within the corridor (orange line) could be connected into the main trunk (central black line). The maximum width of the corridor is about 2 times the span length.

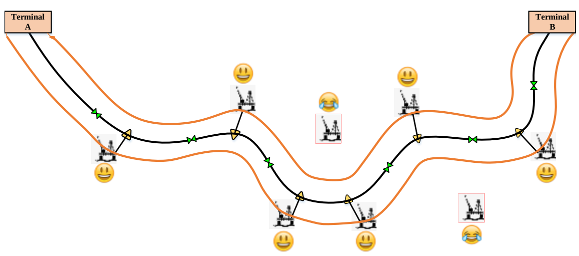

Figure 8: Unrepeatered Branch to Platform

3.2 Nested Network Topology

At the planning and construction phase of the oil and gas submarine cable system, there are two conditions need the extension capability for future connection. The first is that the location of the platform is confirmed but not ready for connection, the route of main trunk shall go nearby the platform to make sure that the platform is within the corridor and deploy a stubbed OADM BU for future connection. The second is that we know there will be a platform at one oil block, however, the exact location is not confirmed yet. In this circumstance, the route of main trunk and location of reserved BU is based on assumptions. If final location of platform is outside of the extension capability corridor, it will be a great challenge to connect the platform to the main trunk.

In order to maintain the extension capability for the second situation, BU pairs (two power switch fiber drop BU) could be reserved within one RPT span, as shown in Figure 9, two fiber pairs is assumed for the trunk. The initial platforms could be connected to FP1 by using OADM BU and FP2 could be reserved for future extension. The route of the main trunk do not need to consider the future platform extension which could save the CAPX and OPEX of initial system.

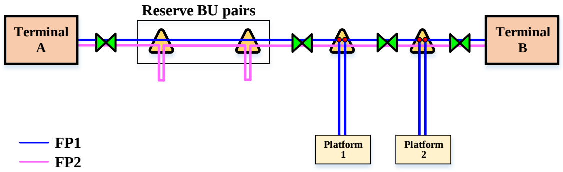

Figure 9: Initial Network Architecture for BU Pairs Solution

The initial power feeding configuration for BU pairs solution is given in Figure 10. Dual end feeding is proposed for the trunk. The conductor of branch cable will be connected to BU sea earth at one end and connected to the earthing unit before reaching the platform at the other end. The conductor of reserved BU stub cable will be connected to BU sea earth.

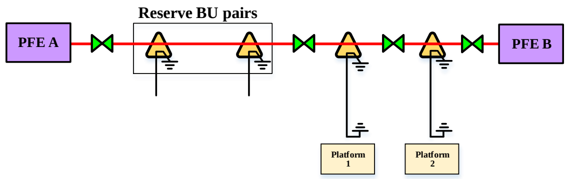

Figure 10: Initial Power Feeding Configuration for BU Pairs Solution

In the future, if there are another four platforms which are far away from the trunk and want to connect into this system, the extension cable could be joined to the stub cable of reserved BU pair and form Ω-type configuration as shown in Figure 11. RPT could be inserted in the extension cable if required. The added platforms could be connected into FP2 through using newly-added OADM BU to achieve the transmission between platform and two Terminals.

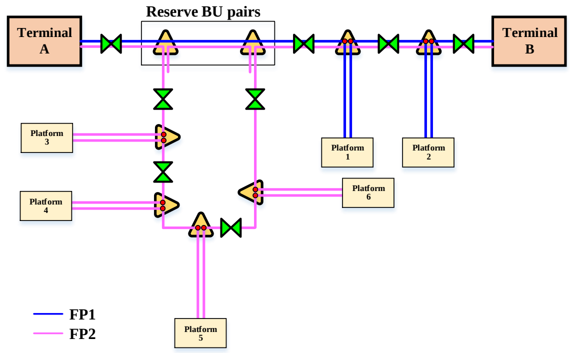

Figure 11: Network Architecture after Extension for BU Pairs Solution

During the installation period of the extension cable, the power feeding configuration will be same as the initial configuration. Consequently, the power feeding for the trunk can be maintained, so it will not affect the traffic on FP1.

After the completion of installation of extension cable, the power feeding state of the BU pairs need to be switched, the final target power feeding configuration after extension is given in Figure 12. The RPT on the extension cable could be powered by main trunk power feeding equipment, so there is no limitation on the length of extension cable. Another BU pairs also could be reserved on the extension cable for future another extension if needed.

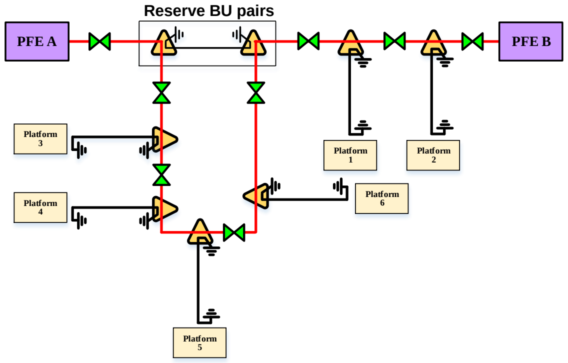

Figure 12: Power Feeding Configuration after Extension for BU Pairs Solution

4. NESTED NETWORK TOPOLOGY IN ISLANDS INTERCONNECTION APPLICATION

For some country, they have lots of islands distributed in a very large area. In order to improve the life quality of people living on these islands, their governments plan to construct submarine cable to provide the international capacity to enrich their life. Capacity requirement for such islands is usually not too much due to limited population. A most cost effective solution is preferred for this kind of project.

Nested network topology is also suitable for many inter island connection projects to maintain the extension capability. Sometimes, for some reasons, some islands cannot be connected into the system. In this case, BU pair could be reserved for extension. If some islands want to be connected in future, the extension cable could be deployed and join to BU stub cable. RPT and OADM BUs could be added into the extension cable to achieve the transmission between the islands and two trunk station. As the RPT in extension cable could be powered by trunk station and the branch to islands could be constructed as unrepeatered branch, so power feeding equipment together with return earth system at those islands is not required, which can save the CAPX.

5. CONCLUSION

In this paper, we introduce a nested network topology using adjacent BU pairs which can provide more flexible extension capability. Moreover, a 2nd BU pairs can be reserved on extension cable for further extension, which can achieve continuous extension in theory. The extension will have no disruption to the existing traffic.

This network topology is especially suitable for system extension in uncertain Oil and Gas platform connection and many islands interconnection project.

At the initial phase, the system design and construction do not need to consider future uncertain extension, so it can greatly save CAPX and OPEX for the initial system.

6. REFERENCES

[1] Stephen Lentz, "Undersea Fiber Communication Systems (Second Edition)", P301 – P338.