APPLICATION NOTE

DAA AGGREGATION

DAA AGGREGATION AND TRANSPORT

Solving the Distributed Access Architecture aggregation and transport scalability challenge

The cable industry is embarking on a significant investment in its access networks in order to meet the relentless demand for more subscriber bandwidth and services and to stay competitive with the telcos. Cable multiple-systems operators (MSOs) across the globe are evaluating the best migration strategies for their network infrastructures, and are assessing a range of approaches that are generically known as Distributed Access Architecture (DAA). These architectures take current cable infrastructure and distribute certain active network elements and content closer to the end user. The goal is to shorten the "last mile" by removing bandwidth bottlenecks, and to reduce the number of customers sharing a given network segment. The early DAA approach of choice for many cable operators appears to be the Remote PHY architecture, which consists of shifting or distributing the physical layer (PHY) of traditional cable modem termination systems (CMTS) from cable head end nodes to fiber nodes deeper in the access network, and replacing the radio frequency optical technology that is currently part of their hybrid fiber coaxial (HFC) with digital optical instead. Remote PHY's current popularity is due largely to its relative ease of deployment. However, some operators are also considering similar approaches, such as Remote MAC/PHY, which also moves the media access control (MAC) function into the access network.

One effect of DAA is that it dramatically increases the number of end points that support dense wavelength-division multiplexing (DWDM)-based aggregation for the hundreds of thousands, if not millions, of Remote PHY devices (RPDs) that will be deployed in cable access networks. From an optical transport perspective, this creates a number of challenges for cable MSOs as they push their existing DWDM-based optical networks deeper into the access network, while simultaneously coping with a massive increase in backhaul traffic. Two further DAA challenges include the introduction of new, higher-capacity packet-optical aggregation platforms into the network and the need for active network equipment in locations that were never designed to support the space and power requirements of DWDM transport. The order-of-magnitude increase in the number of DWDM access locations that need to be deployed and managed by the current field force is a logistical and economic challenge that must also be addressed.

This application note looks at all these challenges and proposes a unique approach to allow network operators to embrace the significant overall advantages that DAA brings to cable networks.

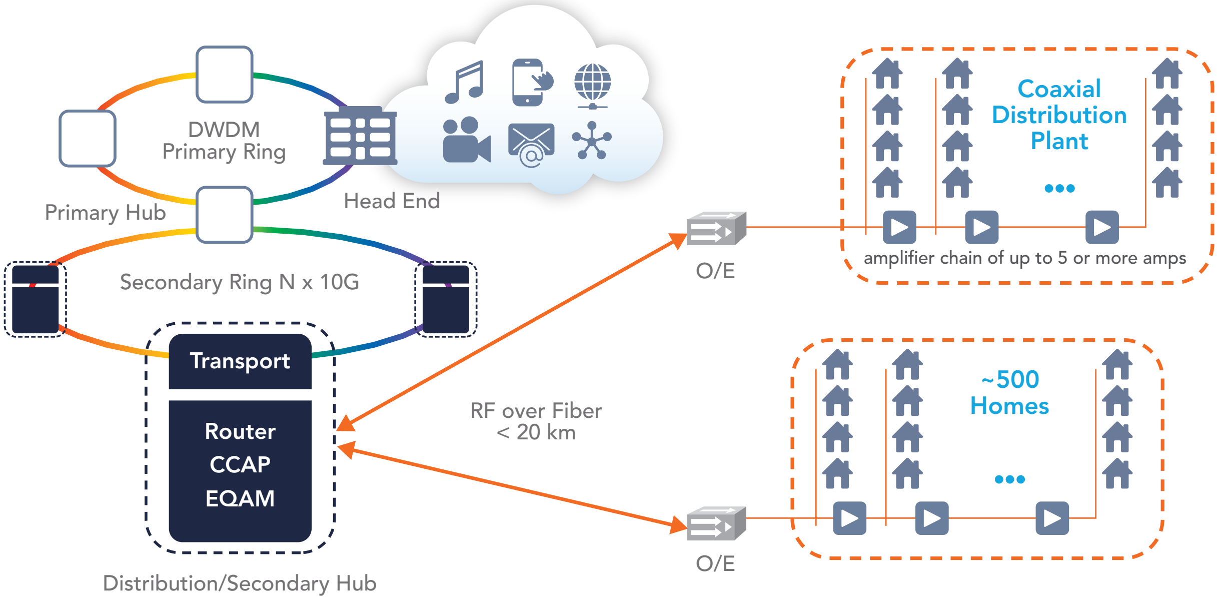

Figure 1: A Typical Pre-DAA HFC-based Cable Access Network

Understanding DAA and the Challenges It Brings to Optical Backhaul

Today's HFC-based Infrastructure

Before we evaluate the DWDM-based optical backhaul network, it is important to understand DAA in general and the Remote PHY architecture specifically. Today's pre-DAA cable access networks are built around an HFC plant that is built in service groups of approximately 400 to 500 homes, as shown in Figure 1.

Each secondary hub supports in the range of 25 to 65 HFC service groups. These are connected via an analog radio over fiber (ROF) connection generated by the edge quadrature amplitude modulation (EQAM) in the secondary hub, which is then converted to the coaxial cable signal we receive in our homes by an optical node (ON). The cable signal from the ON is transmitted over the coaxial plant to the homes through amplifiers, filters and splitters. These networks are described as N+x networks, where N is the ON and x is the maximum number of coaxial amplifiers passed in the coaxial plant. Therefore, the two service groups shown in Figure 1 would be described as N+5 networks. The coaxial amplifiers amplify the signal and allow more homes to be supported in the sector, but they also restrict the available spectrum to the passband of the amplifier. As cable MSOs migrate to DOCSIS 3.1 and take advantage of the higher-order modulation schemes that it supports, this limitation will need to be addressed, and the number of amplifiers will need to be cut to either none or just one.

The three main limiting factors of the current architecture are:

1. The ROF links. These are analog connections and therefore require a very high optical signal-to-noise ratio (OSNR), which makes amplification a challenge and limits reach.
2. The challenges of transporting ROF between EQAM and ON limit the scalability of the access network.
3. Typically, 400 to 500 homes are passed per ON or service group, which means amplifiers are needed and will restrict the amount of spectrum and therefore the available bandwidth to be shared between end users.

There are a few approaches that could allow higher bandwidth per end customer, but many are impractical as they would involve significant expansion of the number of secondary hubs. These secondary hubs are already space and power constrained, and expanding the number of these facilities is economically and logistically challenging.

Migration to DAA

As outlined in the introduction, cable MSOs are now starting the migration to DAA, which involves the following steps:

1. The removal of amplifiers from the HFC plant and the subdivision of the service groups. Each smaller service group requires a new remote device, typically an RPD, to move functions from the secondary hub closer to the end user. These devices are often pole-mounted, environmentally hardened clamshells that can be deployed outdoors.
2. Pushing fiber deeper into the access network to provide a fiber connection to each RPD, and migration to DWDM over the new

access fiber plant and the older ROF plant. This requires support for longer reach to the RPD as well as higher capacity, as each RPD requires a new 10 gigabits per second (10G) DWDM connection. The number of end points for this new DWDM access network is an order of magnitude higher than the previous ROF network due to the proliferation of RPDs in the network.

3. Increasing data rates from 10G to 100G packet-optical aggregation in the secondary hub and upgrading the metro DWDM network to 100G-based backhaul.

As shown in Figure 2, the DAA approach reuses existing network facilities, but must cope with considerably more bandwidth. This requires MSOs to consider a new approach to aggregation and transport. If we look at the specific numbers associated with DAA, we can gain a deeper understanding of the challenges it creates:

- Each secondary hub could be required to support between 250 and 700 or more RPDs. This represents up to 700 or more 10G access wavelengths that require termination and Ethernet aggregation within the secondary hub.
- While the arrayed wave guide (AWG) DWDM mux/demux unit (MDU) filter shown in Figure 2 is housed in the location of the previous ONT, which is typically less than 20 kilometers (km) from the secondary hub, the furthest RPDs could be up to 60 km away.
- Depending on the level of utilization of the 10G access wavelengths, up to 70 100G metro DWDM wavelengths could be required per secondary hub. Layer 2 aggregation will allow operators to deploy these 100G wavelengths efficiently by aggregating a large number of partially filled 10G circuits into a single 100G circuit.

These figures show that a very large number of 10G access circuits will need to be terminated at the secondary hub, and in many cases these locations are already space and power constrained, as outlined above. Innovative solutions are clearly required to support this architectural shift to DAA.

Remote PHY appears to be the early DAA approach of choice for cable operators, due largely to its relative ease of deployment and ability to be more easily upgraded in the future as cable access specifications develop. However, some network operators are considering alternative approaches, such as Remote MAC/PHY, which push additional processing into the remote device.

Infinera's DAA Aggregation and Transport Solution

To address the challenges outlined above, Infinera has created a unique solution for DAA aggregation and transport. This solution can be split into four major building blocks:

1. High-density 100G metro/regional DWDM transport using the XT-3300 platform

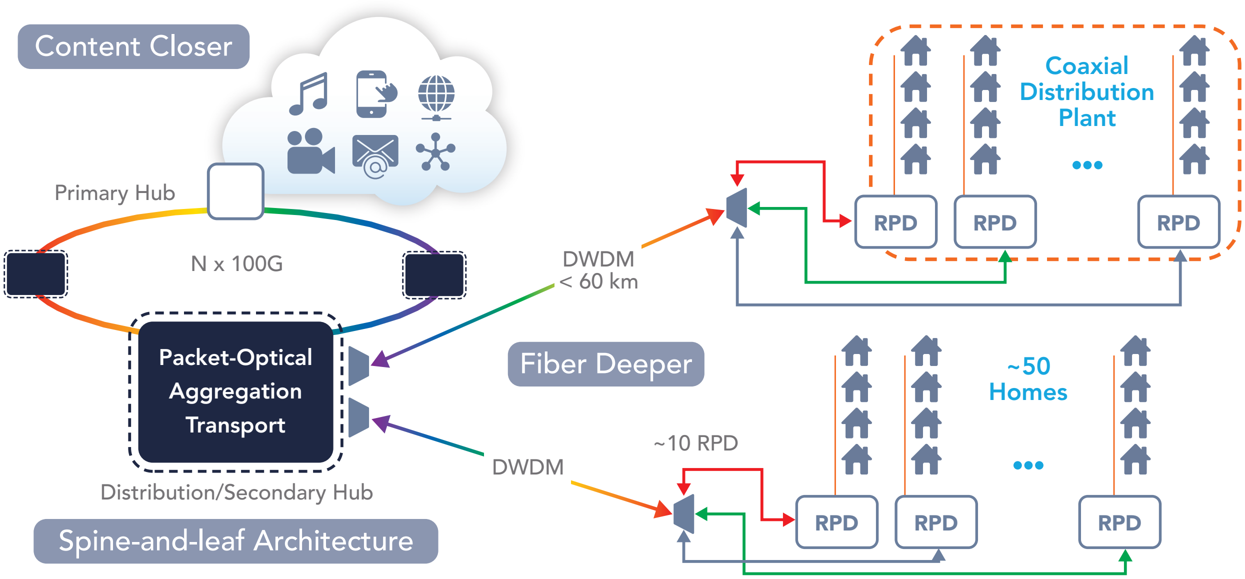

Figure 2: A Typical Remote PHY-based DAA Network

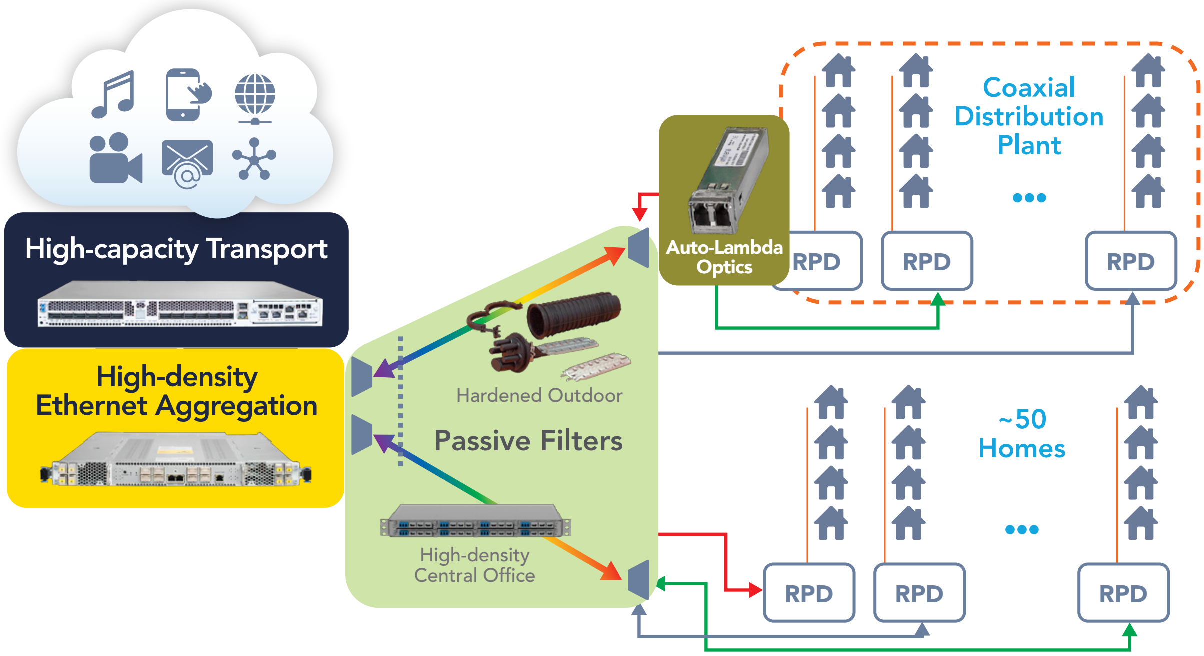

Figure 3: Infinera's DAA Aggregation and Transport Solution

2. High-density Ethernet aggregation using the HDEA (High-Density Ethernet Aggregator)
3. Ruggedized DWDM access-optimized filters from the XTG Series
4. Auto-Lambda autotuning DWDM pluggable optics to simplify RPD deployment and maintenance

Together these components enable Infinera to offer a solution that provides cable MSOs with a number of key advantages over alternative approaches:

- Super-high density:
  - Up to 32 percent better space efficiency than best-of-breed competition, for better use of scarce secondary hub real estate.
  - Up to an 86 percent reduction in fibers to handle compared with best-of-breed competition, greatly simplifying network rollout.
- Easy to operate:
  - Efficient fiber management with multi-fiber push on (MPO) connectors, minimizing fiber handling-related issues.
  - Host-independent Auto-Lambda optics, simplifying rollout and reducing spares holding.
  - Pre-staging that accelerates and simplifies rollout and reduces the chance of configuration errors in the field.
- Open and automated
  - Software-defined networking (SDN) interface for control and management of transport resources.
  - Open platform for multiple services: mobile, business services, etc.

High-density Metro/Regional DWDM Transport

Infinera's XT-3300 provides industry-leading capabilities for high-density 100G transport supporting 12 x 100G services over 1.2 terabits per second (1.2T) of line capacity in a compact 1 rack unit (1RU) "pizza box" platform. The XT-3300 is built for cloud scale networks, such as those required for DAA transport. The platform is based on Infinera's fourth-generation Infinite Capacity Engine (ICE4) to support a wide range of metro core, regional and long-haul DAA transport architectures. The XT-3300 also features industry-leading optical performance, such as unamplified reach of over 35 decibels (dB), which equates to approximately 125 km before additional amplification is required. Over amplified networks, the XT-3300 supports reach of up to 6000 km.

The XT-3300 supports sliceable super-channels, which enable cable MSOs to independently route each of the device's six 200G carriers to any location within the metro/regional network to support network resilience or optical layer capacity orchestration. Overall, the flexibility and performance of the XT-3300 make the platform ideal for 100G DAA transport.

Figure 4: XT-3300

For networks that do not need the ultra-high capacity of the XT-3300, alternative transport solutions such as Infinera's XTM II can also be used for DAA transport.

High-density Ethernet Aggregation

The biggest factor in improving aggregation density and reducing intra-rack fibering is Infinera's HDEA platform. This platform brings innovation to Ethernet aggregation, based on a bottoms-up assessment of the unique requirements of DAA Ethernet aggregation. The HDEA supports an ultra-high volume of 10G access services, with aggregation of up to 80 x 10G services into up to 8 x 100G services that are passed to the XT-3300 for further transport.

The HDEA uses a unique pull-out mechanical design to allow the unit to support such a high volume of 10G circuits from a 1RU device. Having access to the sides as well as the front of the unit enables the sides to be used to support more optical connections than is possible on standard equipment in which connectors are restricted to the front of the unit only. Overall this provides approximately double the density of 10G services that competitive solutions can offer, and the unit also only needs about half the power, with worst-case power consumption of less than 500 watts.

With a broad range of features that are optimized for high-density Ethernet aggregation, the HDEA is ideal for DAA applications. The HDEA uses MPO connectors to drastically reduce the amount of cabling in the rack, as each MPO cable replaces 10 transmit and 10 receive fibers, a 20-fold reduction. Internally, the HDEA supports a feature-rich Ethernet switching and aggregation capability with features such as ultra-low latency, Metro Ethernet Forum (MEF) service support, Synchronous Ethernet (SyncE) and 1588v2 synchronization, enabling business Ethernet or cell backhaul services to be supported over the same infrastructure.

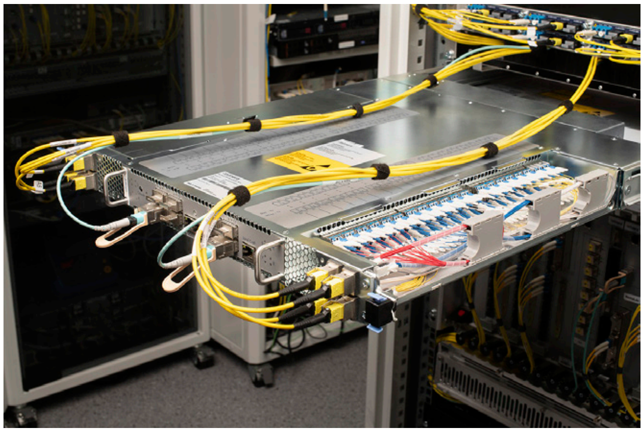

Figure 5: HDEA in Service with Side Cover Removed, Exposing 40 of the 80 10G Optics

The HDEA also supports Infinera's Auto-Lambda technology and can be managed within an open SDN environment, such as the Central Office Re-architected as a Datacenter (CORD) initiative.

Ruggedized XTG Series DWDM filters

To support migration to DWDM in the access plant, Infinera uses the widely deployed XTG Series to provide a broad range of ruggedized DWDM filters that can be deployed in either central office or outside plant environments, such as manhole locations. Specifically designed to support HDEA operation, the XTG Series provides high-density central office AWG MDUs with MPO connectors to reduce the number of cables within the rack and provide up to eight MDU functions in 1RU.

Auto-Lambda Optics

A key challenge with the rollout of DAA is the proliferation of end points within the optical access network. Not only will DWDM capabilities be added to the end point, potentially requiring a new skill set for remote field personnel, but the number of end points goes up by an order of magnitude. The largest cable MSOs will eventually deploy hundreds of thousands and possibly over a million RPDs in their networks. In order to support this massive number of remote locations and the additional DWDM capabilities required without also increasing the size of the field force by the same degree, cable MSOs need to greatly simplify the rollout and ongoing maintenance of the DWDM optics required in the RPD.

To address this particular challenge, Infinera has introduced Auto-Lambda, an autotuning technology for the pluggable optical devices at either end of the RPD and secondary hub link. Auto-Lambda is host independent, which enables support in any remote device that supports third-party optics, and therefore does not require the remote device to have any understanding of the DWDM capabilities of the optics, nor does it require the device or field personnel at the remote site to have any involvement in the tuning of the optics to the required wavelength.

Auto-Lambda supports both single-fiber and fiber-pair operation with a range of reach options, including 80 km optics, to support DAA applications. The remote field personnel simply plug in the remote enhanced small form-factor pluggable (SFP+) optics, clean and insert the fiber(s) using standard fiber handling procedures and leave the rest of the DWDM turn-up to the network itself.

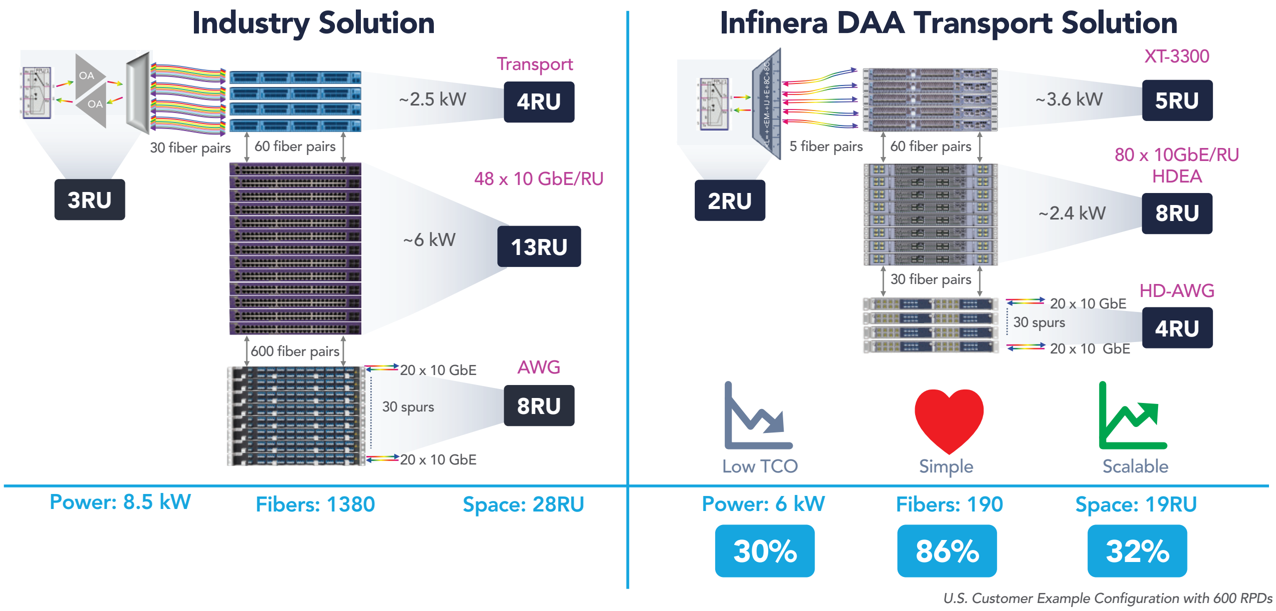

Figure 6: Space and Fiber Savings from Infinera's DAA Transport Solution

Pulling It All Together

Bringing these components together allows Infinera to provide cable MSOs with a highly optimized solution for DAA aggregation and transport that is super-high density, provides ease of operation and is open and automated.

Key proof points include a significant reduction in the number of intra-rack fibers, reduced rack space and the operational advantages of Auto-Lambda. Figure 6 provides an overview of the space and fiber requirements of the Infinera solution compared to best-of-breed alternatives taken from a range of competitors for a demanding 600 RPD secondary hub configuration.

Infinera's solution for this configuration provides space savings of almost a third, and reduces the number of fibers within the rack by 86 percent, which in this scenario is almost 1200 fibers. When combined with Auto-Lambda, SDN control to support CORD environments, high-performance Ethernet aggregation and the ability to support additional services such as business Ethernet and cell backhaul services from the same infrastructure, the Infinera DAA transport solution provides cable MSOs with industry-leading capabilities and a smoother pathway to DAA.

Further Reading:

XT-3300 Brochure: https://www.infinera.com/wp-content/uploads/2016/11/Infinera-BR-DTN-X-XT-Series-Meshponders.pdf

Auto-Lambda Application Note: https://www.infinera.com/wp-content/uploads/infinera-AN-Auto-Lambda.pdf

HDEA Data Sheet

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