PERSPECTIVES OF AN OIL & GAS SUBMARINE CABLE SYSTEM OWNER: ISSUES, ANECDOTES AND FUTURE TECHNOLOGY REQUIREMENTS IN A CHANGING OFFSHORE ENVIRONMENT

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Abstract: The BP Gulf of Mexico Fiber (GoM Fiber) submarine cable system has been successfully operating and enabling a change in oil & gas operational ways for a decade and offshore platforms continue to connect. Owing to its groundbreaking use of optical add drop multiplexing (OADM) technology, GoM Fiber has provided assets with highly reliable, world class connectivity with no downtime. Enhanced operational knowledge has created new opportunities. Operations and project experience has developed a better and reinforced understanding of just how notably different submarine fiber systems in the oil & gas market are from those in the telecommunications sector. Areas such as customer base, partnerships, core business goals, locations, maintenance, system constraints, marketability, project methodologies and much more put a notable twist on this commodity item that oil & gas companies are still working to incorporate into strategic plans and thinking. With a new era of digitization, the utility of submarine fiber systems will continue to grow in the oil & gas market as the connectivity they provide is extended out to mobile devices and the Internet of Things (IOT). As we move into this next decade, the growing experience will enhance the ability to integrate the telecommunications and oil & gas submarine fiber markets, providing win-win results. This paper will discuss the future needs and wants from an oil & gas company perspective of future submarine cables to offshore infrastructure, and possible areas of industry-to-industry collaboration.

1. GOM FIBER GOES LIVE AND CONTINUES TO OPERATE

In 2008, BP finished construction and commissioning of GoM Fiber. This was the oil & gas industries first use of a dedicated submarine fiber cable system with active subsea repeaters and OADM branching units. This system provided unprecedented telecommunication capacity and reliability to BP operated oil & gas production facilities in the GoM. Initially, the system provided dedicated 10 Gbps wavelength connectivity to seven BP assets and replaced low capacity and high latency satellite links. Changes in performance were realized over night as each platform was "lit," and these impacts were seen analytically and more importantly through enthusiastic end user feedback from multiple parties in 2008. GoM Fiber is considered to be a world class system and used as a reference model by multiple projects (W. Nielsen, personal communications, February 2018).

Since the original build, GoM Fiber has more than doubled in size with sixteen connected platforms across four operators and there is another platform connection scheduled for 2020. Furthermore, spare system capacity is being used to support a GoM wide LTE network. The growth in connections has been accompanied by the following highlights:

- Addition of nine platforms with no impact or outages to existing platforms.
- Successful "cut-in" of two additional branching units without outage.

- Branch legs of 150 kilometers which is beyond GoM Fiber design basis [1].
- Use of 100 Gbps transponders.

The unique capabilities of GoM Fiber is led through the use of subsea repeaters and OADM multiplexors as compared to a passive system using platform to platform amplification and several fiber strands. This design brings the following benefits:

- Platform independence – the impact of an outage on one platform is isolated to that platform.
- Power management – isolate cable power to allow cable work without interruption.
- Dual landing backbone – system has proven it can take a single fiber backbone cut and continue.
- Fault location detection – active components assist in identifying location of cable faults.
- Wavelength management – one or more wavelengths can be assigned to a specific platform.
- Extended range – use of repeaters allow backbone and spurs to be extended in GoM.

As a result of this high capacity, low latency and resilient design, the GoM Fiber backbone has realized 100% uptime during more than a decade of operation. Due to the fault tolerant design, this uptime continued during a 2008 cable cut during Hurricane Ike caused by a drilling rig anchor in deep water. The cut was repaired, and full resiliency was restored without loss of connectivity to any platform.

From a capacity perspective, GoM Fiber has nearly "unlimited" capacity compared to reasonable estimates on demand. This abundance of capacity was an investment design decision and is apparent at multiple levels including supporting at least forty platform connections and per wavelength capacity which was initially 10 Gbps and is 100 Gbps for more recent connections.

The capacity when partnered with extreme reliability and terrestrial latency generates a growing list of opportunities and desires to extend the capacity to new devices and use cases including immersive wireless connectivity. It also assists in highlighting the challenges of submarine fiber in oil & gas fields.

After more than a decade of GoM Fiber and similar projects in other regions, there are numerous lessons learned, concepts developed and thoughts for the future of submarine fiber which will be discussed within this paper. Some of these topics include:

- Where submarine fiber sits in the oil & gas connectivity strategy.
- Efficient extension of fiber capacity to point of consumption.
- Critical design decisions.
- Evaluating feasibility of different ownership models.
- Wet plant cable maintenance.
- Dry plant lifecycle management.

2. ROLE OF FIBER IN OFFSHORE OIL & GAS

Without a doubt submarine fiber optic connectivity is critical to oil & gas operations due to its inherent high capacity, low latency and high reliability which allows applications and digital tools to work as expected. In looking at the benefits, while many quickly focus on the capacity of fiber, the highest value benefits can be attributed to the low latency and ultra-high reliability. Evaluation of metrics shows per platform typical utilization is several hundred Mbps even though there is 10-100 Gbps available. This level shows the value of the capacity as satellite is less than 100 Mbps but also helps to draw realism to capacity planning and needs. This is an important note that will be referenced later.

Many have asked why the utilization appears to be low. This is probably most attributable to difference in use cases. Whereas in the telecommunications industry, fiber systems support large data center to data center traffic and aggregate the traffic for tens of millions of users, in oil & gas, at best, they aggregate the demands of a few thousand users. Taking this user ratio into account with the low duty cycle related to the application use cases, it is easy to see why current utilization is low. One can expect this to use to expand as collaboration and surveillance applications are deployed to support modernization. However, this growth will be limited and in bursts.

What cannot be overstated is the incredible value related to latency and reliability of fiber that provides application the real-time performance and daily confidence that allow organizations to embed new processes and tools into their operations. Simply put, many applications do not operate well and create user frustration over satellite latencies of nearly 600 ms. Also, users resist tools that don't function every day.

Now that the latency and reliability are fully appreciated, the desire to access the capacity easily has become the focus area. There is the need to extend fiber from the indoor areas wired for a few devices to providing coverage across all areas of the asset and beyond the asset (e.g., in field) to support new collaboration tools, wearable devices, wireless instrumentation, procedures, documentation, autonomous vehicles, robots, controls, work vessels and drilling rigs. This means that connectivity no longer stops at the transmission gear or wiring closet and instead must reach across the basin or operating regions using lower cost, effective, secure and efficiently deployable technologies such as WiFi and LTE. These wireless technologies can reach out to hundreds if not thousands of devices of all types some of which aren't even known today.

There have been multiple discussions along the lines of whether or not 4G or 5G technologies could be used instead of fiber to provide adequate capacity to offshore environments. The analysis demonstrates that the fiber provides the backhaul from the wireless base stations to get the traffic to shore as wireless range is limited to tens of kilometers. Offshore platforms can be hundreds of kilometers offshore. Thus, wireless technologies are very dependent upon fiber or similar transport for their success.

Also, there has been growing conversation and research around high-altitude platforms and medium and low earth orbit satellite as alternatives which might provide eighty fiber percent of the value fiber without the intensive capital costs. With the exception of medium earth orbit satellite, these alternatives are still in their early stages. The commercial, technical and regulatory viability have yet to be proven. Medium earth orbit satellite is proving itself, however, there are concerns over near-term and long-term spectrum availability in operating regions. Furthermore, satellite systems are subject to weather performance and reliability impacts not realized by fiber. Medium earth orbit has a clear long-term position as a:

- Backup to catastrophic loss of fiber.
- Early field connectivity solution.
- Temporary or short-term solution.

Geostationary satellite solution use cases are limited by their limited bandwidth and high latency. However, they do provide coverage in areas not available to medium earth orbit.

This preceding analysis provides insight into oil & gas strategies for connectivity and the need to think about connectivity in a holistic basis and not purely as a technology choice. This confirms the long-term need for fiber. In addition, it validates that finding ways to deploy fiber and access its capacity efficiently and cost effectively is critical to long term adoption and benefits realization by oil & gas.

3. EXTENDING FIBER CAPACITY

An effective oil & gas connectivity strategy incorporates long distance transport, device access and a network control layer (e.g., MPLS, IP Routing, SD-WAN, SDN, SD-Access, Security). The network control layer integrates transport and access, provides security, manages traffic and authorizes access for all types of needs from enterprise, process control, internet and third party. A focus on just one of these three areas (e.g., transport alone) will lead to less than efficient return and enablement for an oil & gas company. Whereas, a complete solution removes the challenges around connectivity and lets the company focus on the exploration and production of hydrocarbon in safe and efficient ways.

Multiple application deployments have been delayed, denied or at a minimum sub optimally deployed because the underlying transport is not adequate. In other situations, network control layer design prevents traffic from taking most optimal route and can cause performance issues resulting from hairpin routing over satellite links. These types of issues often leads to local server deployment, data management issues and non-standard solutions.

Realizing that connectivity requires quality transport throughout the basin, supports the need to find ways to make the deployment of fiber optic systems more efficient and cost effective. The current challenges commonly seen in this area include:

- Mobilization of cable ships can be 25-50% of the project cost for a 50km or smaller branch leg.
- Resistance to using vessels of opportunity.
- Oil & gas industry is not use to working with telecommunications equipment, vessels and methods.
- Many projects are tiebacks lacking a surface presence where transmission equipment can be deployed.
- LTE and wireless technologies require locations for base stations with good elevation for coverage maximization.

The above challenges are currently worked on a project by project basis. Each project goes through an extended process including an ongoing learning cycle that draws on resources from industry and subsea cable vendors. Often, the final solution is to the detriment of a basin wide connectivity solution because of project constraints or limited understanding of the long-term impact. In some cases, this creates financial resistance to deploying fiber. At a minimum is causes an extended time to commit and deploy the technologies. In other cases, it may lead to not considering the bigger picture such as LTE plans. Newer and higher end projects (e.g., larger budgets) address some of this and can subsequently work though the process more expediently. This is especially when there is an existing infrastructure to use.

The submarine cable industry would be well served to jointly work with wireless companies and the oil & gas industry to systematically address these challenges. For example, some opportunities include:

- Developing seabed deployable transmission equipment that can service multiple platforms from a single wavelength.

- Formalizing a readily deployable vessel of opportunity solution for new branch legs and shorter runs.
- Developing methods to deploy LTE coverage to fill the basin gaps using buoys or other methods.
- Working with oil & gas engineering firms to demonstrate and mutually develop acceptance of the technology.

Accessing solutions to these challenges will promote oil & gas companies to address connectivity needs in a more holistic way versus piecemeal. As discussed previously, this is critical to meet the long-term needs for digitizing and modernizing field operations.

4. CRITICAL DESIGN DECISIONS

As the submarine cable industry works with the oil & gas industry to improve acceptance and develop region or project solutions, discussions will occur around the optimal design for the oil & gas regions. Such designs need to balance:

- Survivability – minimizing the impact of system failures and cable cuts including use of alternate backup technologies.
- Risk reduction – reducing the potential of outages due to local and technology issues.
- Growth allowance – providing a core system capable of handling unknown growth in the basin.
- Accessibility – enabling interfacing to other technologies.
- Capacity management options – how best to manage capacity demands.
- Location of infrastructure – access to terrestrial services and operational resources.
- Capital costs – getting the right balance between technology and business value.

Of course, all of these have to be addressed within a reasonable cost basis. There have been projects in the industry which have ignored cost basis during technical development which has resulted in shelving projects after more than a year of work.

In looking at existing and proposed systems in different regions, one thing has become apparent in that where a basin wide approach or vision was initially adopted, the longer-term ability to evolve a system to maintain high performance and high reliability was simplified. Where each project "did their own thing," one can quickly see where project optimizations begin to challenge the system especially from a reliability perspective such as creating common points of failure (e.g., what's the lowest cost way to install a new branch leg) and thereby requiring additional connectivity such as microwave or low performance satellite. By developing a basin approach at the front end, different what-if evaluations can take place. In addition, this analysis can consider commercial options such as how does one integrate with LTE providers to extend the fiber capacity and thereby increase the benefit or return on investment analysis.

In looking at systems, there are a few fundamental requirements that continue to prevail:

- Redundant landing stations - positioned so that a single event can't impact both.
- Asset independence – minimize risk an asset or branch leg outage impacts others.
- Traffic segregation methods – define how traffic will be separated for different entities.
- Standard equipment – minimize sparing and ensure long term technical access.

- Life of assets – absolute minimum of 25 years to accommodate operational life of assets and reduce future investment.
- No common failure point – single backbone failures should not impact assets.
- Umbilical cables with fiber and wet mate connectors – minimize engineering, clashing, weight and installation of new risers.
- Reliable off shore power – ensure fiber branches continue to operate during all conditions.

Most of these fundamental requirements are easily implemented with the use of active systems with repeaters. Passive systems should be limited to the smallest of basins. Doing a proper concept design and an enhanced desktop study to look at these requirements in order to optimize and develop a solid basin vision is essential to the long-term viability of the project. Yes, variations will occur over time, but a good vision allows one to address the un-expected more readily and successfully.

5. COMMERCIAL MODEL

A key input into developing the vision is looking at the commercial and ownership model for the transport systems (e.g., fiber, LTE) within a basin. The commercial model will help to define the technical requirements and this input will need to be incorporated into the vision and design. Commercial models are a very complex topic to sort through as there are many significant factors. This means having qualified personnel that are able to understand and communicate with others using a vast set of experiences with respect to technology, cost, commercial, construction, legal, operational, local regulatory and other disciplines is critical to the success. These areas cannot be worked in isolation. These individuals will have to work with specialists from each of the disciplines and help to ensure a well thought out and integrated model is adopted.

From a commercial perspective, a handful of common situations have been seen repeatedly:

- Most regions don't have a large and diverse enough demand to generate a complete commercial service model thus leading to some sort of user owned or financed solution.
- Multi-tenant solutions require strong technical and vision alignment between the parties to enable a consortium-based ownership model to deliver in a timely and cost-effective manner.
- Telecommunication users are focused on a large bandwidth and cost of bandwidth unit whereas oil & gas manage to a connection-based model given reduced consumption leading to a conflict in cross industry collaboration.
- Long-term sustainability of the system is critical to oil & gas as they have multi-billion dollar investments dependent upon connectivity for decades of safe and efficient operations.

Creativity with proper risk mitigation is required in order to implement a commercial model that enables future migration to a service based or multi-tenant solution. In some situations, one or a couple of progressive oil & gas operators may partner to quickly build a system and then work to find ways to expand the user population through direct connections, network overlays (e.g., LTE), marketing partners and solutions for new industry partners (e.g., defense, ocean monitoring, cruise ship, fishing, recreational boaters). Bringing together the potential stakeholders is critical to developing and evolving this commercial model while ensuring the core purpose of providing connection for oil & gas operations is maintained.

The other aspect to this is how to combine the telecommunications or content industry with the oil & gas needs to build shared systems. This potential is growing as telecommunication cables for content owners is expanding, more regional work is built and oil & gas develops in new markets. Together, the industry players need to work together to find ways where the connection versus bandwidth needs are addressed. The oil & gas industry wants to access a piece of infrastructure or connection so as to minimize bandwidth management. This would mean telecommunication cables would need to ensure they have a way to tie in offshore assets (e.g., branching units) and wavelengths assigned for this purpose. This model provides value to oil & gas especially when done on international cables as it provides faster routes to cloud services and contents versus always landing in country and then rerouting over other international cables.

Work on developing successful commercial models will be an ongoing effort that will generate numerous ideas and evaluations. However, only a few will be feasible and viable for the parties. The ability to quickly discard non-viable concepts is important to allow for focus on valid options. Continued work in this area and in consideration of basin wide communications is critical to the long terms success and evolution of submarine fiber systems in oil & gas.

6. WET PLANT MAINTENANCE

Once systems are built, maintaining the wet plant is important. Fortunately, the rate of wet plant cable damage is occurring at a slower rate than planned (e.g., multiple years between cable cuts). This is good for multiple reasons including reliability, trust in system, cost of operations and technical assurance.

This creates a challenge on finding an effective solution that can be rapidly deployed in the event of a cable failure. Early solutions included participating in cable maintenance consortiums. However, this has been challenging to ensure compliance with oil & gas standard such as vessel ratings, crew characteristics, regulatory (e.g., Jones Act) and retainer costs. In addition, there has been confusion and questions around standard cable versus non-standard cable installations such as how to deal with pipeline crossings, shore ends, branch legs, fiber distribution canisters and riser cables. For example, making sure access to the different vessel types needed based on work required and access to the wet plant spares in region needs to be addressed.

Developing qualified solutions for wet plant maintenance is needed including alternatives to standard solutions is needed. One example is to develop a workable approach to using oil & gas work vessels as vessels of opportunity for repairs and small jobs. This is an area of research where more definitive guidance and approaches needs to be produced.

7. DRY PLANT MAINTENANCE

The onshore cable landing stations require significant ongoing multi-discipline maintenance activities. For a submarine cable, they are the lifeline of the system as they provide the power and the onshore termination. Without them being reliable, the system uptime will not be maintained. The landing station’s electrical and HVAC systems are a stress point in as much they are subjected to the local environment conditions (e.g., salt laden humid air) and growth in equipment all of which leads to degraded performance while exacerbated by increasing requirements.

The growth in equipment has originated from incorporation of additional parties and the cable landing stations becoming a connectivity services hub providing hosting for voice gateways, network inter-connects, controllers for offshore wireless (e.g., EPC). In addition, the landing stations are subject to weather and environmental conditions making them subject to degradation and inducing issues such as building leaks and corrosion of outdoor systems (e.g., generators and HVAC units). Maintaining a strong landing station inspection, maintenance and lifecycle refresh program may be the most critical activity in running an oil & gas fiber system. This will have the largest impact on the system reliability. Having personnel cable of doing “facilities management” versus having only IT skills is the foundation of cable landing station maintenance program.

8. CONCLUSION

The oil & gas industry’s dependency on reliable connectivity as provided by submarine fiber systems continues to expand as oil & gas fields modernize their operations. Unlike the telecommunication industry, connectivity is between thousands of devices and with globally distributed servers as compared to between large data centers and millions of users which drives a connection-based approach. Therefore, to meet the near and long-term use cases, a basin wide approach incorporating fiber and wireless technologies is needed that can facilitate connectivity to an expanding set of use cases and devices. This means a more holistic approach to financing, developing, constructing and supporting submarine oil & gas fiber systems is necessary. This starts with having a long-term vision of where the basin system may go and developing a technology plan, operations & maintenance plan and commercial approach that can provide immediate results and adapt as results are realized over time. GoM Fiber provides an excellent case study which can be referenced along with other projects when developing projects in other regions to understand the nuances and impact of local conditions. These learnings and comparisons can be used to inform to create long term sustainable success. GoM Fiber and similar projects in other regions confirms such projects are possible and will bring benefit to the oil & gas industry. The submarine cable companies, telecommunication providers and oil & gas industry need to work together and with other parties to continue to develop this potential.

9. REFERENCES

[1] S. Stanley, A. Carpinteyro, R. Rogers, “Upgrades to Oil & Gas Fiber Optic Network; 2018 Marine Campaign”, Suboptic 2019