Long Term Real Time Observatories for Environmental Monitoring in Offshore Drilling and Production Areas

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Abstract: Understanding the ocean environment is of heightened interest to all stakeholders in the offshore oil and gas community, including operators, service providers, regulators and researchers. It has become increasingly important to be able to continuously measure a wide variety of oceanographic parameters to establish baselines, understand natural variability and provide a means to detect measure and track potential impacts of offshore activities. Proposed advancements in undersea communications technology that enable persistent measurements coupled with the potential availability of offshore production infrastructure, with their multi-decadal life cycles, present unique opportunities to support long term ocean observations. This paper discusses the integration of sensor networks, demonstrated in the science community, with the high bandwidth fiber optic communications networks that service offshore oil and gas platforms.

1. INTRODUCTION

The past decade in undersea telecom technology has seen significant advances in the ability to deliver tremendous amounts of bandwidth, in undersea connectivity techniques, and in the broadening of the base of undersea fiber applications and users. In addition to supporting traditional and non-traditional telecom carriers, sophisticated undersea cable networks have been developed and produced for both the offshore oil and gas (O&G) and the ocean science communities. These two groups have much in common in their working environment, their subsea technology, and their fundamental grounding in all aspects of the ocean sciences.

The oil and gas industry and the ocean science community have independently and successfully procured dedicated, high-use undersea cable networks in recent years but with different objectives. Oil and gas networks are constructed to support exploration, drilling, and production in specific energy development fields and regions. Scientific networks tend to be built around regional features that support the focus of their research mission. Technology is under study that would allow the scientific community to create observatories on the same undersea networks used by the oil and gas industry.

This paper will review the need for offshore observatories in areas of offshore drilling and production, along with the current technology used to create offshore fiber-optic networks. New technology and architectures are described that enable independent scientific observatories to draw power and to transmit data over high bandwidth channels. This offers the possible establishment of real time long term facilities that could be operated and maintained with, or independent of, an offshore facility, coexisting on the same data network. Data and power from an offshore platform may no longer be needed to enable the sensor network. Undersea installation and maintenance considerations will also be addressed.

2. SCIENTIFIC NEED FOR OBSERVATORIES

The ocean science community is increasingly utilizing ocean observatories to advance basic research of oceanographic processes and phenomena. This is a result of the confluence of advancing technologies that enable the persistence of platforms and sensors undersea and the recognition that to better understand the complex ocean system requires the systematic, continuous collection of data over extended periods of time. Ocean observatories can include autonomous moorings, cabled arrays, mobile assets, or a combination of these sensor platforms, taking measurements at the seafloor, in the water column and at the air-sea interface. The unifying characteristic of ocean observing infrastructure is the availability of reliable bandwidth and sufficient power. Over the last decade, the ability to access data from oceanographic sensors in real or near-real time either via satellite or submarine cable has further enhanced the utility of such systems, providing the possibility of a regular and consistent operational use of the information, in addition to enhancing science. One could envision a future when ocean observing systems would have the same ubiquity as our terrestrial weather sensor systems.

As technologies have advanced, and funding priorities have realigned, academic ocean observatories have progressed from simple, single node systems to complex multi-faceted arrays.

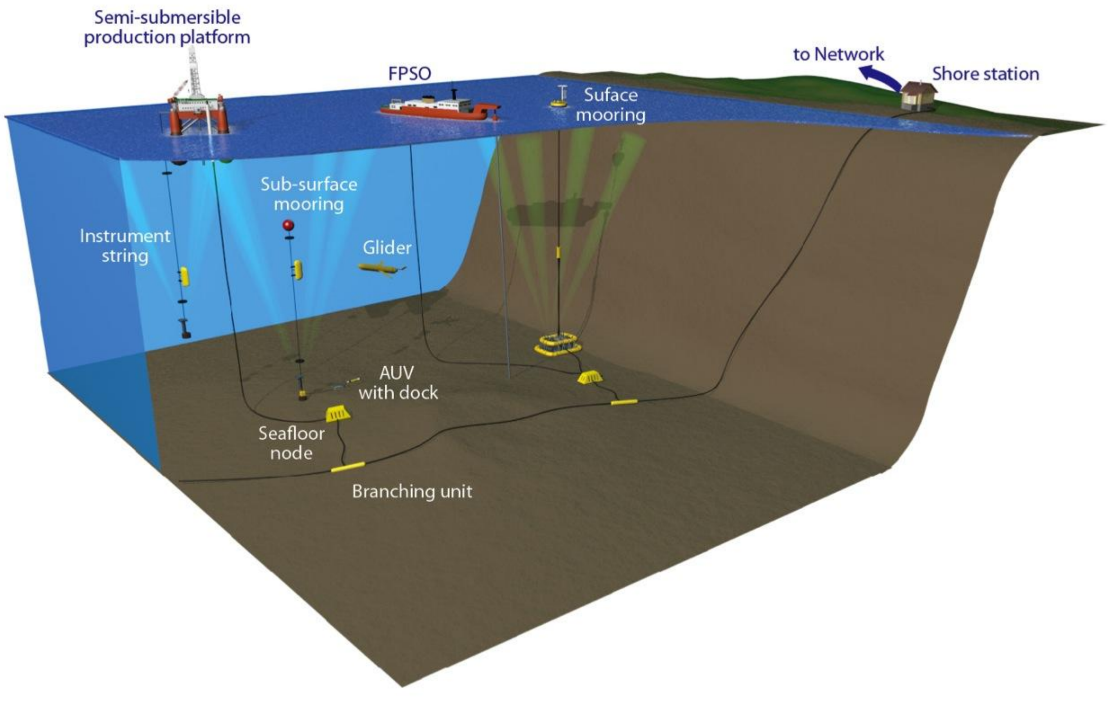

Figure 1: Notional depiction of ocean observing capabilities with offshore oil and gas infrastructure (Jack Cook, Woods Hole Oceanographic Institution)

The largest such system, which is currently under construction, is the Ocean Observatories Initiative (OOI) of the U. S. National Science Foundation[1]. The OOI is comprised of the Coastal and Global Scale Nodes (CGSN), consisting of autonomous moorings, and the Regional Scale Nodes (RSN), a 3000 km cabled observatory with multiple nodes. Gliders and autonomous undersea vehicles (AUVs), extend the spatial coverage of the fixed arrays and nodes providing an operational capability to respond to emerging events. The OOI sites were chosen with the goal of addressing large science questions such as biological productivity, water mass formation and variability, geologic processes and climate change' while at the same time characterizing oceanographic parameters at unprecedented granularity. The CGSN will provide continuous data in real time from nearly 700 sensors deployed to 6 geographic locations over 25 years.

The potential of ocean observatories is becoming increasingly relevant in areas of offshore oil and gas development. Whether lease block purchaser, producer, operator or regulator, understanding the ocean is crucial to successful management, operations, risk mitigation, oil spill response and good stewardship. The march to deeper waters has added to the area under development many fold and increased the complexity of the interactions and impacts between facilities and the environment. Historically, the lack of baseline oceanographic data has hindered the ability of oceanographers to reach conclusions about the impact of a spill[2]. Individual, fortuitous programs that were active in the Gulf of Mexico at the time of recent environmental events, such as observations of the Loop Current using gliders[3] and studies of deep water corals at sites in the vicinity[4], demonstrate the extraordinary value of baseline monitoring.

Ocean observatories in offshore oil and gas developments would benefit each of the key stakeholders: industry, government and academia. Sensors such as mass spectrometers could provide measurements of hydrocarbons in the environment, which would provide objective benchmarks against which the impacts of spills could be detected and measured. These measurements would also help to understand and document hydrocarbon inputs that enter the environment due to natural seeps. Understanding natural seeps is critical to understanding geologic and biologic processes and can provide markers for oil and gas reservoirs. Continuous current profiles could help with routine operational planning and be used to predict the trajectory of contaminants released into seawater as a result of drilling operations or a spill, much like a weather forecast is used to plan activities or a hindcast to analyze an event. The range of measurement possibilities is large and growing and could include passive acoustic sensors for marine mammal monitoring, imagery for monitoring important habitats such as hard substrate that attract deep water corals, arrays for detecting and measuring gas bubbles, seismometers to detect localized faults, and so on.

Ocean observatories with objectives related to offshore oil and gas have been deployed. Several examples include the Cyprus Coastal Ocean Forecasting and Observing System (CYCOFOS)[5] off Cyprus, the Deep Ocean Long Term Environmental Observatory System (DELOS)[6] off Angola and the Lighthouse Ocean Research Initiative (LORI)[7] off Oman. These are standalone systems that, to varying degrees, target the needs and objectives of the scientific, operational and regulatory communities in areas of potential and ongoing offshore oil and gas activities. Incorporation of ocean observing technologies such as those developed for OOI, CYCOFOS, DELOS and LORI into existing and planned oil and gas undersea telecommunications systems, exploiting the available power, significant bandwidth and physical infrastructure, would represent a major and logical evolution of the concept. Examples of this convergence provide the basis for multiple models and designs on how to enhance the BP Gulf of Mexico Fiber Optic Network to support ocean observing elements[2,8].

3. EXISTING OIL & GAS OFFSHORE NETWORKS

Oil and gas facilities are now being served by fiber-optic telecom networks that provide facilities with reliable high-bandwidth service. Fiber connectivity serves their day-to-day communications needs, improves operator enterprise IT processes, and provides oil and gas production professionals with bandwidth levels that drive the development of applications inconceivable a few years ago.

Oil and gas operators also create and manage their own facilities for subsea sensing and monitoring specific to their production operations. Such equipment adjacent to offshore facilities can be considered to be an application-specific scientific observatory, relying on power and data relay services provided by the host facility.

The earliest architectures serving oil and gas facilities were unpowered single segment point-to-point and then daisy-chained festoon networks connected to multiple shore landings. These non-repeatered networks have been effective in bringing increased bandwidth to platforms. Reliability can be improved by strategically equipping multiple fiber pairs and the bypassing (leap-frogging) of facilities. But these strategies require the favourable distribution and arrangement of platforms and unique terminal equipment solutions. There are typically dependencies between facilities, which oil and gas operators of major facilities strive to avoid.

These drawbacks were overcome by the powered trunk-and-branch optical-add-drop-multiplexing (OADM) network which has been successfully implemented and expanded[9]. This architecture is enabled by the OADM node, which typically incorporates the function of a power switched branching unit (PSBU), or an independent subsea body. Both broadband and filtered- broadband architectures can be supported. OADM enables point-to-multipoint transmission from any shore station (Figure 2).

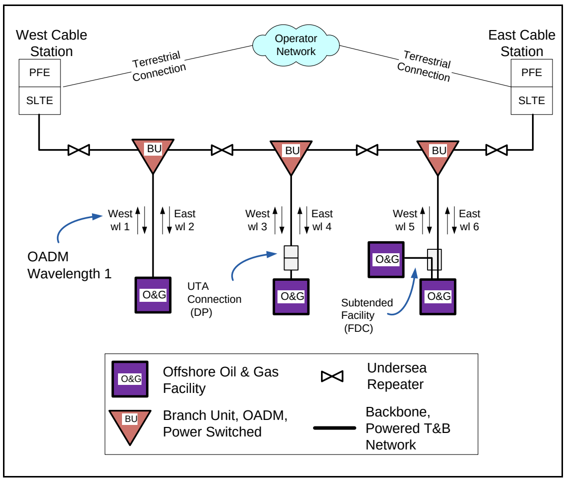

Figure 2: Powered Trunk and Branch OADM Offshore Network

Undersea repeaters are powered by subsea telecom constant-current shore-based Power Feed Equipment (PFE). The backbone powering configuration is controlled from shore by changing branch unit power state, allowing for transmission over a redundant segment during a backbone repair.

The broadband OADM fiber architecture supports wavelength drops to offshore facilities, express wavelengths, fiber pair segregation, and element management partitioning. Express fiber pairs can be included for shore-to-shore commercial telecom traffic. Offshore bandwidth needs are typically more than satisfied by 10Gb/s channels, but 40Gb/s and 100Gb/s channels are also requested due to the industry trend in these line-rates.

Connection of an undersea cable to an offshore facility is established by a fiber-optic riser cable that may be static, dynamic, or part of a multi-purpose umbilical supporting fiberoptic, electrical, and hydrocarbon transport. The multi-purpose umbilical is terminated at an Undersea Termination Assembly (UTA) with fiber access by industry standard fiber-optic wet-mateable connectors (WMC). Connection of the undersea cable to the UTA is by Deployment Pallet (DP) and Flying Lead (FL), both wet-mate connector based products installed by remotely operated vehicles (ROV).

A Fiber Distribution Canister (FDC) can be included with a riser that provides seafloor fiber access from topside, by Wet Mate Connector, enabling operators to install undersea sensing and control elements. These sensors are dependent on the adjacent platform for power and data transmission and any scientific use would rely on the host platform (Figure 3).

FDC, DP, Flying Leads, WMC connectors, and OADM are the technology building blocks that have enabled the interconnection necessary for sophisticated trunk-and-branch oil and gas networks. These networks are no longer new and have offered an opportunity to observe how the operators use these networks and what they want from the next step in technology.

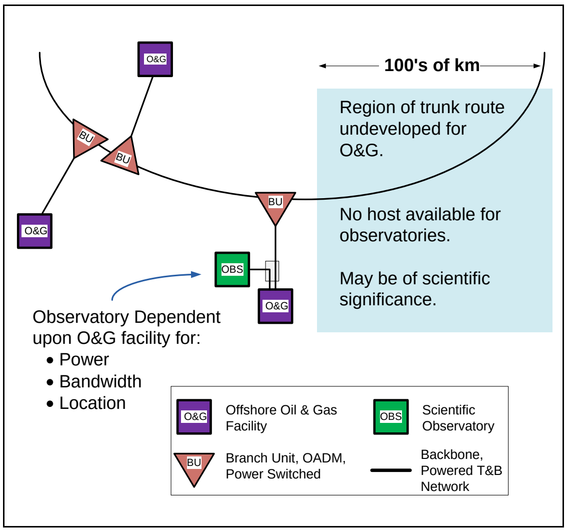

Figure 3: Observatory with O&G Facility Host

4. TECHNOLOGY ADVANCE FOR SUPPORT OF SUBSEA OBSERVATORIES

The industrial and institutional experience with subsea connection products such as FDCs and DPs have resulted in new and innovative sensing and data collection methods providing increased autonomy and real-time data interaction. These technologies will continue to be applied to serve the data collection needs[10].

In response to applications that do not rely on a topside host facility, and as oil and gas fiber optic deployments have matured and become increasingly accepted as the principal medium for data transmission, the undersea telecom industry has proposed the development of new tools which would enable even more efficient and effective uses of the two primary resources undersea networks bring to the seafloor: data and power.

Product concepts such as OADM branching units with power converters, could deliver clean, isolated power from a trunk cable into a branch cable for consumption by both undersea telecom equipment, such as repeaters, and end-user devices such as scientific sensors and monitoring equipment. Combined with standard undersea cable and Power Feed Equipment on shore such a branching unit could transform an undersea trunk-and-branch backbone into a land-based, undersea power infrastructure. These systems tend to be regional with low power requirements (5kV at 1 Amp), although most undersea telecom networks are qualified to handle higher levels of power (either through high voltage or high current). The power is usually delivered to the undersea network itself with significant unused capacity. This type of branching unit would enable sensors and other non-telecom related devices to utilize the excess capacity increasing the overall efficiency and effectiveness of the network.

With other new telecom products such as TE SubCom SL Dual Conductor Cable the total amount of power available for subsea consumption can effectively double. By adding a second power conductor that is not powering the backbone, more power can be delivered to the sea floor for sensing applications from additional land-based PFE[11].

While a branching unit with power feeding capability could facilitate the delivery of clean and isolated power into a branch cable, a complementary product is then needed to groom the branch power and provide data to scientific sensors and other non-telecom related devices. Undersea distribution hubs could provide groomed power and data to sensors and other devices via industry standard WMCs. Containing marinized telecom transceivers, switches, and routers, the hub would be able to provide direct access to the undersea network without the need for a host platform or topside installation (Figure 4).

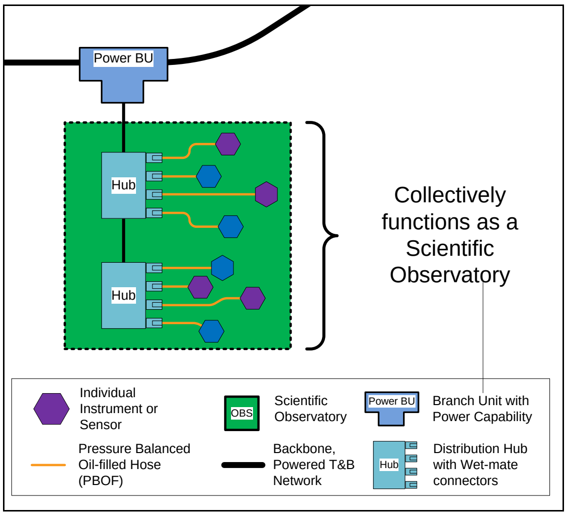

Figure 4: Hubs forming Observatory

Supporting a wide array of standardized and reconfigurable communication protocols, such as Gigabit Ethernet, RS-232, RS-422, etc., this type of node would host a large number of subsea applications for the scientific and offshore industries. In addition to the range of communication protocols, the physical arrangement of the hub's wet-mate connectors would be electric, optic, or hybrid electro-optic. This allows almost any piece of subsea equipment to interface with the node, long-term or short-term.

The ability to deliver ample power and high-speed communication directly to the sea floor would greatly improve the way data is gathered, processed, and analyzed. Sensing arrays, monitoring systems, and other devices could realize true autonomy by enabling real-time decision making and prompt responses. All of this may be accomplished without the need for topside installations and host platforms in turn enabling wider-scale scientific deployment in areas of interest previously overlooked due to lack of topside infrastructure or oil and gas investment potential (Figure 5).

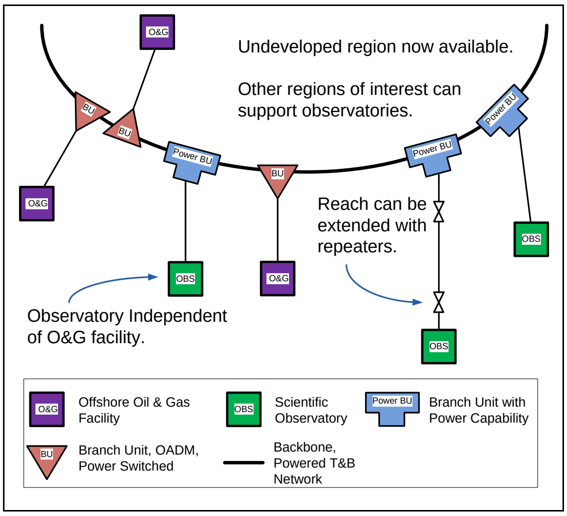

Figure 5: Observatories with Independent Access to Network

The primary advantage of a hybrid, co-use network equipped with advanced branching units and distribution hub technology is that a scientific observatory or oil and gas data collection system could be added-on or cut-in to a modern, existing undersea network via standardized marine installation techniques already in use by the industry. An observatory, independent of any oil and gas facility, could be added anywhere along the backbone that is of interest to the scientific user. The protocols for assuring quality, accessing and archiving data generated in ocean observatories require consideration among the users. Balancing the rightful proprietary restrictions of the operator with those of the science community can be addressed through the appropriate partitioning of data.

5. MARINE OPERATIONS AND EXISTING TOOLS FOR MAINTENANCE AND INSTALLATION

These non-carrier networks and observatories can be installed and maintained with existing marine undersea cable installation and repair vessels, ROVs, and positioning technology. On the majority of cabled scientific systems, the submarine cable industry, node manufacturers, and science community have worked well together integrating their technologies to create an installable scientific package, allowing the marine installer to utilize existing tooling and vessels to successfully integrate, deploy, and test the system.

Tailing the hub or science node with standard submarine cable enables the node to be integrated through the use of existing splicing and jointing techniques that are standardized in the industry utilized by all submarine cable installers.

With standard submarine cable, existing shipboard machinery is capable of deploying the system. The cable tanks, cable drums, linear cable engines (LCEs), stern sheaves, and cable raceways of a cable lay vessel, such as the TE SubCom Reliance-class (Figure 6), meet the bend diameter and other stowage requirements of the cable manufacturer with no additional equipment required for cable handling.

Figure 6: TE SubCom's Reliance Class Cableship

Operations to overboard the node, and lower it to the seabed, depend on the design of the node and the number of cable legs. Purpose-built cable ships have an A-frame and/or cranes, along with capstans and other rigging points, required for moving and placing the node into the water. Nodes should be lowered to the seabed on the submarine cable or utilizing a bridle. If a bridle is used, the cable lay vessel will require multiple cable engines, preferably bow drums and a stern LCE, to control the submarine cable tails and lowering bridle. All three engines may be needed to move, overboard, and lower science nodes. The engines may also be used to deploy the science packages to the seabed that will be connected to the nodes

All of the tools utilized for cable protection for a commercial cable system are also applicable to scientific systems. For most of a cable lay, a cable plow may be used to bury and protect the submarine cable, needing to be recovered in the vicinity of the nodes. A cable trenching ROV may attempt burial in and around the nodes, perform inspection, and conduct burial operations in remedial areas.

There are similar equipment requirements for overall system maintenance and repair. Equipment used for cable handling and bight deployment during a standard cable repair would also be used for node recovery and replacement. Equivalent splicing materials and tools are used to integrate repair cable and new nodes. The ROV may be used to de-mate science packages prior to node recovery, and to perform burial of repair cable.

Note that scientific sensors, secondary nodes and other smaller appurtenances can be installed and maintained by oceanographic research and other smaller, low cost vessels with dynamic positioning capability, providing enhanced Operation and Maintenance (O&M) flexibility for the ocean observing elements of oil and gas networks.

Operators can share a common structure or service for O&M on the backbone. Wavelength management can allow for partitioning of separate element and network management systems. Common elements are backbone maintenance, trunk powering, repeater and BU supervision, and shore terminal equipment. Partitioned elements include individual wavelengths, branch components, data communication networks (DCNs) and offshore terminal equipment.

6. CONCLUSION

Ocean observatories generate large amounts of data. The bandwidth available in fiber optic cable systems is sufficient to handle this demand, in real time, making such systems in oil and gas applications the ideal medium. Proposed advancements in undersea communications technology that enable persistent measurements coupled with the potential availability of offshore production infrastructure, with their multi-decadal life cycles, present unique opportunities to support long term ocean observations.

The undersea telecom industry has combined common undersea telecom elements that have been used for decades (undersea cable, branching units, EDFA repeaters) with those of the oil and gas industry (wet-mateable connectors, fiber distribution canisters, deployment pallets) enabling the establishment of scientific observatories hosted by on-shore or offshore/topside platform facilities. New products can bring power and data to observatories via these non-carrier networks that can eliminate observatory infrastructure dependence on the offshore/topside facilities.

The integration of sensor networks, demonstrated in the science community, with the high bandwidth fiber optic communications networks that service offshore oil and gas platforms provides an opportunity to significantly expand our understanding of the ocean.

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