EVOLUTION OF REPEARTERLESS SYSTEMS ARCHITECTURES

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Abstract: The Cable & Wireless Networks network is a good example of the evolution of repeaterless systems architectures. Recent upgrades performed on a number of C&W Networks infrastructures in the Caribbean have taken thus far disparate unrepeatered systems and integrated them into a unified network, seamlessly bridging North America to South and Central America.

1. INTRODUCTION

Traditionally, submarine repeaterless systems have taken the shape of a long single span between two cable landing stations or of a festoon (or ring - a closed festoon), a cascade of single span systems interconnected by back-to-back terminals. This is no longer the case. In an effort to better integrate repeaterless systems into an operator's global network, repeaterless systems architectures have evolved significantly along several axes. Two main factors have fueled and made this evolution possible. First, technology advances in optical transmission have bolstered the [Capacity x Reach] performance metric of unrepeatered systems (for instance, with the introduction of 100G technology). Second, a change in the mindset of the network providers who no longer view submarine repeaterless systems (and, for that matter, submarine repeatered systems as well) as having different requirements (in particular in terms of reliability) and as separate systems from their terrestrial network.

Advances in technology combined with the acceptance of a common transport platform for both subsea and terrestrial applications, managed by the same Network Management System, have facilitated direct PoP-to-PoP connections, often reducing the equipage of the cable landing stations (CLS). Back-to-back terminals in existing festoons are "stripped down" to a repeater/amplifier, eliminating the interface cards; in the process, significantly reducing both Capital and Operational Expenditures. More recently, added flexibility has been provided by converting back-to-back SLTEs (or deploying instead of back-to-back SLTEs) into multi-degree Reconfigurable Optical Add/Drop Multiplexers (ROADM), allowing the seamless integration of repearterless spans with terrestrial backhauls or their interconnection with repeatered submarine systems. All these transformations result in a more efficient, more robust network, easier to operate, and more cost-effective.

This evolution is illustrated below by examining the transformation of the C&W Networks network.

2. THE C&W NETWORKS NETWORK

C&W Networks owns and operates the largest fiber-optic network in the Caribbean. This network encompasses more than 42,000 km of subsea fiber, over

60 cable landing stations, and 24,000 km of terrestrial fiber. The network comprises 17 subsea systems, including (*u*, for repeaterless and *r* for repeatered): Antillas-1 (*u*); the Americas Region Caribbean Ring System (ARCOS-1, *u* & *r*); Bahamas-2 (*u*); the Cayman Jamaica Fibre System (CJFS, *u*); Gemini-Bermuda & Caribbean-Bermuda US (C-BUS, *r*); the East Caribbean Fiber System (ECFS, *u*); the East West Cable (EWC, *r*);…to name a few. Refer to [1] for a network map as well as a complete list of the constituting subsea systems.

3. NETWORK EVOLUTION

Historically, 2 consecutive spans in a festoon system have been interconnected via back-to-back Submarine Line Terminal Equipment (SLTE), as illustrated in Figure 1. In this configuration, the incoming DWDM waves are demultiplexed and detected by channel cards, referred to here as transponders (TPDR).

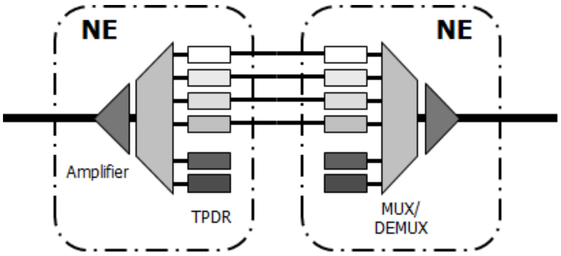

Figure 1: Back-to-back SLTEs interconnecting 2 repeaterless spans

For the "pass-thru" or "express" waves (the waves not terminating at that site), the client side of the transponders of the first span are connected to the client side of the transponders of the second span. The DWDM waves are then multiplexed and launched on the second span.
It should also be noted that the 2 SLTEs are usually managed as two separate network elements (NE).
Advances in the transmission performance of repeaterless systems (thanks to enhanced Raman amplification schemes, advanced modulation formats, stronger forward error-correction…) would, in some instances, allow the "express" waves to be optically "patched-thru" the back-to-back SLTEs and remove the need for back-to-back transponders (Figure 2). The optical "patch-thru" is done between the MUX/DEMUX in each NE.

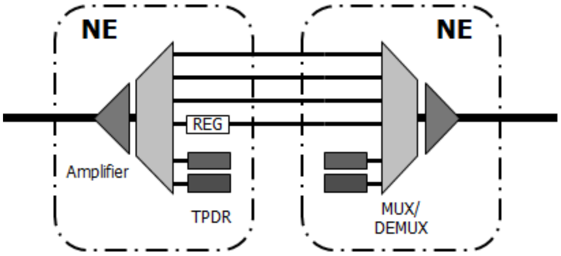

Figure 2: Back-to-back transponders eliminated on express waves or replaced by regenerators.

This configuration change was implemented during one of the early dark-fiber upgrades of the ARCOS system. ARCOS is an 8,600km-long submarine festoon, set in a ring configuration, which extends between 14 countries around the Caribbean (Figure 3) [2].

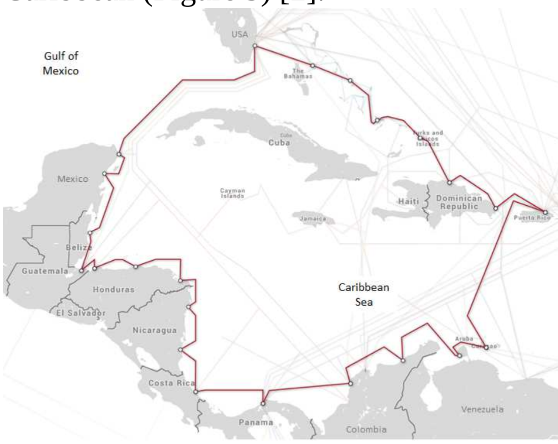

Figure 3: The ARCOS-1 system

The systems consists in 22 repeaterless spans and 2 repeatered links, all interconnected by back-to-back SLTEs. The transponders were eliminated in 5 back-to-back SLTEs (with no current local traffic requirements) between repeaterless spans without sacrificing the committed capacity. More spans could have been combined but at the expense of a reduction in maximum capacity.

This architecture change resulted in significant savings, both in terms of CapEx as the number of waves was increased, as well as OpEx due to the reduction in power consumption. The CapEx to add one new wave around the entire system was reduced by close to 25%. Moreover, the transponders removed from the 5 back-to-back SLTEs were re-used throughout the network to provision new circuits.

From an OpEx perspective, removal of the transponders at the 5 sites resulted in a reduction in power consumption of the transmission equipment, which further resulted in lower heat dissipation. This, in turn, led to a lower AC usage, adding to the overall power consumption reduction and OpEx savings. At a time when carbon footprint of all industries is under intense scrutiny, reduction in power consumption is an important consideration for operators, not only from a financial perspective, but also from an image perspective.

Another benefit of this configuration change is increased system reliability. Elimination of the transponders – often a key contributor to the system availability – shaved over 5 minutes per year from the unavailability figure of an unprotected bidirectional circuit.

Should one of the “express” waves need to be terminated locally at a later time, the optical “patch-thru” between the two MUX/DEMUX can be broken off to add the transponders without affecting the adjacent “express” waves.

In case the back-to-back transponders cannot be removed, they could be replaced by a regenerator, a less expensive one card solution placed in one of the 2 NEs. As the back-to-back SLTEs are managed as 2 separate NEs, the regenerated wave would have to be managed as an “alien wavelength” by the NE without the regenerator.

This “patch-thru” concept can be taken one step further. At sites where no local traffic will ever be needed, the back-to-back SLTEs can be replaced altogether by an inline amplifier (Figure 4), resulting in further savings, however, possibly at the expense of reduced design capacity.

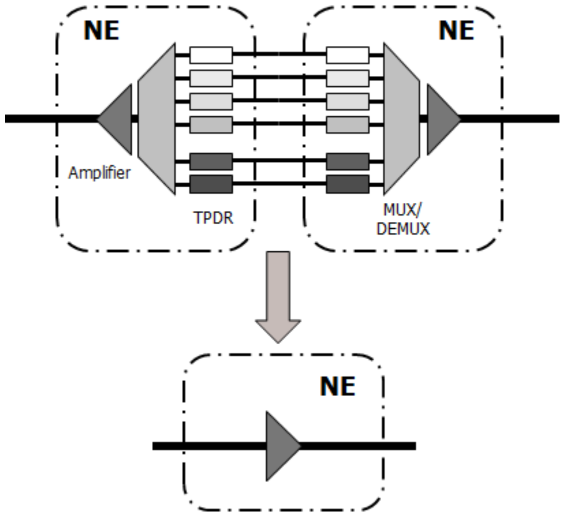

Figure 4: Replacement of back-to-back SLTEs by an inline amplifier

Figure 5 shows the power evolution of 8x 100Gb/s channels along a cascade of two repearterless spans where the back-to-back SLTEs has been replaced by an in-line amplifier (ILA). The first span is 303.5km long (59.7dB) (G.652D fiber) and the second is 342.9km long (60.8dB) (G.654C fiber) [3].

In this particular example, the ILA consists in an EDFA and of backward and forward distributed Raman amplifiers.

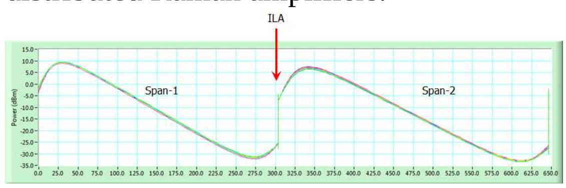

Figure 5: Power profile of 8x 100G over a cascade of 2 repeaterless spans with an ILA in between.

Pushing the evolution further, recent deployments and upgrades of repeaterless systems have seen the implementation of the SLTEs as dynamically Reconfigurable Optical Add/Drop Multiplexers (ROADM), providing flexible per wavelength add / drop / passthrough capabilities. Figure 6 depicts the interconnection of 2 repearterless spans by a 2-degree ROADM. In this arrangement, the ROADM is managed as a single NE.

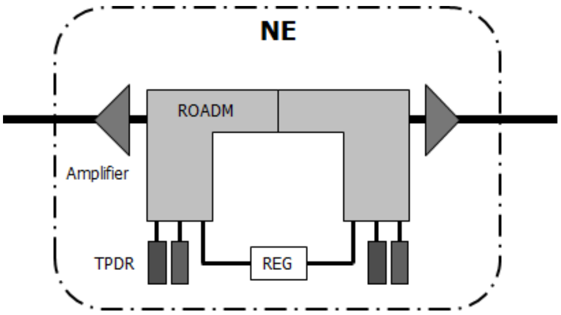

Figure 6: Cascade of 2 repeaterless spans connected via a ROADM

With advanced software capabilities, ROADMs help create an agile, end-to-end transport network. There are several benefits to the use of ROADMs.

- They can be remotely reconfigured as the traffic pattern evolves (for instance, if traffic needs to be added and/or dropped at sites where no local traffic was previously terminated). In case some wavelength pre-planning was done (where channel cards are pre-deployed ready to be activated), traffic reconfiguration can be achieved in a matter of hours or even minutes.
- They can be grown in-service to include more degrees to interconnect to other systems (subsea or terrestrial), resulting in multi-degree nodes.
- They are a key element to providing optical restoration, increasing network robustness and availability.

ROADMs were installed at all sites when the 3rd fiber pair was lit at 100G on the back half of the ARCOS ring. They were also deployed at all sites during one of the latest dark-fiber upgrade of the ECFS system. ECFS is a 1,700km-long festoon connecting Tortola (BVI) to Trinidad and Tobago (see Figure 7).

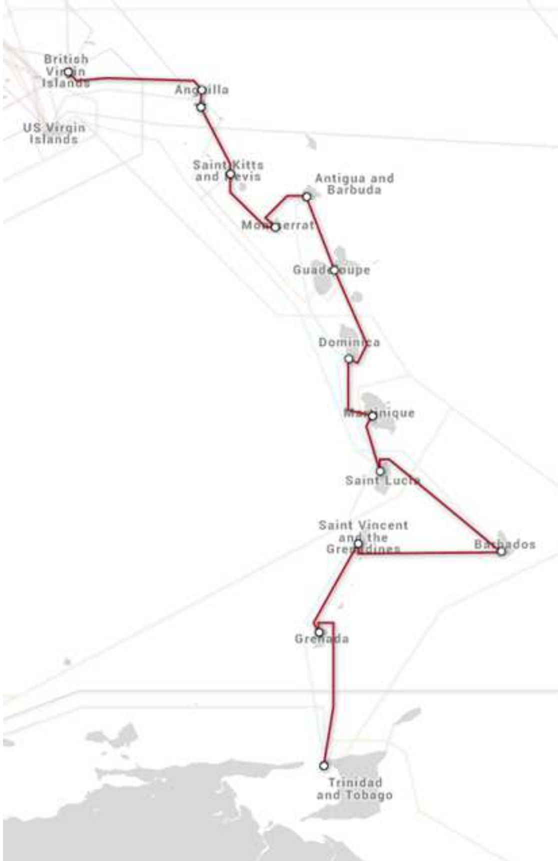

Figure 7: ECFS

Even the two end sites of the festoon (Tortola and Trinidad) were configured as 1D ROADM instead of the standard terminal configuration. A few other systems (for instance, C-BUS, EWC) of the C&W Networks network also land in BVI. Configuring the Tortola SLTE as a ROADM makes it easier to interconnect ECFS to these other systems.
Some data paths between islands require regeneration along the way. Regeneration is easily accomplished on an as needed and on a per wavelength basis as shown in Figure 6.

It should be noted that the same network architecture evolution presented here in the context of repeaterless systems has also occurred in submarine repeatered systems.

4. CONCLUSION

Most, if not all, of the architecture changes witnessed in submarine systems, repeaterless and repeatered, in the last few years had taken place in the terrestrial space a long time ago. Their introduction in submarine systems have erased the historic boundary between terrestrial and submarine networks. For an operator, this evolution has allowed the migration of their disjoint networks towards a global network and provide more efficient, reliable, and cost effective delivery of services

5. REFERENCES

[1] See OUR MAP and NETWORK SYSTEMS at www.cwnetworks.com
[2] Source: www.submarinecablemap.com
[3] D. Chang et al., “8 x 120 Gb/s Transmission over a Cascade of Two Spans with a Total Loss in Excess of 120 dB,” NFOEC 2013, Paper NM2E.6