HOW TO MAXIMIZE THE RELIABILITY OF SUBSEA NETWORKS

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Abstract: Subsea cable failures are the nightmare of every subsea cable owner or operator. With so much data nowadays traveling through submarine cables, the impact of an outage is tremendous, even when alternative (redundant) routes are available. Knowing that dispatching a ship for a repair costs tens of thousands of dollars per day, network failure occurrences must be reduced to a minimum. In fact, many of the potential issues impacting a subsea network can actually be avoided right at turn-up, by applying rigorous a commissioning procedure. In this paper, we will discuss the most common issues leading to network breakdowns or sub performance, and explain how they can be prevented, mainly by relying on thorough testing. The problems discussed will include attenuation, noise, dispersion, reduced throughput, faulty transceivers, etc. Then, solutions to address these problems will be presented, both for ad hoc testing and continuous monitoring.

1. INTRODUCTION

Subsea cable downtime is the nightmare of every subsea cable owner or operator. Since a network failure is such bad publicity, it comes as no surprise that little information on this topic is publicly available. In this paper, we will first review the costs and main causes of subsea networks failures, and then discuss how network performance and reliability can be optimized with proper testing methods at the turn-up and with monitoring.

2. THE COSTS OF NETWORK FAILURES

The costs of network breakdown fall in two categories: the direct costs of the repair, and the hidden costs of lost revenues. The direct repair costs can be minimal if the cause can be fixed from the cable landing station, but they go up very quickly if a ship must be dispatched, at a typical cost ranging from $50 00 to $100 000 per day. If the fault is located in deep water, far from the coast, this means that the direct repair cost can come close to a million dollars in some cases. But these costs are nothing compared to the “hidden” lost revenues. Depending on its duration, a network breakdown might result in lost customers, churn, and even inability to secure future business should the fault become publicly known. All of these missed opportunities can add up to millions of dollars.

3. THE MAIN CAUSES OF NETWORKS BREAKDOWNS

Data compiled by TE Subcom, Alcatel-Lucent Submarine Networks and Global Marine Systems that was presented at SubOptic 2016 sheds some interesting light on the common reasons for subsea network breakdowns[1]. The authors report that approximately 150 to 200 faults occur globally every year, and that over 90% come from “external aggressions”, a category encompassing fishing, anchors, geological activity, etc, as exhibited in figure 1.

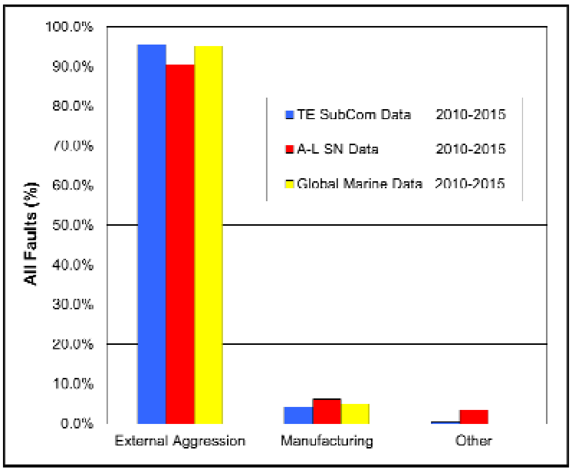

Figure 1: Overall causes of fiber optic cable failures [1]

"The overall fault rate due to human activity (mostly fishing and anchors) remains in the 75% range" [2]. Digging further into the data, it appears that about 80% of external aggressions happen at water depths of less than 300 meters (figure 2).

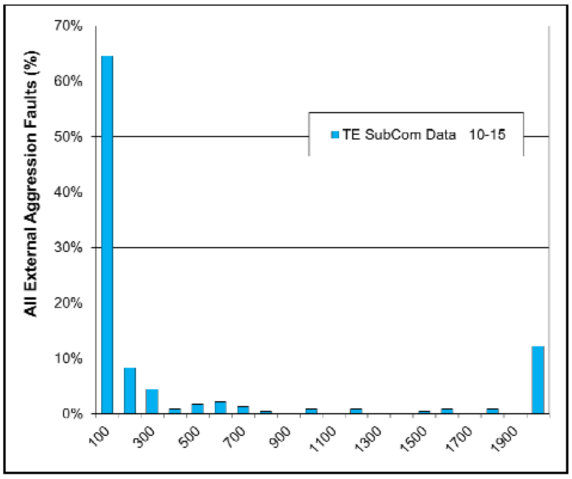

Figure 2: Depth distribution in meters of all external aggressions faults [2]

Accordingly, it clearly shows that efforts to prevent network breakdowns should focus on faults happening on the continental shelf due to external aggressions.

4. FIBER MONITORING TO PREVENT NETWORK FAILURES

As discussed in the previous paragraph, most faults occur at shallow depths, and will result from damaged cables or cable cuts due to fishing and anchors. These events can happen at any time during the cable lifetime, so it highlights that monitoring (i.e., regular testing) can help reduce network downtime. The test technique known as fiber monitoring directly meets this requirement. Indeed, the location of a broken or damaged optical fiber can be readily pinpointed thanks to the fiber monitoring technique, the optical time domain reflectometer (OTDR), which is basically an instrument that sends light pulses in the fiber and analyses backscattered light to characterize the fiber attenuation, length, return loss, etc.

Fiber monitoring can help reduce the mean time to repair by determining precisely the fault location, but even more importantly it can in some cases prevent the fault from occurring. Indeed, an anchor will exert a mechanical stress on the cable by pulling on it, without breaking it initially. There could be several hours between the beginning of the cable pull by the anchor and the actual cable break. The fiber monitoring system, which can take measurements every couple of minutes, is able to spot changes in attenuation due to this mechanical pressure, and trigger an alarm. Through fast intervention, the ship in cause could be contacted, and the anchor be moved swiftly, avoiding the expensive cable fault.

5. TESTING AT COMMISSIONING TO OPTIMIZE CABLE PERFORMANCE

While cable reliability can be improved with fiber monitoring, commissioning is a key moment to optimize cable performance, as well as to increase even further network reliability. Table 1 lists the common impairments, their impact, and the way to prevent them. Each impairment is discussed in greater details below.

Issue	Impact	Solution
Attenuation due to dirty connectors and macrobends	No transmission	Inspect connectors with probe (FIP). Run OTDR test.
Dispersion (CD and PMD)	No transmission or high BER	Ensure that fiber CD/PMD are within the system thresholds
Channel power below Rx sensitivity	No transmission or high BER	Measure channel power with OSA
High noise level	No transmission or high BER	Measure OSNR with OSA
Faulty transceivers	Reduced performance, downtime	Validate transceivers
Transmission errors	Reduced reliability, long troubleshooting	Perform 72 hours BER test
Reduced throughput	Customer complaints and wasted fiber bandwidth	Validate throughput according to standards

Table 1: Common impairments and the related solution

Attenuation or loss issues arise from defective or dirty connectors, macrobends, and cable cuts. An OTDR test will easily spot those problems, even if they are within the landing station itself. If the OTDR test reveals a high loss at the position of a connector, it makes sense to inspect it with a fiber inspection probe, and eventually clean it.

Dispersion is in fact pulse broadening that causes successive pulses in time to overlap, leading to errors in transmission. Dispersion comes in two types of single-mode fibers: chromatic dispersion (CD) and polarization mode dispersion (PMD), each with their own very distinct properties. Dispersion issues can be prevented by measuring it with a dispersion tester, and ensuring that the system operates below the CD/PMD thresholds.

The tests described above are normally performed right after construction, but before commissioning. Let's now turn to the tests that are carried out during commissioning, to optimize network performance.

Receivers have a characteristic called sensitivity, i.e. a minimum channel power that they can detect. Below this threshold, the signal won't be recovered, or it will contain errors. Low signal power issues can be prevented by measuring the power with an optical spectrum analyser (OSA).

OSAs are also useful to identify high noise levels, which can result in no transmission or high BER. Such problems can be avoided by measuring optical signal-to-noise ratio (OSNR), the ratio of signal power divided by noise power, and ensuring that the measured OSNR is higher than the receiver minimum OSNR value. Different OSNR methods exist for different data rates, and care should be taken to use the correct OSNR method. For instance, 100 Gb/s or 200 Gb/s signals should be analysed using the Pol-Mux OSNR or in-service Pol-Mux OSNR methods.

Although line cards are generally speaking reliable, we have seen these past years large quantities of defective client side optics, such as CFPs (compact form pluggables). Users will often swap them randomly, without being able to find the root cause of their malfunction. Modern transport layer testers such as EXFO's iOptics feature automated sequences of tests (skew, power consumption, Tx power, etc) to validate the quality of transceivers, and accordingly reduce downtime.

No matter the data rate, transmission errors always remain a major concern for subsea networks. To ensure optimal network performance, EXFO recommends performing a 72 hour BER test at commissioning.

Finally, client side throughput is the source of many customer complaints. Indeed, if service is not correctly configured on a single device within the end-to-end path, network performance can be greatly affected. Testing throughput against industry standards ensures that fiber bandwidth is maximized and that the large investments in a subsea cable are leveraged. RFC 2544 is a popular Ethernet service testing methodology that includes throughput, round-trip latency, burst and frame loss. While this testing methodology provides key parameters to qualify the network, it is no longer sufficient in terms of fully validating today Ethernet services, because it does not include all required measurements, such as packet jitter, QoS measurement and multiple concurrent service levels. This is why the ITU-T Y.1564 standard has been introduced, which is aligned with the requirements of today Ethernet services. Contrary to other methodologies, EtherSAM (the test implementation of Y.1564) supports new multiservice offerings, because it can simulate all types of services that will run on the network, and simultaneously qualify all key service level agreement (SLA) parameters.

Figure 3 below shows more precisely where in the subsea network each of these tests is performed.

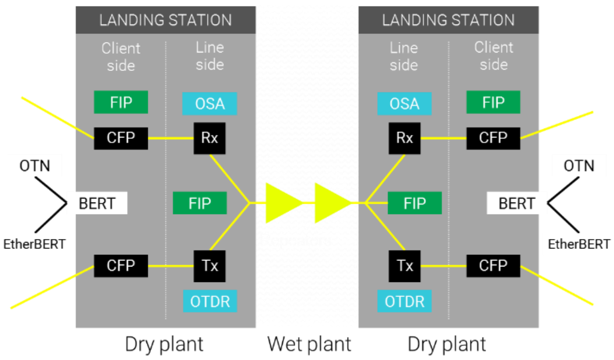

Figure 3: Location of typical testing

6. CONCLUSION

This paper discussed that network failures costs are staggering, and stem from two sources: actual repair costs, and lost revenue. It then mentioned that most network breakdowns are due to external aggressions causes such as fishing and anchors that occur at depths less than 300 meters. Fiber monitoring is a perfect solution to reduce the time to repair of these faults on the continental shelf, and to even avoid them in some cases. This paper then reviewed that commissioning is the right moment in the subsea cable lifecycle to optimize its performance, and also increase its reliability, by using a thorough testing methodology. Recommended tests to avoid bit errors and reduce downtime include fiber inspection to check connector cleanliness, OTDR test to pinpoint dirty/bad connectors and macrobends, spectral analysis to measure channel power and OSNR, and transport tests to assess throughput and BER.

7. REFERENCES

[1] Maurice E. Kordahi et al., Global Trends in Submarine Cable System Faults, SubOptic 2016, Dubai, April 2016, Emerging subsea networks track.
[2] Ibid, page 3.