APPLICATION NOTE

Infinera®

Auto-Lambda

Infinera's Solution for Autotuneable DWDM in Access and Aggregation Networks

Network operators, ranging from large Tier 1 operators with huge international networks to enterprise operators that run their own smaller dedicated networks for internal traffic, are all looking at new advanced automation techniques to help streamline operations, reduce risk, and manage costs. In most cases the focus is on powerful network management and orchestration software, but beyond this, automation has a role to play in the wider context of optical networking. Recent innovation within optical networking hardware has introduced autotuneability capabilities to DWDM optics that help network operators in their drive toward increased automation in their networks.

Autotuneable optics provide a wide range of benefits within access and aggregation networks, and help address the challenges associated with the proliferation of DWDM in access networks created by fiber deep initiatives such as distributed access architecture (DAA) in cable networks and 5G migration in mobile networks. In these networks, the operational challenges of deploying large numbers of DWDM optics in remote locations can be substantial, and any step toward automation that simplifies the process can significantly reduce the ongoing operational cost of deploying and maintaining these networks. As this application note will explain later, the introduction of autotuneable optics can also enable all network operators, large and small, to rethink how they design DWDM access and aggregation networks by removing the need for DWDM hardware in access nodes. Initial deployments of the solution have been shown to halve the initial capital expenditure of these networks and reduce ongoing space- and power-related operational costs.

Autotuneability has been at the heart of the International Telecommunication Union's (ITU) G.698.4 standard, widely known by its original working title of G.metro, for many years. G.metro builds on work within the optical networking industry to build a WDM-PON-based access network that delivers symmetrical bandwidth at speeds of at least 10 Gb/s with PON-like plug-and-play operation. Infinera has been a long-term participant in the G.metro activities, including developing an earlier WDM-PON solution using seeder light technology. The company has continued to innovate G.metro-based autotuneability concepts, culminating in the development of the company's most recent innovation in the space, Auto-Lambda.

Infinera has patented the Auto-Lambda scanning process, creating a unique networking solution for both simple point-to-point G.metro-based applications and more sophisticated amplified aggregation networks. The solution enables network operators of all sizes to simplify and cost-reduce their networks in a range of applications, including Remote-PHY backhaul in DAA; point-to-point and ring-based fronthaul, midhaul, and backhaul in 4G/5G mobile networks; and similar backhaul or router aggregation networks such as DSLAM backhaul, PON OLT backhaul, and business services aggregation networks.

This application note explains the Auto-Lambda solution and the benefits it brings to this wide range of network applications.

BENEFITS OF INFINERA'S AUTO-LAMBDA SOLUTION

- **Greatly simplify and cost-reduce** network rollouts and ongoing maintenance with simple plug-and-play autotuneable DWDM optics that behave like grey/uncolored optics
- **Halve the cost of access and aggregation networks** with Auto-Lambda DWDM optics directly hosted in third-party devices/systems, removing the need for traditional DWDM hardware
- **Support a wide range of network architectures**, from simple point-to-point to sophisticated amplified rings and mixed 10G, 25G, and 100G+ operation
- **Bring G.metro-based operations to access and aggregation networks** with the complete Auto-Lambda networking solution
- **Support many network upgrade scenarios** in the simplest and most cost-effective way – DWDM underlay additions, capacity upgrades, node insertions, and many more

WHAT IS AUTO-LAMBDA?

At the heart of the Auto-Lambda solution are innovative autotuneable optics, which are essentially standard tuneable DWDM small form-factor pluggable (SFP+) optics with additional firmware that runs the Auto-Lambda scanning process. This means that their optical performance and characteristics are exactly the same as those of standard tuneable SFP+s, whereas some other approaches to autotuneability create reduced optical performance. Infinera has patented the company's autotuning process and has built a complete, unique metro networking Auto-Lambda solution comprising:

- Auto-Lambda autotuneable SFP+ DWDM optics
- Support for point-to-point and ring-based architectures
- Support for alien wavelengths when optics are used in third-party devices
- Additional capabilities when used in some XTM Series transponders and Layer 2 transport switches
    - Enhanced management/monitoring capabilities
    - Pre-aggregation of Layer 2 services in router upgrade scenarios
- Optional optical amplification
- Additional optical monitoring capabilities via optical time-domain reflectometer (OTDR) and optical channel monitor (OCM)
- Updated installation and commissioning procedures

HOW DOES AUTO-LAMBDA WORK?

Infinera's Auto-Lambda solution is built around autotuneable optics that contain additional firmware that runs the wavelength scanning and locking process. This means that optical performance is exactly the same for Auto-Lambda optics as for the standard tuneable optics that they are based on, with no impact on the standard optical design rules for those optics. Auto-Lambda optics can therefore be used in the same networks as standard 10G optics and even higher-speed coherent optics. The Auto-Lambda scanning process utilizes the inherent capability of DWDM arrayed waveguide (AWG) optical mux/demux filters to block all but the intended wavelength from being passed through an AWG port. The process couples scanning across the wavelength range with a communication process that speeds up wavelength locking.

In the simple example in Figure 1, Auto-Lambda optics are inserted into SFP+-based devices in the central office and the remote CPE. Once inserted, these optics start to scan across the available wavelengths. Here we have four wavelengths – red, blue, green, and purple. The network designer has earlier determined that the blue wavelength will be used for the channel between this particular CPE and the central office, but the technician installing the DWDM SFP+ modules at a later date does not need to know this level of detail. The installer simply installs the SFP+, cleans the transmit and receive fibers, and inserts them into the SFP+ module. At the remote node there will often only be one pair of fibers, greatly simplifying the process as the installer will only need to identify the transmit and receive fibers from the fiber labeling and not worry about the actual wavelength required.

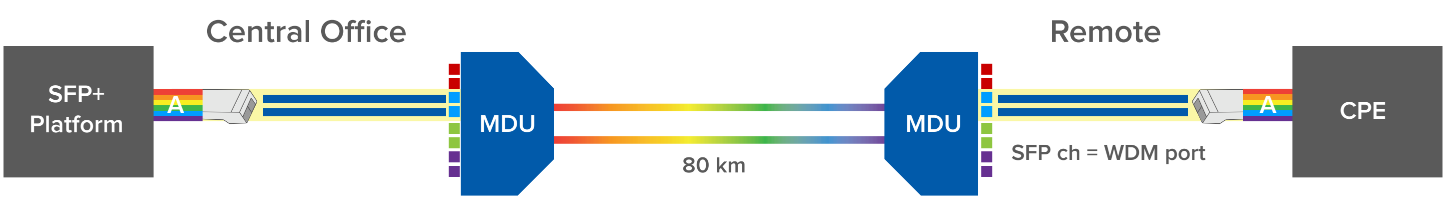

Figure 1: Auto-Lambda basic operation

Once the optics are powered up, the scanning process starts. In this simple example, if we assume the worst case, then the longest scan will start by trying green, then purple, then red, and finally blue. Each of the initial three attempts will be blocked by the AWG-based mux/demux unit (MDU), and once the optics try blue then the light will pass through the optical plant to the receiver at the far end. As the MDU blocks all the earlier incorrect scanning attempts at the input port, there is no impact on the real green, purple, and red wavelengths in our network. Once the correct wavelength is attempted, the receiver within the SFP+ module at the far end of the link will receive the scanning signal. As the receiver is a wideband receiver, it sees that light has passed through the network, but it doesn't know what the actual wavelength is. To ensure that the process works in a useable timeframe, the Auto-Lambda process also encodes data into the scanning attempts that includes the wavelength being attempted and any known information about received scanning attempts from the other end – essentially "I'm trying blue and your attempt at blue came through OK" in this case.

Each Auto-Lambda SPF+ module operates independently, enabling single fiber working in the outside plant with different wavelengths for each direction. Once both ends of the link have found the correct wavelength, then the link is established in exactly the same way as standard SFP+ optics.

Auto-Lambda optics are currently available in both conventional temperature (C-temp) and extended-range industrial temperature (I-temp) options, and with options for 48 or 96 wavelengths over the extended C-band. 48-wavelength Auto-Lambda optics typically autotune within one minute, and within three minutes in the worst case. 96-wavelength Auto-Lambda optics typically autotune within two minutes, and within six minutes in the worst case.

OPTICAL FLEXIBILITY IN THE OUTSIDE PLANT

The Auto-Lambda solution utilizes the range of standard DWDM filters within the XTM Series, as well as the extensive range of XTG Series hardened DWDM filters. This broad range of options enables Auto-Lambda to be deployed over a wide range of access and aggregation architectures, including:

- Point-to-point networks:
  - Bulk point-to-point between two locations
  - Linear networks with intermediate add/drop locations
  - Tree/spur networks utilizing band splitters and add/drop and terminal mux/demux units
- Ring networks:
  - Standard add/drop rings
  - Rings with spurs, utilizing band splitters
  - Rings with subtended rings, utilizing band splitters

KEY CHARACTERISTICS – SELF-TUNING AND HOST-AGNOSTIC

Auto-Lambda optics have two main characteristics that differ from regular tuneable SFP+ modules: they are self-tuning and host-agnostic. The self-tuning capability, as described above, essentially means that field technicians sent to a particular site to install DWDM optics can treat these optics as if they are grey/uncolored optics. They need to follow standard fiber cleaning and handling processes, but they do not need to know which wavelength they need to install in a device and therefore do not need to find a specific optic within a pool of fixed-wavelength optics or use a tuning device or management system to tune a tuneable optic to a specific wavelength. This makes the task simpler, quicker, and more reliable as it isn't reliant on correct wavelength information being passed on to the field technician. Overall this can have a significant impact on lowering the operational cost of installing and maintaining DWDM optics in access networks, especially in cases where a large number of DWDM optics are being pushed deep into access networks to support applications such as DAA or migration to 5G.

The host-agnostic nature of Auto-Lambda optics means that in addition to the field engineers treating these optics as if they were grey, third-party devices can too as they do not play any role in autotuneability either. To enable this capability, the host device needs to be able to accept third-party optics in 10G grey optics ports. This capability has become increasingly common in recent years, to the point that the majority of modern devices in networks can accept third-party grey optics, including some extended-temperature devices intended for street cabinet or outdoor deployments. To date, Infinera and the company's partners and customers have tested a broad range of third-party devices and found that the majority accept Auto-Lambda optics.

REARCHITECTING ACCESS AND AGGREGATION NETWORKS WITH AUTO-LAMBDA

The host-agnostic nature of Auto-Lambda optics enables network operators of all sizes to reconsider how they build DWDM access and aggregation networks, particularly when they are considering an upgrade from devices interconnected by grey optics to a traditional DWDM network. In these network upgrade scenarios and other DWDM network growth scenarios, the host-agnostic nature of the Auto-Lambda optics enables network operators to place DWDM optics directly into third-party devices such as routers, cell site gateways, Remote-PHY devices (RPDs), DSLAMs, and optical line terminals (OLTs). In these cases, the third-party end devices become IP-over-DWDM capable, removing the need for the dedicated DWDM hardware that usually converts traffic between DWDM and grey optics. The removal of this now-unnecessary hardware can help to greatly cost-reduce the initial capital cost of the network, and it can help reduce the ongoing operational costs associated with space and power.

But this DWDM hardware usually provides more than simply a means of converting from DWDM to grey optics, and these factors need to be considered. For example, this hardware adds a management/monitoring point and helps in the initial installation and commissioning process. To address this, a full system-wide approach to autotuneable optics is required that includes additional management/monitoring capabilities, updated installation and commissioning procedures, and updated operational processes in hardware such as amplifiers to enable them to work in an autotuneable optics environment. Infinera has addressed this wider requirement with the development of the full Auto-Lambda solution.

NETWORK OPERATOR CASE STUDY

A good means of conveying the benefits of this new approach to access and aggregation networks is to look at a case study of an operator deploying Auto-Lambda.

Background

The network operator is a large operator running a national fixed and wireless network in a large Asian country with a population of over 100 million people. The operator has a national network of access rings that interconnect edge devices at access nodes and aggregate the traffic at aggregation nodes for transport deeper into its network. These rings support a range of access technologies, such as 4G/5G cell site gateway routers, OLTs for fiber-to-the-home networks, and multi-service access nodes for business services. The access rings typically interconnect four to six access nodes, but in some rarer cases may interconnect up to 10. Each ring shares a daisy-chained 10G connection between the nodes using grey optics to connect from device to device. The total capacity in the ring is limited to 10G, so on average a node in a four-node ring would be able to support 2.5G, while a node in a 10-node ring would only be able to support 1G. These rings are now getting close to total capacity. Due to ongoing bandwidth growth and preparation for 5G, the rings need capacity expansion via a DWDM underlay network that provides a dedicated 10G wavelength per node.

Initial Customer Request

The network operator planned for a DWDM upgrade to these access rings in which each access node would have a dedicated 10G wavelength, enabling each device to scale up to its intended bandwidth level. The operator approached the optical networking vendor community for a traditional DWDM network design for these rings based on ROADMs and either Layer 1 or Layer 2 optical transport:

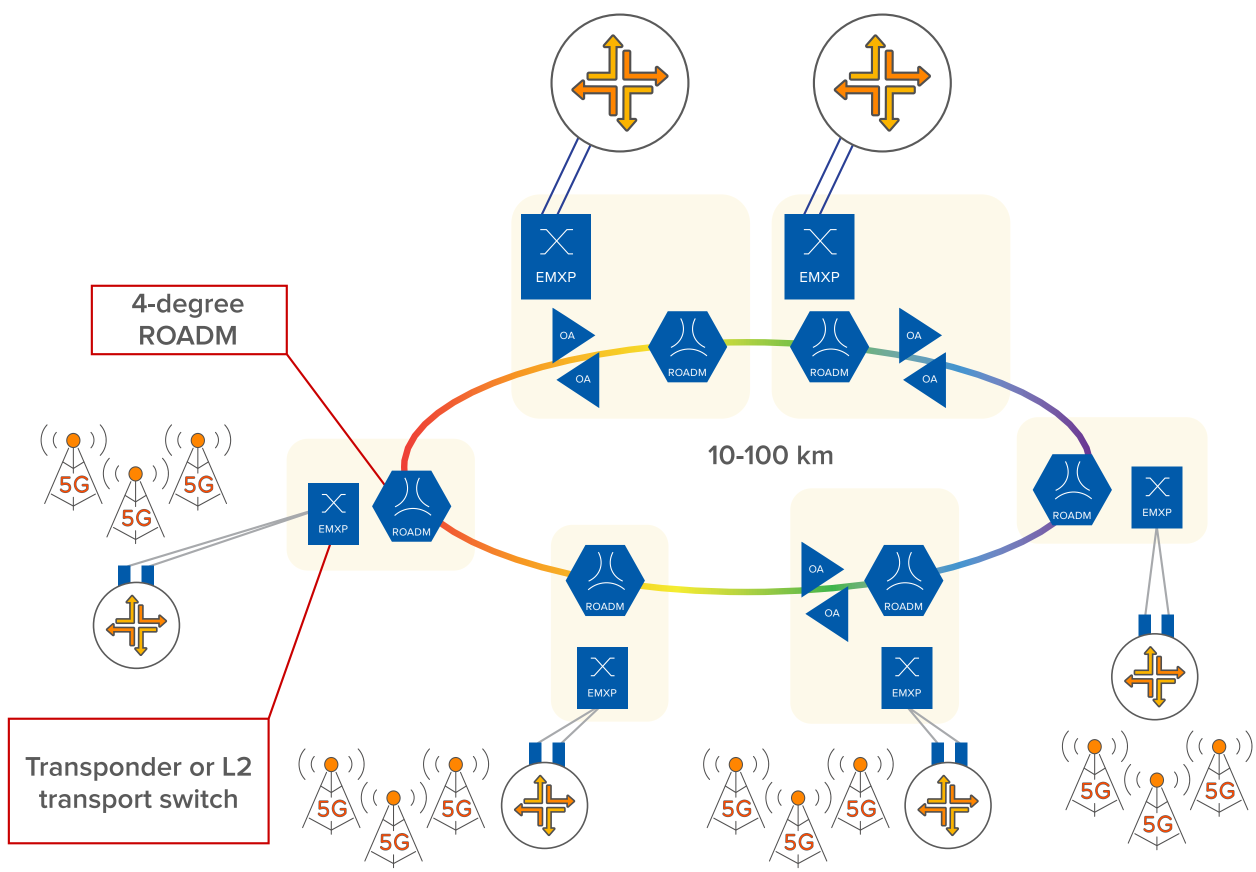

Figure 2: Traditional ROADM-based DWDM design

These access rings vary in number of nodes, as previously mentioned, and also in terms of total distance spanned. Some rings will require optical amplification to reach the longer distances of 100+ kilometers or to cope with the insertion loss of the ROADM devices in rings with a large number of nodes.

The traditional ROADM-based design meets all the requirements of the network operator, and if Layer 2 packet optical devices are used, then the traffic can be pre-aggregated using Layer 2 switching at the aggregation node to minimize the number of ports needed on the aggregation router. A Layer 1-based design would interconnect the cell site gateway routers to the aggregation routers with a dedicated Layer 1 wavelength regardless of the actual traffic level. An example ring with four access nodes would need four partially filled 10G ports per aggregation router, with each port only running at 25% of the capacity in the previous shared grey 10G scenario on average on the day of the upgrade. An example using Layer 2 aggregation would have just two 10G ports per aggregation router, one fully loaded with existing traffic and one ready for growth traffic, as shown in Figure 2, where the EMXP devices provide Layer 2 switching and aggregation.

Infinera, along with other vendors, provided a quotation for this design, and Infinera also provided an additional quote based on an alternative Auto-Lambda-based design.

Alternative Auto-Lambda Design

The alternative Auto-Lambda-based design greatly simplified the network architecture and reduced capital and ongoing operational costs. This was achieved in two steps. The first was to remove the ROADM modules from each site. These were requested so that each node had a simple way to expand capacity in the future, which can be achieved more cost-effectively with Infinera's broad range of hardened passive filters. In this case, each site was provided with a simple four-wavelength add/drop filter, which provides up to 600 Gb/s of growth capacity via three upgrade wavelengths capable of up to 200 Gb/s each. A broad range of other filter options is available. This first step removes approximately a third of the initial capital cost of the network without impacting the network's capabilities.

The next step is to use Auto-Lambda optics directly in the third-party cell site gateway routers, making them IP-over-DWDM capable without any upgrade to the router. Removing the transponders does remove a management point within the network, so some additional management tools are added, such as OTDR and OCM, to provide the necessary level of monitoring and fault-finding capabilities.

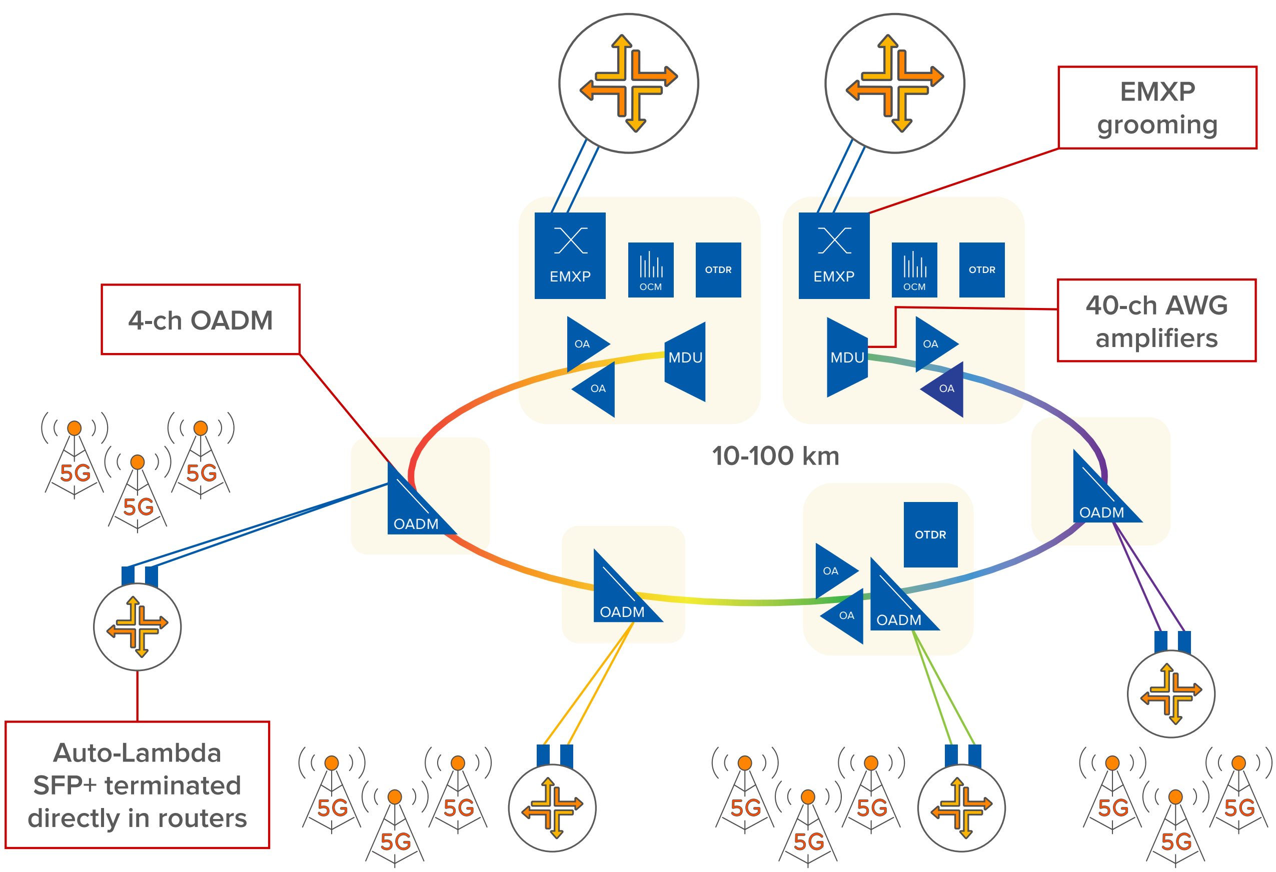

Figure 3: Alternative Auto-Lambda-based design

This Auto-Lambda-based design still utilizes Layer 2 pre-aggregation in the main aggregation nodes to avoid unnecessary burden on the router ports of the aggregation routers. Overall, the revised Auto-Lambda-based design removes another third of the remaining cost after the removal of the ROADMs, thereby approximately halving the cost of the original design.

In addition to the initial capital cost savings, ongoing space- and power-related operational costs are also greatly reduced as most access sites now only need a passive filter. In the four-node example above, the overall power consumption of the optical network components in the ring is reduced from 1712 W to 514 W, giving a savings of 70%.

Case Study Summary

This particular case study addressed a network operator that has deployed Auto-Lambda in volume for a network upgrade scenario where existing routers needed a DWDM underlay network to provide additional capacity to support growth plans for 5G. The savings shown in the case study are equally applicable to any other router upgrade scenario where a DWDM underlay network is being considered. As the network is a large collection of similar rings, all the savings shown in the case study are applicable to any customer, from the largest network operators with hundreds or thousands of similar access rings to enterprise customers who may only have a single ring interconnecting regional offices back to a centralized headquarters location.

The case study showed that the Auto-Lambda-based alternative halved the initial capital cost of the network and provided significant ongoing space- and power-related operational cost savings. Using the capabilities of the management system, as well as additional optical monitoring and fault-finding capabilities, the operator is able to manage the network well even without the former transponders.

FUTURE EVOLUTION

The Auto-Lambda solution continues to evolve as more customers evaluate it for an ever-widening range of applications. The solution today covers a broad range of physical network topologies, third-party network equipment and applications, and network growth scenarios. The approach taken by Infinera works by applying a tuning process to standard SFP+-based DWDM optics that support both simple G.metro-based point-to-point networks and more sophisticated amplified aggregation ring networks. Today the solution supports a range of 10G SFP+ extended C-band optics modules covering 48 channels at 100 GHz spacing and 96 channels at 50 GHz spacing, and both C-temp and I-temp options. The next logical step is to apply the Auto-Lambda process to 25G SFP+ DWDM optics as these become available in 2020. 25G DWDM optics are typically limited to about 12-15-km reach, which limits their use in many applications but makes them highly attractive for eCPRI-based 5G mobile fronthaul, which is one of the main drivers for 5G and is already limited to about the same distances due to the latency limitations in fronthaul networks.

A further development that is currently underway is the addition of a toggle mode for Auto-Lambda optics modules where a user can select from a range of operational modes to help with the initial installation of the optical ring or to change the behavior of the Auto-Lambda optics under fault scenarios. The toggle mode feature will enable the user to set the mode of the optics through a handheld tuning box that can be managed by a smartphone or through selected XTM Series devices such as the EMXP Layer 2 packet optical transport switches.

SUMMARY

Auto-Lambda optics and the complete Auto-Lambda solution can have a significant impact on simplifying and cost-reducing the installation and maintenance of many access network applications. In simple G.metro-based point-to-point networks, the simplification of the installation of DWDM optics makes them as easy to install as grey optics, which can speed up installation, reduce errors, avoid the need for additional DWDM training for field engineers at remote locations, and simplify inventory and spares handling. The host-agnostic behavior of Auto-Lambda optics and the complete support of the wider Auto-Lambda solution can also reduce initial capital expenditure by up to 50% and greatly reduce ongoing network operational expenditure by removing the need for some networking hardware. In all cases, the breadth of the complete Auto-Lambda solution is critical to enable deployment in a wide range of networking topologies and to ensure full management of the network.