Recovering and Re-laying Cables for Building New Subsea Systems

Redeployment projects can offer cost and time savings vs. the new build approach for specific applications. Xtera has unique experience and expertise to assess the viability of such projects and flawlessly execute them.

Why Cable Re-lay?

Below the water, laid on the sea floor, numerous high-capacity submarine cables connect countries and continents. Today, optical subsea cable systems carry more than 95% of the world's international voice and data traffic. This figure clearly shows that very little international traffic is carried by satellite, which is still a popular misconception.

With the prevalence of submarine cable systems in international communications, two trends can be observed in the development of the subsea long-haul transmission infrastructure worldwide.

Trend # 1: Increasing Capacity on Existing Routes

Fueled by video and cloud services, there is an insatiable quest for higher bandwidth in optical backbone networks. Thus, there is a need to increase the capacity transported by the busiest existing routes (e.g. transatlantic, transpacific, South East Asia to Europe). This capacity increase can be achieved by either building new subsea cable systems or upgrading existing ones (the upgrade option consists of moving to more advanced transmission technologies, e.g. 100G channels, at the terminal equipment level in the cable landing stations, leaving the submerged plant untouched [1]).

Trend # 2: Building New Subsea Routes

One of the biggest challenges facing the global submarine optical network is that many parts of the world are still vulnerable to disruptions in service due to lack of redundancy. There is therefore the need to open new routes in order to bring physical diversity to existing routes to increase the global resiliency of international connections in the event of natural disasters, such as mudslides and earthquakes.

Another driver also leads to the building of new submarine routes. Small island countries and other small communities are faced with the issue of infrastructure development to provide their inhabitants and businesses with reasonable communications services. As vital as water and power infrastructures, communications today play a crucial role not only in such obvious fields as emergency, health and other social services, administration and commerce, but also in stimulating economic growth, increasing the flow of trade and information and enhancing quality of life. Lack of access to international connectivity and high-speed information prevents small communities from staying current with progress and advancing globalization.

More generally speaking, it is widely recognized that growth of GDP is strongly linked to access to broadband communications. One study demonstrated that an increase in broadband speed has increased household income from 2.2% to 4.7% [2]. In addition to increasing income, broadband penetration has a direct correlation to a reduction in unemployment. An ITU study highlights a specific example in the Dominican Republic where a 1% increase in broadband penetration results in a 0.29% reduction in unemployment [3].

Price and capacity wise, satellite communications are not in a position to meet these connectivity needs. The last bastions of satellite dependency, including the land-locked countries in Africa and islands across the Pacific and Caribbean, are each now finding that their economic development needs are often better served by fiber than satellite, and new fiber connectivity is being built to connect many of these places to the global network. Switching from satellite to optical infrastructure is the way to increase the capacity, enhance the availability and reduce the latency of the network, improving both quality and stability of service.

So we have seen more and more projects in the recent years aiming at offering optical connectivity to small, remote islands. One example of this is the future subsea cable system between Guam and Palau, an island located in the western Pacific Ocean and populated by about 20,000 inhabitants.

Here Comes Cable Redeployment

In essence, the new subsea cable systems developed to offer small communities connectivity to the rest of the world do not require huge capacity but need to offer a low price point in order to make the business case viable (keeping in mind the intrinsic small number of residential and business customers).

Xtera, which has implemented multiple cable redeployment projects, is the market pioneer in this market segment.

Two options are available: (i) building a new subsea cable system, using new components carefully selected in order to minimize the required investment (e.g., 10G channel rate, small number of fiber pairs, and long repeater spacing to minimize the number of submerged repeaters, as enabled by Raman amplification [4]), or (ii) recovering and redeploying a subsea cable system that has been decommissioned by its owners, most often because of the unfavorable ratio between capacity and operational expenses on highly competitive submarine routes.

Xtera, which has implemented multiple cable redeployment projects, is the market pioneer and innovator in this market segment. In Xtera's experience, connecting small communities or building regional low-capacity systems on new routes represents the applications where cable redeployments make sense. On cable system operators' side, cable relay is a concept that is more and more accepted [5].

Cable redeployments can result in cost-optimized submarine systems, especially for small/remote communities in which the business case does not support new cable at normal price. But, there are other considerations, both technical and commercial, to factor in on a per project basis in order to ensure that a cable re-lay is the right solution.

The Logic of Re-Using Existing Submarine Cables

Cable Lifetime

Submarine cables, including repeaters, are designed, specified and manufactured to offer a nominal life span of 25 years. Practically speaking, the lifetime of subsea cables can be much longer than what was originally thought [6] due to different causes:

- In order to meet the 25 year lifetime requirement and minimize the amount of underwater repairs to be made once the system is put in commercial service, submarine cable systems tend to be over-designed with margins higher than strictly required.
- Investigations on decommissioned and still in-service subsea cable systems show that materials used in cables have much longer life than what originally thought. These materials include, in addition to silica optical fibers, copper, stainless steel, polyethylene, polypropylene yarn and bitumen.

In a recently worked example, Xtera looked at an opportunity where the decommissioned cable had been in use for just short of 10 years. Taking the pessimistic n value of 3 [See papers by Davies et al., Southampton University] and the reliability being proportional to kV to power n, Xtera showed that if the cable was originally operating at 7kV and subsequent to that at 3kV in a shorter system then the cable had in excess of 600 years left at these voltages.

Practically speaking, subsea cable lifetime can be much longer than 25 years.

For the balance of the wet plant, and in particular the repeaters, the arguments are a little more tortuous but equally tractable. The major factor here is that there are several elements that allow the status and expected lifetime of a cable to be assessed. These elements are: very few active optical elements in a repeater (in fact, only the semiconductor lasers), a well-documented fault history and, in general, access to the repeaters to indicate how well these were performing prior to decommissioning.

Taking the same system and knowing that the wear-out mechanism for lasers follows a lognormal distribution, the total laser (and associated electronics) failure rate increases from 85 FITs at 25 years to 128 FITs in a further 25 years. Xtera was able to show that this corresponded to 0.65 ship repairs over the next 25 years. As this rounds up to 1 then this is no different to a new build equivalent for the same link.

This is not always the case but generally holds if the following is true:

- A long system is subsequently cut into several shorter pieces prior to reuse;
- The fault history of this type of system is known (which can be then analyzed both specifically and generally);
- Satisfactory records of the system performance are available to the purchaser.

Armed with this, experts such as Xtera can then calculate the cost risk benefit of a redeployed link.

A further level of comfort can be gained from the understanding that, in general, most ageing occurs in the early life of a system. This means that, several years after commissioning, the subsea cable operators have a pretty good idea of the "physical shape" of their wet asset: either multiple, regular failures happened and a pattern can be deducted to predict degradation in the midterm, or no degradation happened after 1 or 2 years of commercial service and there is a high level of confidence that the subsea cable was properly designed, manufactured and installed, and that it will retain good characteristics and performances for the future.

Of course, there is an alternative scenario when there is some doubt. The solution is to reuse the cable and replace the repeaters, and this too has been shown to be cost effective

Consequently, except for the subsea cable systems that are known to exhibit design issues or experience problems due to improper installation on the sea bed, the chance is high that a submarine cable can be recovered to be re-used in another deployment.

Maintenance Cost

The maintenance cost of a submarine cable systems scales with distance, not capacity. The mobilization/demobilization fees and the daily rate of maintenance cable ships are totally uncorrelated to the capacity transported by the system. Instead, the maintenance cost is mainly governed by the location of the failures, the sea conditions, the water depth and the way the cable was installed on the sea bed (surface laid or buried).

Maintenance cost can make some subsea cable systems uneconomical on trunk routes compared to newer ones, i.e. thicker pipes offering higher capacity thanks to more recent optical transmission technologies. Such an unfavorable maintenance cost / capacity ratio can occur after time spans as short as 10 years. An even shorter period of time was observed with the Gemini transatlantic cable system that was designed and manufactured just before the advent of more powerful optical transmission technologies. As a result, the Gemini cable became quickly obsolete and was phased out only 6 years after its commissioning in 1998.

Cables that are out-of-date from a technical performance perspective on demanding subsea routes can be re-used as thin pipes on other routes.

Such cables, which are out-of-date from a technical performance perspective on demanding subsea routes, are still useable as thin pipes for applications where connectivity matters more than capacity or for regional systems. In the latter case, these cables are re-deployed on a shorter distance than per original design; this will typically increase the capacity because of the better Optical Signal-to-Noise Ratio (OSNR) performance, due to a smaller count of cascaded repeaters (leading to smaller accumulated optical noise) and a wider system optical bandwidth (fewer repeaters result into reduced optical gain self-filtering).

Benefits from Cable Redeployment

The cable redeployment approach can offer multiple potential benefits to both system suppliers and network operators. These benefits include lower project cost, shorter lead time and greener sourcing.

Lower Project Cost

The typical cost structure of a new regional submarine cable system is depicted in Figure 1.

The largest portions are cable, repeaters, transfer to the deployment location, and marine operations. These portions also represent the biggest opportunities for cost savings.

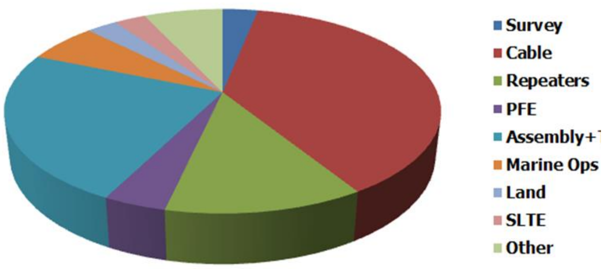

Figure 1: Typical cost structure of a new regional cable system.

Lowering the global project cost for new subsea system deployments has been the dominant motivation for recovering and re-laying existing cables.

The cable re-lay approach can lead to significantly lower system price compared to new builds.

On the one hand, cost is saved on the cable (and repeaters if they are recovered and re-used as well). On the other hand, some extra marine operations are required for this wet plant recovery. The extra marine operations cost is primarily driven by level of difficulty required to recover the cable from the sea bed, and is dependent on the original installation (surface laid or buried). Also, some armored end cables may need to be sourced for shore ends and shallow waters (see below).

But in the end, and when the transportation costs of new cable from the few cable factories dotted around the world are factored in, the cable re-lay approach can lead to significantly lower system prices compared to new builds as represented in Figure 2.

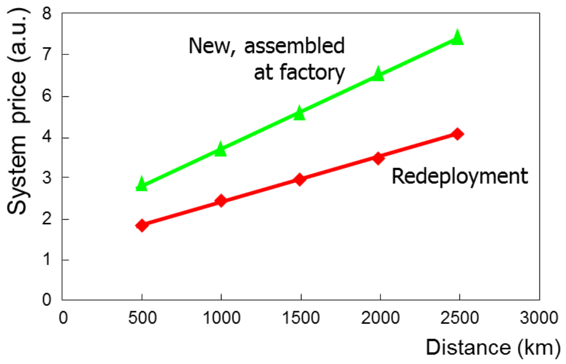

Figure 2: Comparison of system price as a function of system length between new build and redeployment approaches.

The price comparison in Figure 2 is between a new cable system and the redeployment of a two fiber pair system. The price comparison also assumes a system in deep water with little burial, but some new cable purchased for the shore ends.

One factor impacting the price comparison is the cost associated with the transport of the recovered cable from the recovery location to the redeployment location. This transport cost is governed by the distance between both locations and also by the transport mean (cable ship or freighter). Figure 2 assumes a short distance between recovery and redeployment locations.

The cost comparison between the redeployed or new cable options shall be carried out on a per project basis, and requires a good level of expertise in order to correctly identity, quantify and optimize all the factors impacting the project cost.

Shorter Lead Time

Another key benefit from the cable re-lay approach is the shorter lead time for project execution compared to new builds based on new cable.

Shorter lead time stems mainly from two factors:

- **Cable Sourcing –** Manufacturing a long optical submarine cable can take several months (a typical figure is 9 months). On the other hand, if carefully planned with respect to sea conditions and cable ship availability, recovering an existing cable will require quite less time. In general, Xtera would target the recovered cable to be in the region of the redeployed cable so we may be talking about a 3-4 month lag prior to redeployment and of course the 9 month figure may be wildly optimistic if the diminishing number of cable factories are busy, as is the case at the time of writing.
- **Cable Permitting –** A significant amount of time can be saved if the cable landing can be reused as well. This is the case if the cable to be recovered originally connected Points A and B, and is to be redeployed to connect Point A to a new Point C. The landing in Point A can then be re-used: this will not only avoid having to go through lengthy and uncertain permitting processes but will also avoid the need to recover the armored cable in shallow water (likely to be buried).

Greener Approach

Manufacturing a new cable requires energy and multiple materials, some of them being scarce or costly to produce. On the other hand, recovering an existing cable requires minimal energy (namely cable ship fuel).

A global comparative study about the potential environmental impacts of submarine cable systems has shown, however, that the recovery and re-lay of an existing submarine cable correspond to about 5% of the environmental impacts caused by the manufacturing and deployment of a new cable [7].

The recovery and re-lay of an existing cable correspond to about 5% of the environmental impacts caused by new build.

From an environmental impact perspective, it is worth noting that the re-used cables are often picked up from the deepest portion of the ocean, where the cable is not buried but simply surface laid. In those circumstances where shallow-water, buried cable is recovered, it is not done in environmentally sensitive areas where there are species to protect such as coral reefs or sea grass.

Cable Considerations

In order to make a redeployment project viable from both economic and technical perspectives, there is more to consider than simply the physical status and obsolescence of the cable that is candidate for recovery and redeployment.

Where Is the Cable Coming From?

Cable redeployment is an appropriate approach if the cable is recovered from a less or similarly benign seabed than the destination seabed.

Because recovery of extensively well buried armored cable can be a slow and risky process, the re-deployment cable solution works best for a destination that needs minimal amount of armored cable and maximal quantity of deep water cable.

When the existing cable is simply surface laid, cable recovery is fast and is very unlikely to degrade its mechanical characteristics.

Additional Technical Challenges

Optical Line Design

Backed by the experience and expertise of both upgrades and new builds, Xtera has the competences and the skills to optimize the optical line design for new subsea cable systems based on recovered cables. For this purpose, Xtera developed circulating loop and straight-line test beds with the capability to use different types of line fibers and different generations of repeaters (from Gen 1 to Gen 3). These powerful test beds, coupled with accurate optical transmission modeling tools, enable Xtera to replicate the new subsea cable system and maximize its performances.

Cable Recovery

The cable recovery process has to be well controlled in order to avoid applying on the cable and repeaters mechanical tensions exceeding the upper specified limits. Here, the challenge is to maximize the cable recovery yield, i.e. the amount of the existing wet plant that can be effectively re-used. Ideally, this work should be continually monitored by 3rd party experts and from a recognized platform.

Landings

Where possible, existing landing should be re-used in order to avoid cost of permits, lead time to obtain them, and all the installation activities needed for the landing itself. Armored cable is required for shore ends and shallow water. In general, this will be a new build (see arguments above). This is of course harder to get in the timescale but less is required than for a new build!

Power Feed Equipment

If working Power Feed Equipment (PFE) is available on the decommissioned cable, this equipment may be re-useable for the new project. Redeployment and re-commissioning of old generation PFE will require special skills due to safety considerations and Xtera has access to know how in this area of expertise.

Line Monitoring

If repeaters are part of the recovered cable to be redeployed, they must be monitored in the new system. The line monitoring equipment generates and detects the test signals appropriate to the system and can be used to detect any significant changes, thus locating the fault to within one repeater section. There are essentially two types (passive or active) of monitoring scheme that have been used by the subsea cable system industry and Xtera has deployed both types on a number of systems.

Project Management

Management of a redeployment project is quite different from a new cable project as many more boundary conditions need to be taken into account. As one does not start from scratch, with brand new, clearly specified wet components, cable redeployment project are typically more challenging projects to execute.

Xtera's Experience

Starting in as early as 2007, Xtera has been developing for the past several years its expertise and gained an unrivalled experience in cable recovery and re-lay projects.

Gemini-Based Projects

Gemini system was a two-leg transatlantic cable system that was phased out only 6 years after its commissioning in 1998 due to its obsolete terminal transmission technology. Pieces of the decommissioned Gemini cable were recovered and redeployed for the three re-lay projects depicted in Figures 3 to 5.

The Gemini Bermuda network is a 1,572 km submarine cable system between Manasquan (New Jersey, USA) and Bermuda, and is shown in Figure 3.

Figure 3: Gemini Bermuda redeployment project based on decommissioned Gemini cable.

The Caribbean Bermuda US (CBUS) submarine cable system is a 1,692 km subsea route between Bermuda and Tortola, as depicted in Figure 4.

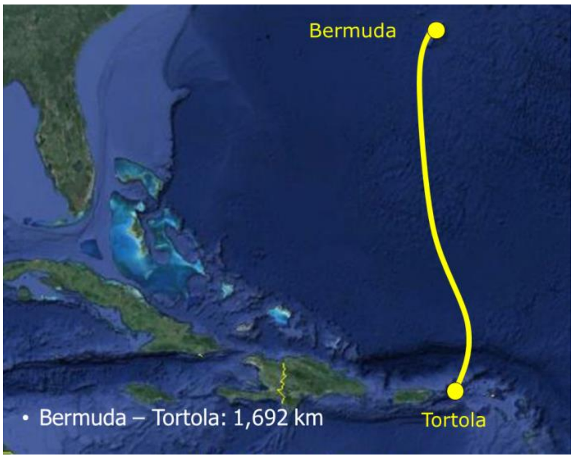

Figure 4: Caribbean Bermuda US (CBUS) redeployment project based on decommissioned Gemini cable.

The most recent cable system built with recovered pieces of Gemini system is the East West Cable system installed in 2011. This 1,745 km network connects Jamaica, the British Virgin Islands and the Dominican Republic, as represented in Figure 5.

Figure 5: East West Cable redeployment project based on decommissioned Gemini cable.

Xtera's scope of work for these projects includes the following responsibilities:

- Line design and cable re-engineering support
- Equipment and training for shipboard testing of repeaters and cable during re-assembly
- Supply of submarine line terminal equipment
- Installation of new power feed equipment
- Project management

HUGO Project

The upgrade of the wet plant to the HUGO cable system represents another type of cable recovery and re-lay project. Xtera deployed in May 2015 its next generation repeater into the High capacity, Undersea Guernsey Optical-fiber (HUGO) subsea cable system connecting Porthcurno (UK), Guernsey (UK) and Lannion (France). The submarine cable was recovered at the specific locations where the repeaters were inserted before being put back to the water. The marine operations required for the insertion of the repeaters were similar to those carried out for a simple cable repair.

The repeater insertion into the HUGO submarine cable system was made possible by the existence of a copper-based power conductor inside this subsea cable, which is a redeployment of parts of the 2005 decommissioned repeatered Gemini cable system. HUGO is made of two unrepeatered segments (between Porthcurno and Guernsey, and between Guernsey and Lannion) following the removal of Gemini repeaters and the splicing of Gemini cable spans.

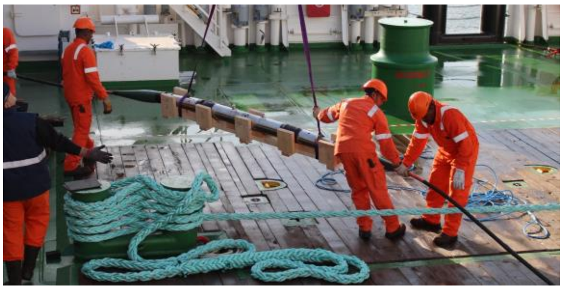

Figure 6: Inserting new repeaters in HUGO subsea cable system in the English Channel.

This wet upgrade was the first deployment of Xtera's repeater in a commercial system, as well as the industry's first deployment of a Raman-based submarine repeater. Inserting new repeaters can also be an effective way to improve the capacity performance and lower the cost per transported bit of a repeated cable system deployed with old gen repeaters.

Conclusion

There are many compelling reasons to use recovered cables around the world. Compared with new build, cable re-lay offers the following benefits:

- It can be significantly quicker to get the system up and running with funding in place;
- In some cases, we can see saving close to 50% when compared with new build;
- There are massive environmental savings upwards of 95%.

Recovering a phased out cable system with the objective of building a new system in another location is a challenging endeavor requiring additional skills with respect to standard new builds based on new wet plant from the factory. Also, the commercial benefit the purchasers can expect from the re-lay approach is strongly driven by multiple factors, including original marine installation of the cable to be recovered, relative locations of existing and new systems, and project requirements.

Given the number of factors impacting the cost of the re-lay solution, Xtera, as the pioneer of this market segment, is uniquely positioned to assess the viability of any redeployment project on a per project basis and to deploy re-lay projects with a maximized cost saving compared with new builds.

Xtera's capabilities to execute redeployment projects include:

- Supporting the customer in deciding whether a redeployment makes sense – technically and commercially;
- Planning the project for efficient and seamless execution;
- Desktop study, route survey, and cable engineering;
- Transmission system design;
- Testing of recovered submerged plant using Xtera's shipboard test kit specifically developed for this purpose;
- Management of the re-lay process, including decisions on route modification driven by external events (seabed conditions, damaged wet plant);
- Redeployment or installation of PFE;
- Supply of submarine line terminal equipment;
- System integration and test of the system including terminals, PFE, network integration with the client network;
- Global project management.

With the industry's highest count of re-lay projects, Xtera has extensive expertise and experience in implementing new submarine cable systems based on recovered wet plant to support any cable re-lay project.

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