Coherent Technologies and Requirements in Next-Generation MSO Networks

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Abstract: Cable MSO networks are undergoing a fundamental shift from centralized to distributed architectures, and from analog to digital optics. Interoperable coherent optics based on CableLabs specifications can serve as a key part of that transition.

Cable HFC Access Networks Today

Cable Multiple System Operators (MSOs) today typically employ a Hybrid Fiber-Coax (HFC) access network to reach to their customers with video and data services; a simplified example is shown in Figure 1 below.

In this example, in the downstream (or forward path) RF signals for data and video are generated in a Hub facility; converted from electrical signals to optical using an analog laser; converted back to electrical signals in a Fiber Node; and transmitted over a coaxial cable network to end customers. In the upstream (or return path) a similar set of operations occurs, originating at the customer premises and terminating at the Hub. The distance from the Hub to the Fiber Node is typically 20-80km, along longer distances are possible; the distance from the Fiber Node to the end customer is generally just a few km.

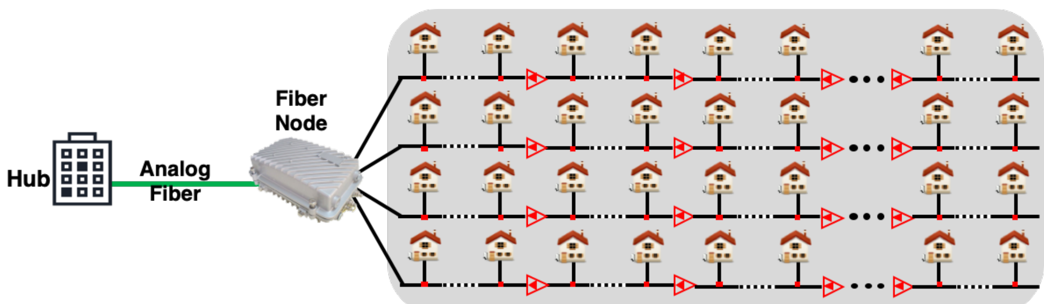

Fig. 1. Simplified Cable HFC Architecture

When the capacity requirements of a group of customers sharing the network (a Service Group) exceed the capacity of a Fiber Node, operators will split a Fiber Node into multiple Nodes. Those new Fiber Nodes will often share a single fiber pair using Dense Wavelength Division Multiplexing (DWDM) to save costs. Each new Service Group also requires new equipment at the Hub site, which can create pressure on space, power, and cooling.

A Fundamental Shift in Cable Access Networks

In response to these pressures, many MSOs are beginning a fundamental shift in their networks: they are moving the RF generation previously performed in the Hub out into the network and converting the signals on the fiber portion of the plant from analog to digital (typically Ethernet), creating a deep fiber Ethernet network. This is referred to as a Distributed Access Architecture (DAA), because many functions that were previously centralized are now distributed; a simplified version is shown in Figure 2 below. On the survey it looks very similar to Figure 1. However, the fiber is now carrying Ethernet data over a digital network, and the RF is all generated at the RPD or RMD onto the coax without an electrical-optical-electrical conversion.

This change has a number of advantages: it reduces the equipment requirements for Hubs and Headends; it allows cable MSOs to utilize lower cost off-the-shelf digital optics for the fiber link instead of specialized analog optics; fiber maintenance becomes easier; and by avoiding electrical-optical-electrical conversions, the signal to noise ratio (SNR) of the electrical signal on the coaxial cable is increased, in turn allowing devices based on the DOCSIS 3.1 specifications to operate at higher modulation orders more reliably (increasing network capacity).

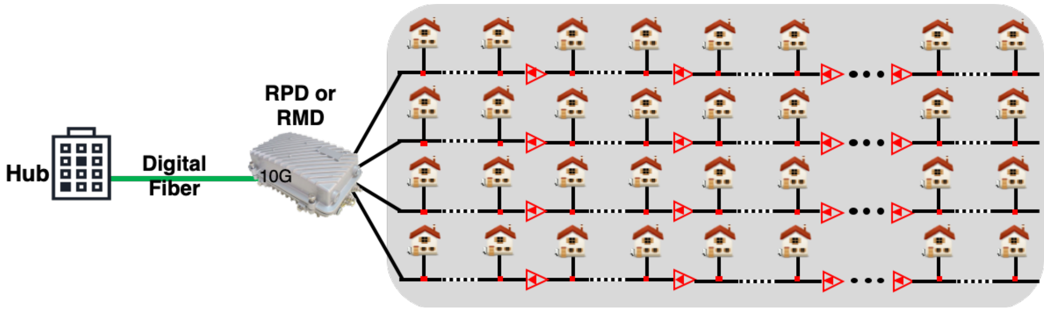

Fig. 2. Simplified Distributed Access Architecture

The Need for Aggregation

If Fiber Nodes were simply being replaced with RPDs or RMDs on a 1:1 basis, then all that would be required to connect them to the Hub would be a single 10 Gbps optical link to address the capacity needs of an RPD or RMD. However, since these changes are being driven by the need for more Service Groups with fewer customers each, Figure 3 shows a simplified version of a scenario where the Fiber Node is split into multiple Child Nodes.

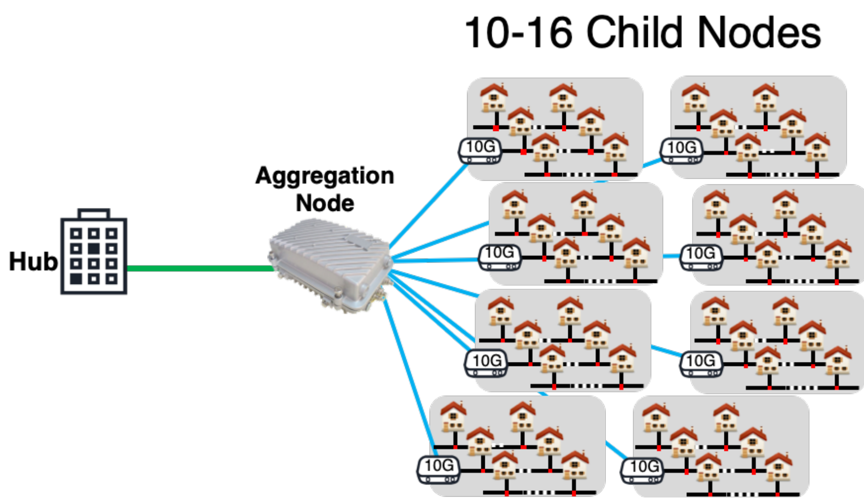

Fig. 3. DAA with multiple Child Nodes

In this approach, the capacity needs of each Child Node will be aggregated together onto the existing fiber. One straightforward means of doing so would be to passively aggregate 10 Gbps optical links from each Child Node using DWDM, with the Aggregation Node being a passive mux/demux. This technology is readily available and well understood, and so represents a logical initial approach.

However, it has its limits: with 100 GHz spacing, cable MSOs will be limited to about 48 of these 10 Gbps links over a single fiber pair. And the cost goes up with every 10 Gbps link.

The Case for Coherent

CableLabs postulated that utilizing a single coherent optics link at 100 or 200 Gbps might prove advantageous over multiple 10 Gbps optical links with DWDM. That link would be terminated at the Hub and the Aggregation Node; the Aggregation Node would also terminate multiple 10 Gbps links from the Child Nodes, which could utilize low cost grey optics operating at 10km or less. The Aggregation Node could be a Layer 1, 2, or 3 device.

Our internal analysis has shown that while the cost for a small number of Child Nodes is lower with the 10 Gbps DWDM approach, because the additive cost for each Child Node is lower with the coherent optics approach, above a certain number of Child Nodes coherent optics becomes more cost effective. Our analysis also showed that the potential to cost reduce coherent optics technology was likely greater than 10G DWDM technology, suggesting an opportunity to lower that crossover point.

Coherent optics provided additional benefits as well: since DWDM operation is also supported, coherent optics signals could coexist with existing analog and digital signals to enable a smooth migration (a key MSO requirement); DWDM also means that additional coherent optics signals could be added in the future, resulting in a 10-20x increase in capacity for the existing fiber network that cable MSOs already have deployed.

Further, the larger capacities made possible through coherent optics technologies – combined with the move to deep fiber Ethernet networks –enables cable MSOs to pursue new business opportunities, such as mobile fronthaul and backhaul, high capacity business services, and various Fiber-to-the-Premises technologies when and where it makes sense to do so. This leads to a converged cable access network, as shown in Figure 4 below.

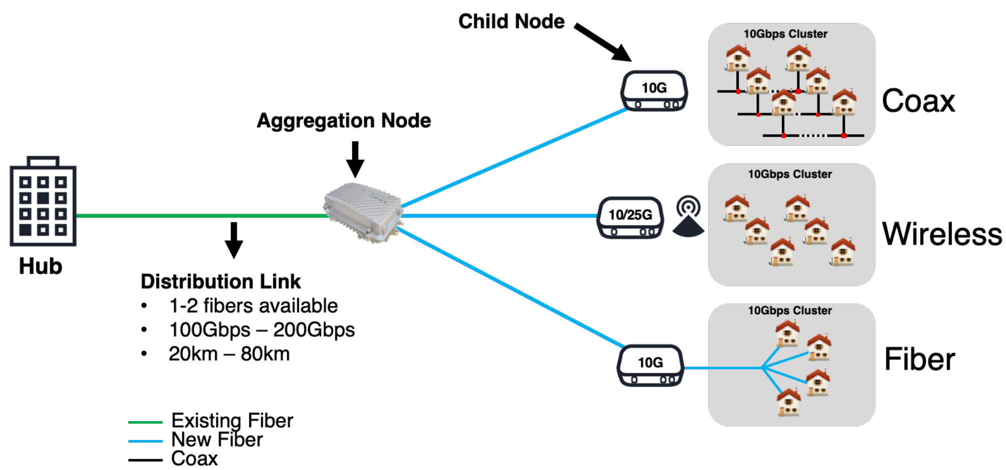

Fig. 4. Converged Cable Access Network

CableLabs Specifications

CableLabs decided to develop specifications for coherent optics for two key reasons.

First and foremost was a desire to reduce cost. Our experience has been that the use of common specifications results in interoperability, which in turn increases both scale and competition, both of which tend to reduce costs.

Secondly, we wanted to identify aspects of a cable access network deployment that might be unique from other environments. Part of that was working to identify possible cost optimizations for a cable access deployment. Another part was to point out different environmental requirements: unlike current coherent optics deployments in which the transceivers are located in temperature-controlled facilities, in a cable access network at least one end of the link (the Aggregation Node) would likely be outdoors. This requires different considerations for temperature and weather hardening. It also means that optical amplifiers are generally only practical at the Hub side of the link. Therefore, in order to maximize reach, this drives the certain technology choices, such as the use of QPSK instead of 16QAM modulation (for better Optical Signal to Noise Ratios), and the selection of a high net coding gain Forward Error Correction technology when operating at 200 Gbps.

In the end, CableLabs publicly released four specifications to address these and other issues, developed jointly with manufacturers based on cable MSO requirements: an Architecture specification to describe the overall cable access architecture and identify MSO requirements; a Physical Layer version 1 specification to describe physical layer interoperability at 100 Gbps per wavelength; a Physical Layer version 2 specification to describe physical layer interoperability at 200 Gbps per wavelength; and an Operations Support System Interface specification to address management requirements in a common manner. We've since successfully demonstrated multi-vendor interoperability at 100G and hope to do the same for 200G in 2020.

Conclusion

As cable network capacity needs increase, cable MSOs are fundamentally the way their networks operate in order to cost effectively support that growth. A key tool in supporting that transition will be coherent optics technology, which allows them to aggregate multiple lower speed links into a single link and opens up a wealth of new business opportunities. To support those needs, CableLabs and manufacturers developed a series of specifications defining interoperable coherent optics solutions targeted at the cable access network, which are resulting in interoperable devices that will hopefully be deployed in cable MSO networks in the coming months.