WET RECONFIGURABLE STAR NETWORKS BY ADAPTATION OF TECHNOLOGIES FROM OIL AND GAS

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Abstract: Established technologies used in undersea communications for offshore oil and gas applications offer new options also in telecommunications, in particular towards increased network flexibility and reconfigurability, or as an alternative to trunk and branch type systems for networks that need to support many landings, today or in the future.

1. INTRODUCTION

A barrier to development of services in regions of low population densities can be the number of distinct countries with low traffic requirements. This provides particular challenges when interconnectivity is considered. One of the more common terrestrial configurations applied to address this issue is the star network, typified by satellite systems which can provide economic access to a large number of regions. While the trunk and branch type systems (which are analogues of the star network) have been widely deployed in subsea networks, there are connectivity issues and cost implications when capacity needs to pass through high numbers of line segments. Local traffic passing through other counties nodes before reaching its destination can also be an issue.

On the other hand, there are numerous commonalities between submerged components and technologies used in Submarine Communications and in Oil and Gas industries. Yet there are also certain elements that are not yet applied across both industries. An example of this is the use of underwater star nodes utilising wet-mateable connectors [1]. Employing these field-proven underwater demountable connectors offers a low-risk solution with the flexibility to add or augment connections, and to reconfigure the system throughout its life. In combination with pre-fabricated landings [2] this offers an economic solution to meet variable communications requirements over the system life cycle.

In this paper the authors consider systems with star branches and compare them with equivalent trunk and branch type systems, which by default require much more hardware if many landings are required. Based on this, we consider submarine star topology networks with flexible routing, offering reconfiguration throughout the system life, and the applicability of wet-mateable connectors for this purpose, taking into account reliability, maintenance, and cost. Other aspects to be considered for a real-life deployment scenario of an optical distribution unit are its deployment, reconfiguration effort and protection.

2. NETWORK TOPOLOGY

The familiar trunk and branch network configuration, see Figure 1 below, is often deployed in the submarine world to offer “collapsed ring” architecture by the simple expedient of fibre routing (see Figure 2).

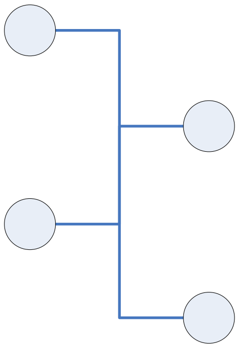


Figure 1

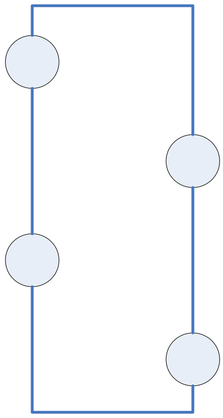


Figure 2

This concept is often extended further by the express and omnibus model (Figure 3) The deployment of systems such as these is fully cost effective; for completeness, in network theory there is the fully connected topology (Figure 4) where each node is directly connected to all other nodes.

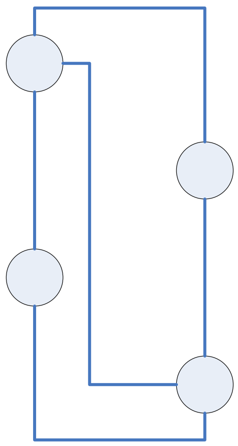


Figure 3

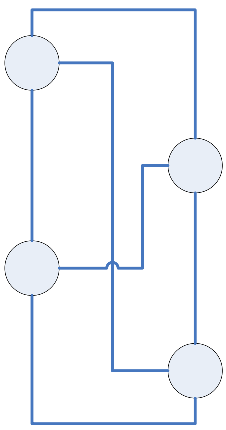


Figure 4

However, these systems do not adapt particularly well to reconfiguration or enhanced connectivity, particularly if it is proposed after the original installation. This restricts the design engineer to a limited number of technical choices for system augmentation without significant investment by the sponsors. It is quite common for systems to be constructed with Branching Units (BUs) with spurs configured for later connection to the network. However there are technology options already deployed within the oil industry that offer a wider palette of tools to the system designer. They also permit phased system interconnection and development at the pace of each individual party. These technologies will be discussed in the next section.

With access to such flexible interconnection technologies, and of course subject to the usual transmission limits, an analogous network can be developed offering the same “connectivity” as those discussed above: see Figure 5a.

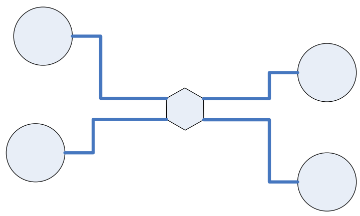
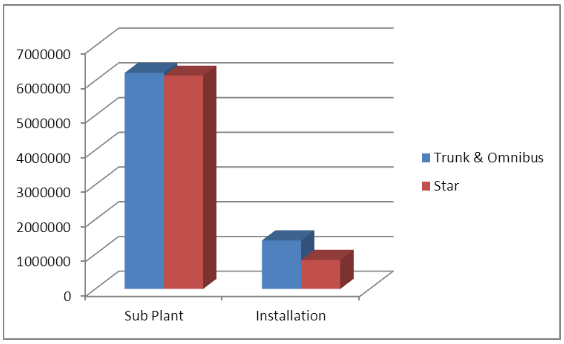


Figure 5a

A model calculation of the economics confirms the intuitive judgment that the approach shown in Figure 5a tends to be more cost effective than the one shown in Figure 1 (physical layout) and Figure 4 (logical connections). Such study takes into account the cost of the underwater star connector unit, including the actual wet-mateable connectors, and compares with the cost of branching units.

Some results are shown in Graph 1 for a sample network. They consider both, the actual hardware cost for the submerged plant, as well as the cost of deployment. For the shown case the hardware costs are fairly similar, but some savings can be anticipated for the initial installation.



Graph 1: Comparison of submerged plant and installation costs between a Trunk and Branch (Figure 1) and the Star Network (Figure 5a)

Furthermore, this approach offers some interesting future upgradeablity benefits - not only from a connectivity perspective, but also in terms of cost. With only little additional effort, the star system shown in Figure 5a can be extended to offer the capability to have a branch or branches added, also utilizing its capability to reconfigure the fibre pair connectivity of the whole system, as shown in Figure 5b.

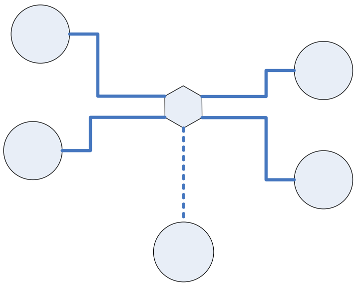


Figure 5b

3. UNDERSEA DISTRIBUTION UNITS

Key to this approach are reconfigurable undersea distribution units. The good news is that these exist and are already being applied in offshore communications applications. However, will they meet the standards and requirements for telecommunications applications?

These units typically consist of two main parts: a mechanical unit and a wet-mate connectors.

The mechanical unit can come in different forms and shapes, depending on the application, e.g. a cable end unit where only a single wet-mate connection is made (e.g. instead of a final splice), or a cable distribution unit where several connections are made – as required for our star network application. Such a submerged distribution unit is shown in Figure 6 below.

Figure 6: Submerged Distribution Unit (Photo: Nexans)

These units use wet-mate connectors, which are obviously a core part of the wet reconfiguration solution.

Typcial specification parameters for these connectors are (as stated by manufacturer ODI, [3]):-

- Up to 8 optical connections per connector
- Qualified up to 10,000 psi ambient pressure
- At least 100 mate cycles before maintenance procedure required
- Single or Multi-Mode Optics
- Insertion Loss <0.5dB, typically <0.3dB
- Mate/De-mate force <120 lbs/<100 lbs

A photo of a typical connector is shown in Figure 7 below. It includes a bulkhead mountable plug (on the left), and flying lead receptacle (right) supporting handling with a Remotely Operated Vehicle (ROV).

Figure 7 Wet mateable connector (Photo Seacon)

Critical to the performance of wet mateable connectors is the connection between the cable and the connector in such way that no water or contamination can enter the cable, given the high pressure on the sea floor compared to the low pressure inside the cable tube. This is achieved by the use of oil filled pressurised chambers to seal the optical terminations in the connector during the mate/de-mate cycle. The connection to the main fibre optic cable (FOC) is usually done in the cable factory. It is worth noting that the connectors do not require to be made in matched pairs for optimum optical performance.

Another key parameter for the actual re-configuration work is the maximum mate force, which is in the range of 112 to 140 lbs for commercially available connectors. Such forces will present difficulties for divers, and therefore these operations usually require deployment of a ROV for making or unmaking a connection under water.

The following aspects require attention when a solution with wet re-configuration is considered for submerged networks.

Submerged plant reliability is generally a larger issue in telecommunications than it is in offshore applications. This is particularly valid in the deep ocean, where recovery and repair can be very time consuming and costly. However, wet connector suppliers claim impressive figures for the field record of their wet mate connectors, e.g. over 32 million accumulated operating hours and a mean time before failure of 6.9 million hours (~800 years) [4]. Another supplier states that over 100,000 connectors have been delivered, which have accumulated 4 billion service hours with a reliability of greater than 99.9%.

Another important technical consideration likely to be more relevant for telecommunications, is increased optical loss that may be induced by a non-optimally made connection or degradation of a connection. Although the manufacturers quote a 25-year life and 100 mate/de-mate cycles, it will be important to establish the variation or increase in insertion loss during this period. Such loss will have to be addressed in the optical System Design. The impact of loss variations is largest for repeaterless links, where any loss directly translates into a reduced capacity or performance. The two most obvious ways to address this are by assuming the maximum possible loss (possibly with added margins) for the initial design on day, or inserting additional equipment cards to the terminals at a later stage if/when the performance has degraded. Dedicated unrepeatered submarine line terminal equipment offers the latter option by adding so-called span extension modules.

For repeatered networks the impact of loss is less relevant because submerged optical amplifiers are operated in gain saturation, meaning that a fairly large amount of loss increase between two repeaters can be absorbed without impacting performance or link capacity. However, repeatered links require power feeding (except for repeaterless branches) which would require a wet-mate electrical connector capable of handing very high voltages.

A fault-resistant communications network not only requires reliable connectors; the question of reliability also extends to protection of all submerged plant on the sea floor. Having established a suitable location for the wet connections to be made, it is likely that a distribution unit will be deployed at this location. The cables, which will have been pre-terminated with a connector end, will then be laid onto the seabed adjacent to the distribution unit.

In shallow water (i.e. in less than 1000 metre depth) fibre optic cable is usually protected against external aggression such as fishing and anchoring by armouring and burial into the seabed. Therefore it will be necessary to protect the cable ends; but also make them readily accessible for re-configuring the wet connections at the distribution unit. This type of activity would be compatible with the use of an ROV, where the cables can be jet buried over short distances, or protected by mattresses.

In very shallow water localised protection of the cable could be achieved by divers using airlifts; but this would be much slower than ROV operations.

4. DISCUSSION

The technology making wet connections, including the option to reconfigure these, has reached a mature state, even for telecommunications systems. Component reliability and optical loss even after many cycles appear to be good, based on many years of field data in offshore oil and gas applications. However, it will still be advisable to appropriately address a possible increase in system loss in the system design for a new system, e.g. by additional margins or using submarine line terminal equipment that can be tailored to cope with a future increase of the span loss.

Other aspects to be further considered include how often the wet connections are likely to be changed, and the consequent impact on protection and accessibility. Since making wet connection will usually involve deployment and operation of a ROV this will have an impact on the speed and cost of such reconfiguration.

Consequently it may be advisable to perform some further sea trials, covering aspects such as protection and recovery, long-term impacts of making and changing connections. including the viability and limits for utilising divers to perform reconfiguration work, which would likely be more flexible and less costly than ROVs.

All this supports the viability of star type submarine networks, and there several of these currently under development or consideration. A model calculation for a hypothetical network clearly confirms that such networks make a lot of commercial sense in certain regions and applications, i.e. where not only capacity, but also connectivity and re-configurability are key aspects.

Further afield, the possible development of dual cored submarine cables may open up extended applications for submerged distribution units, e.g. by facilitating off-shore interconnection points in combination with fixed multi-core landings. Such developments would further serve the need and interest in flexible submarine networks for certain market segments or regions

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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