Facebook Perspective on Submarine Wet Plant Evolution

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Abstract: Because of an ever-increasing demand for capacity, submarine cable system design is evolving and the wet plant equipment design and technology are facing new challenges.
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1. Introduction

From TAT-12/13 and TPC-5 cable systems [1,2] to today, we have seen, first, the development of optically amplified submarine systems and the corresponding technologies (EDFA, line fiber, WDM, DWDM,…), and then, the fast-paced revolution of coherent communications during approximately the last 10 years [3,4]. We went from 5 Gbit/s per fiber pair to more than 20 Tbit/s per fiber pair. Because we are now approaching the limits of capacity per fiber pair, a paradigm shift from an optical system design point of view is happening and we are moving towards cable systems having a much higher number of fiber pairs.

2. Facebook submarine network

Driven by the growth of users (2.23B MAU – DAU/MAU = 66% - June 2018 [5]), the number of required data centers (15 – September 2018 [6]) and the evolution of technologies requiring more and more compute power (Augmented Reality - AR, Virtual reality - VR, Artificial Intelligence - AI), Facebook started a few years ago to build its submarine network. The start was through lease of fiber pairs (FP) on existing cables and then co-builds of new submarine cable systems… leading to MAREA [7] and Facebook is now involved in a large number of these projects among which: PLCN, Havfrue, HKA, Jupiter, SJC2, BtoBE, Malbec, … The need for capacity is illustrated on Figure 1 [8]. In this presentation, we concentrate on the wet plant, its architecture, design and hardware evolution to face the coming challenge [9]. Last year, Facebook presented its perspective regarding terrestrial long-haul and submarine transmission [10,11].

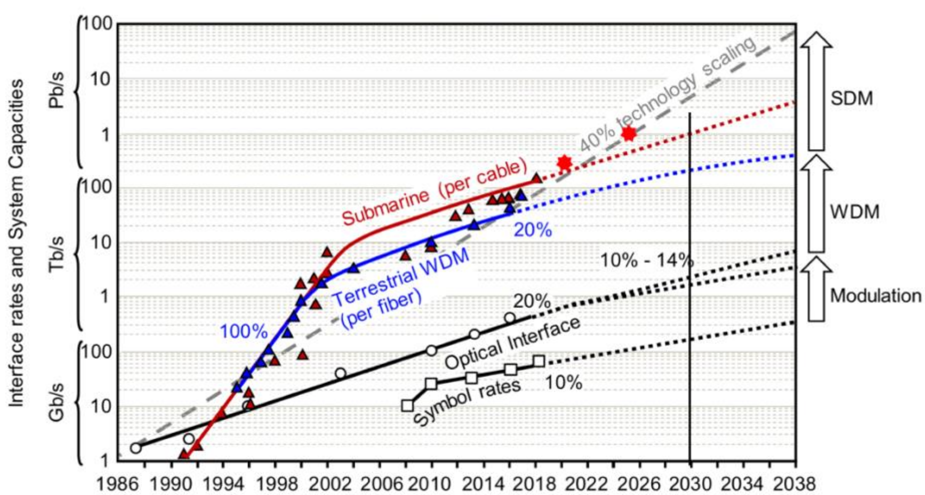


Figure 1: Submarine capacity per cable [8]

For Facebook, the key drivers are: Capacity per cable and Cost per bit. Moreover, it is also important to improve the flexibility of submarine networks.

3. System Design Evolution

To continue increasing the capacity of cable systems, the need for parallelism is now established [12,13]. The submarine cable systems are constrained in 3 ways:

- The Shannon limit per fiber pair: Today's systems are close to this limit from a practical and economical point of view.
- Electric power limitation: Submarine system submerged equipment are powered by Power Feed Equipment (PFE) located in the landing stations. Line currents are around 1A and maximum voltage today is 15kV.
- Real estate limitation: To increase the number of fibers beyond 32-50 fibers may need a complete redesign of the cable (even with the use of 200 µm O.D. optical fibers). Regarding the repeaters, it could be the same in terms of limitation.

Firstly, in order to side step Shannon, it is necessary to increase the product [optical bandwidth per optical core] x [number of optical cores]. Work has already been done to extend the first factor either by using a single amplifier having a bandwidth beyond the C-band or combining multiple bands such as C+L systems [14,15]. The increase of the second factor is receiving a lot of attention at the moment and involves cable systems with a large number of optical fibers. The optimization of capacity is then done at the level of the total cross-section of the cable and not anymore per fiber pair. These systems have a lower OSNR per FP as compared to the systems optimized at the FP level. The new systems are more "linear" systems. These systems with a large number of optical fibers are the first step towards SDM systems.

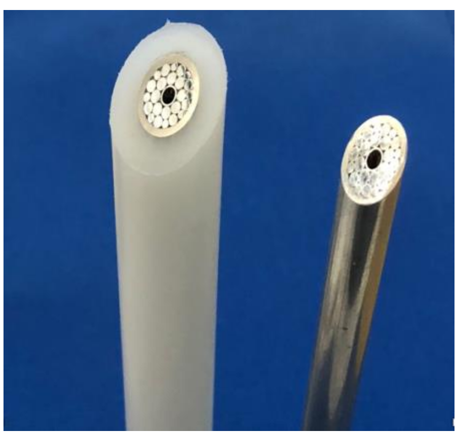
4. Submarine Technology Evolution

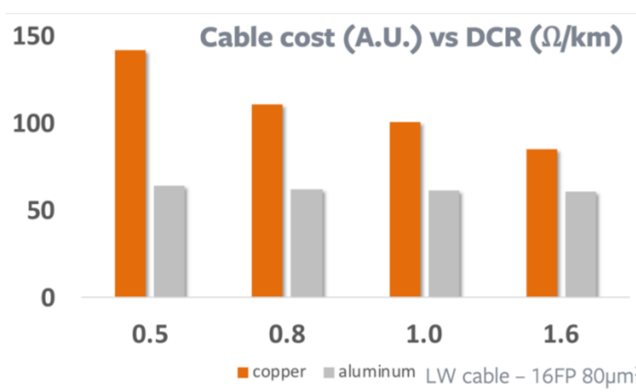
Optical line fibers

Regarding line optical fibers, from the advent of optically amplified cables to today, we have seen a continuous improvement of the lineic loss of optical fibers, down to 0.14 dB/km, which is paramount to submarine communications [16]. At the same time, we have seen submarine fibers with larger and larger effective area, from 80 μm^2 to 150 μm^2. Today, we may see a reverse move as systems are more linear and the micro- and macro-bending sensitivities are more critical to pack a high number of fibers in the cable. In the next 2 years, the number of FPs per cable is going to increase up to 16FPs and maybe up to 25FP using 200 µm OD optical fibers (obtained by reducing the plastic jacket thickness).

Cables

A renewed emphasis is happening on the electric power budget of submarine cables, and therefore, research and development on new cable conductors. First, average DCR (lineic resistance – Ω/km) for submarine cables is optimized for optical system performance and cable price (between 0.7 and 1.6 Ω/km).





Figures 2 and 3: Submarine cable with aluminum conductor.

Cost comparison between Al and Cu conductor cables

But, we see also research and development on new cable conductor material such as aluminum (see Figures 2 and 3). Aluminum is a cost reduction factor as compared to copper but it is also an enabler as the cable voltage drop can then be much lower which then allows to increase the number of FPs and then decrease the cost per bit.

Submerged equipment: Repeaters and Branching Units

To increase the number of FPs per system, pump sharing (or pump farming) is now happening across fiber pairs. A side benefit is the availability improvement of the cable system while breaking the fiber pair independence. At the same time, effort to reduce the footprint and the power consumption is underway. Power conversion efficiency from the PFE to the output power of the repeaters (PFE, cable, repeater power electronics, pump diodes, EDFA) is the key parameter to improve.

Regarding system flexibility, WSS-ROADM units [17] are now a reality for submarine networks and are planned to be deployed in 2019. WSS-ROADM are becoming mainstream in today's submarine cable RFPs allowing dynamic bandwidth management and also minimizing the stranded bandwidth. With the emergence of cables with a large number of FPs, it is expected that networks will require the use of submerged units doing not only wavelength switching but also optical fiber switching.

5. Marine Operations

With the worldwide extent of submarine networks, we are also looking to improve marine planning and operations both for lay operations and maintenance operations. Some examples and directions will be given.

6. Future Directions

A "natural" evolution to go beyond 25FP cable systems would be to go from high fiber count cable systems to Space Division Multiplexing (SDM) systems [18,19]. For this to happen, several issues need to be resolved. We will keep here 2 key ones: improvement of the overall power conversion efficiency (PFE to amplifier output power), improvement of optical amplification (power conversion and space). If this does not happen, submarine cable systems will have to go through a drastic wet plant redesign (cable, repeater, etc…).

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