AUTO-LAMBDA: INFINERA'S SOLUTION FOR AUTOTUNEABLE DWDM IN ACCESS NETWORKS

Introduction

The demand for access capacity continues to grow, most recently driven by major fiber-deep architectural shifts, such as 4G LTE-A in mobile networks and the evolution to Converged Cable Access Platform (CCAP) and Distributed Access Architecture (DAA) in cable networks. This trend is set to continue at an ever-faster rate as mobile networks move to 5G and the DAA approach in cable networks leads to the mass rollout of Remote PHY devices (RPD).

The G.Metro initiative within the International Telecommunications Union (ITU) has been looking at standardizing how wavelength-division multiplexing (WDM)-based networks can support simplified, cost-reduced access networks to support this trend, and describes a WDM-based passive optical network (WDM-PON) approach at symmetrical transmission speeds of 10 gigabits per second (10G). This includes optics modules that autotune to the required wavelength to simplify network rollout and sparing. Network operators using this technology can then achieve a reduction in both the time and cost required to rapidly and economically scale their optical networks to support these new fiber-deep architectures.

Infinera has been an active participant in this standardization initiative and is now introducing Auto-Lambda, the company's autotuneable dense wavelength-division multiplexing (DWDM) technology, to the XTM Series to enhance the platform's range of access-optimized capabilities in packet-optical Ethernet and Layer 1 applications.

In this document, we describe Infinera's Auto-Lambda technology, which currently provides two options for autotuneable DWDM. The first, based on G.Metro, is a sideband-based approach with a wider application scope, including but not limited to fiber pair applications, while extending reach and increasing capacity. The second also extends reach and capacity, but takes a wavelength scanning-based approach to support both single fiber and fiber pair applications. Both options support host-independent operation. In other words, the autotune logic can be implemented within the enhanced small form factor pluggable (SFP+) module, and does not require explicit support in the remote end hardware, making these options highly suitable for access applications.

Both of these autotuneable DWDM options operate over a standard C-Band, allowing standard DWDM filters to be used, and allowing the technology to be deployed over previously deployed DWDM networks.

Finally, the XTM Series with Auto-Lambda is integrated into an open software-defined networking (SDN) control and management architecture to further reduce operational costs and enhance scalability. Infinera's Xceed Software Suite SDN platform, for example, offers a turnkey solution for the Auto-Lambda access implementation.

Wavelength Routing in the Optical Plant

The Infinera XTG Series consists of a family of passive coarse/dense WDM filters and splitters, housed in a range of form factors for deployment in central office facilities as well as other environments such as street cabinets, underground chambers and manholes. The XTG Series complements the optical filters within the XTM Series, and networks can mix and match filters from the two product ranges to meet specific network deployment requirements. The XTG/XTM Series wavelength multiplexers can be deployed in a linear, ring or mesh topology, allowing fully flexible routing of selected wavelengths over the chosen fiber paths.

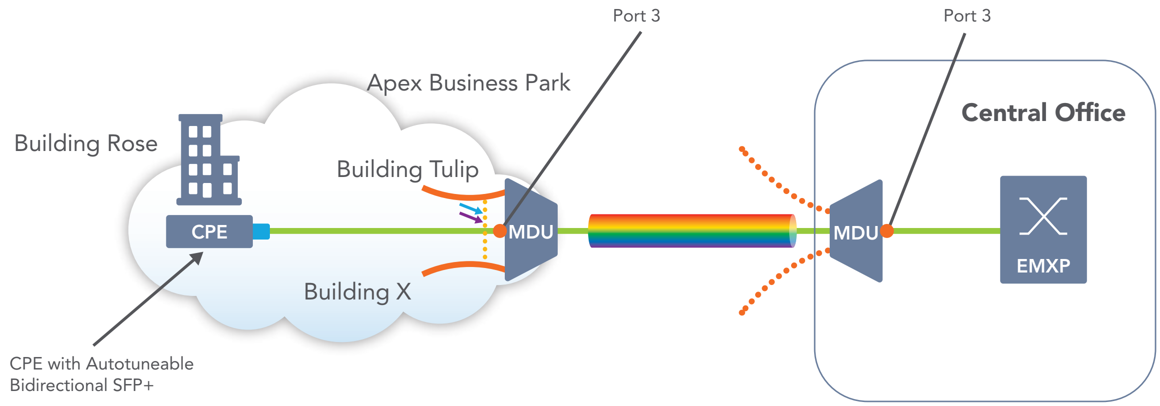

Figure 1: Note that the Port 3 to Port 3 Mapping Shown Here Assumes the Same Type of MDU is Used at Each End of the Link (e.g. 8-channel to 8-channel). It is Also Possible to Deploy, for Example, a 40-channel Unit in the Central Office and Cascade a Number of Smaller MDUs in the Optical Plant

In the context of Infinera's Auto-Lambda capabilities, Figure 1 illustrates a typical scenario for the deployment of high-speed services into a sample multi-tenant location—Apex Business Park. Note that the fiber between the central office and the Apex Business Park mux/demux unit (MDU) will carry multiple wavelengths, while the function of the MDU is to split these wavelengths and send them over individual fibers to the appropriate buildings. Each port of the MDU is configured to allow only one wavelength through the MDU, onward through the multi-wavelength optical plant and toward the central office.

In this example, the fiber from Building Rose in the business park is connected to port 3 of the MDU and is associated with the "green" wavelength - only light of this wavelength will be routed through the optical plant to the corresponding port 3 in the optical line terminal (OLT) in the central office. If, as indicated in Figure 1, an engineer in Apex Business Park plugs a "red" or "blue" optical module into port 3 by mistake, or if an autotuneable module scans across the C-Band, any light other than the green wavelength will be blocked at the MDU and will not pass onto the multi-wavelength fiber. Most importantly, it will not interfere with any existing wavelength services already on multi-wavelength sections of fiber. Likewise, if a green module is plugged into any other port than port 3 on this MDU, it will be blocked, and will not interfere with existing services.

Note that the optical plant is symmetrical in terms of this wavelength selectivity. In the central office OLT, port 3 is also associated with the green wavelength, and if a different wavelength is injected into this port by mistake, the MDU in the central office will block it and prevent interference with existing services on the shared fiber. This port 3 to port 3 mapping assumes both MDU units are of the same type, e.g. 8-channel or 40-channel DWDM MDUs, as shown in Figure 1. It is also possible to build networks with 40-channel filters in the central office and a number of cascaded smaller MDUs out in the access network. In this case, port 3 on an 8-channel MDU in the access network may map to a different port on the central office MDU.

This property of the optical plant is entirely passive. It requires no moving parts, is extremely temperature-insensitive, and requires no electrical power. The passive wavelength routing described above is essential to the operation of both autotuneability mechanisms described in this application note, and makes the system robust in the face of failures or misconfigurations.

Auto-Lambda Options

This document describes two different and potentially complementary approaches to autotuneability within XTM and XTG Series-based optical access networks at data rates up to 10G. The key features of each are summarized in Table 1.

	Auto-Lambda Options	
Variant	Sideband-based	Wavelength scanning-based
Data rates	1 Gigabit Ethernet (GbE)-10 GbE, Common Public Radio Interface (25G future)	2.5G-11.3G (25G and 100G+ future)
Single- or dual-ended operation	Dual-ended	Single-ended
Fiber plant	Single fiber	Single or dual fiber
Transceiver fiber type	Single	Dual
Reach	20 kilometers (km) (20 decibels [dB])	Various options including 80 km (23 dB)
Channels	40 (100 gigahertz [GHz]) C-Band	40 (100 GHz) or 80 (50 GHz) C-Band
Host independence	Yes	Yes
Remote-end temperature range	E-temp	C-temp/E-temp options

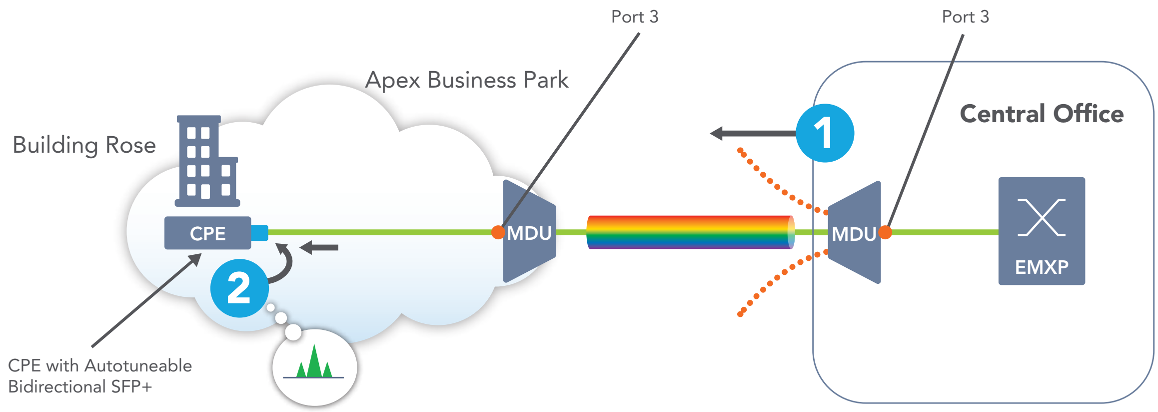

Figure 2: Sideband-based Auto-Lambda Installation

Note that most of the features in Table 1 are self-explanatory, but the following clarifications may be useful.

Single- or Dual-ended Operation

One of the challenges in optical access networks is to provide dense and cost-efficient optics at the head end, where all the remote connections are aggregated together. The wavelength scanning-based variant of the Auto-Lambda feature can be deployed with one type of optics in the remote end and another in the head office, i.e. single-ended operation. This allows for further optical innovation at the head end, such as using fixed 10G optics or access variants of photonic integrated circuits (PICs) to increase scale and density and reduce cost. The sideband-based option uses the same optics in both ends and is therefore referred to as dual-ended operation.

Host-independence

Both options are referred to as host-independent, as the autotune protocol is implemented in the SFP+ itself. This means that any customer premises equipment (CPE) or remote device that supports the SFP+ form factor should be able to benefit from the autotune feature. Both options require that the DWDM system in the central office have software support to manage the autotuneable capabilities.

Sideband-based Auto-Lambda

This variant of the Auto-Lambda technology is optimized for single-fiber access options and is compliant to the G.Metro specification. Using a sideband-based variant of WDM-PON, this option brings a range of benefits to access networks. The sideband is a low-frequency communications channel between the optics at either end of the link that is separate from the main data channel, which can be used to share additional management information between the two optics modules.

Figure 2 can be used to explain the basic configuration of the side-band-based option. In this scenario, the link always uses a single fiber, not a fiber pair.

A packet-optical switch such as the Infinera EMXP is located in the central office, housed in an XTM Series chassis. At the remote end, any CPE device may be used because the sideband-based option is host-independent. What this means is that the autotune protocols are integrated into the Auto-Lambda SFP+ module itself.

The following procedure assumes that port 3 in the MDU in Apex Business Park is configured to allow the green wavelength to be routed to the corresponding port 3 on the MDU in the central office.

Note that the term "management system" currently refers to Infinera's Digital Network Administrator for XTM Series (DNA-M) management system, but the EMXP comes equipped with an OpenFlow application programming interface (API), so the management processes can also be implemented using an SDN controller, such as Infinera's Xceed platform.

Step 1: Central Office Configuration

In the central office, port 3 on the MDU is patched to an Auto-Lambda SFP+ in the EMXP unit. The SFP+ will start up and tune to the wavelength configured in the host device – in this case the EMXP traffic module will tune it to the green wavelength. Note the central office host device will require software support for this type of autotuneable optic.

The green wavelength will be directed through the optical plant, emerging at port 3 on the MDU in Apex Business Park.

Note that a low-data-rate sideband communication channel will be transmitted by the central office device over the green wavelength. Prior to any handshake with the remote end device, this sideband will carry the information that this is the green wavelength.

Step 2: Remote End Configuration

At some point, an engineer will install the remote end CPE device. The SFP+ will start up and the wideband receiver will immediately receive light from the MDU, including the sideband information that will allow the module to tune into the green wavelength. It will follow this instruction and a two-way communication will be established.

At this point, the sideband communication will switch to a performance monitoring protocol, which will continue for the duration of normal operation. The CPE device itself is not involved in this interaction and therefore host-independence is achieved.

Failure Conditions and Handling

In any access network, failure conditions can arise for various reasons, including equipment malfunction or accidental misconfiguration. The autotune protocol for the sideband-based option is designed to minimize the impact of these failure conditions. For example:

Fiber Break

Figure 3 illustrates that, in the event of a fiber break at any point in the optical pathway, both ends of the link will be forced to return to their initial configurations. In other words, the central office SFP+ will be tuned to the green wavelength, and will send this configuration over the sideband.

The remote end SFP+ will be ready to receive light from port 3 on the MDU, and will tune to the green wavelength when it receives the appropriate instructions over the sideband once the fiber break is repaired.

Remote End SFP+ Failure

In the event of a failure of the SFP+ in the remote end device, an engineer will be sent to replace the SFP+ module. The central office SFP+ will switch to its initial state once the optical signal is lost, and will transmit the green wavelength configuration information over the sideband. When the new tuneable SFP+ in the remote end is installed, the configuration information will be received and installation will complete as normal. Note that this is a significantly simpler process than replacing a normal DWDM SFP+ as the field engineer does not need to know which wavelength is required if fixed optics are used, nor does the remote end CPE need to be configured to tune the new optic to a specific wavelength if standard tuneable optics are used.

Central Office End SFP+ Failure

If the autotuneable SFP+ in the central office fails, the replacement autotuneable module will go into its initial state upon installation, and the EMXP will configure the SFP+ to the green wavelength, then transmit this information over the sideband.

Meanwhile, the SFP+ in the remote end will have switched back into its initial state upon loss of signal. It will tune to the green wavelength once it receives the configuration information on the sideband from the new central office SFP+.

Remote End Equipment Failure

In the event of hardware failure and replacement in the remote end, it would be common to swap out an entire unit, as opposed to individual SFP+ or chassis parts. In this case, the affected SFP+ module would go into its initial state, sending wavelength informa-

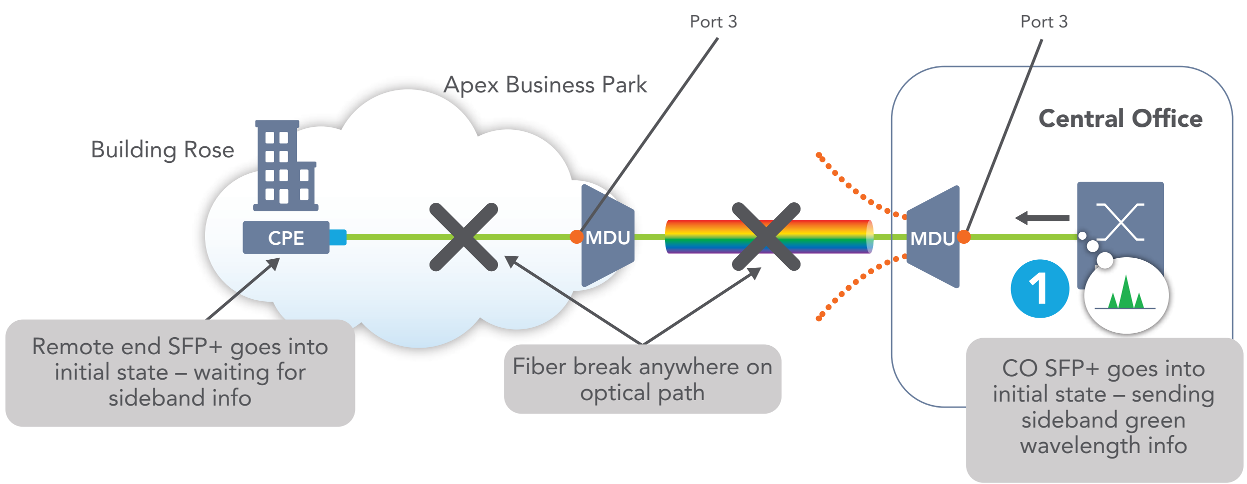

Figure 3: Sideband-based. In the Event of Fiber Break, Both Ends Enter Initial State

tion over the sideband. When the replacement chassis is powered up at the remote end, the SFP+ will pick up the sideband and tune to the green wavelength.

Central Office Equipment Failure

In contrast to the remote end, central office equipment will most likely be replaced on a port-by-port or slot-by-slot basis, unless a major failure occurs. Upon failure or removal of the affected card, the remote end SFP+ modules will be forced into standby mode, waiting for a sideband to appear. When the new equipment is brought up in the central office, the sideband signal will be sent, and the remote end SFP+ will tune to the green wavelength.

Wavelength Scanning-based Auto-Lambda

This variant of the Auto-Lambda technology extends the capabilities of the sideband-based option to include both single- and dual-fiber options, allowing deployment scenarios to encompass longer reach and higher bitrates. The wavelength scanning option enables CPE/ remote optics to use an Infinera scanning and handshaking capability to autotune the remote SFP+ to the correct wavelength.

Figure 4 can be used to explain the basic operation of the wavelength scanning-based option.

As before, the following procedure assumes that port 3 in the MDU in Apex Business Park is configured to allow the green wavelength to be routed to port 3 on the MDU in the central office, but in this case the fiber plant may be either dual-fiber or single-fiber.

Step 1: Central Office Configuration

In the central office, port 3 on the MDU is patched to an SFP+ in the EMXP unit. There are currently two options for the service provider in choosing this SFP+, with potentially more in the future, as outlined above in the description of single- and dual-ended operation, as shown in Figure 4.

If the service provider wishes to use a tunable SFP+, then the EMXP will be configured using the management system so that when the SFP+ is plugged in, it will be set to standby mode. In this mode, the transmitter will be tuned to the green wavelength with the laser off.

Alternatively, the service provider may choose to use a fixed-wavelength laser, in this case a green wavelength SFP+. Fixed-wavelength lasers are less expensive than tuneables, creating further cost savings for the service provider. To reduce spares management, service providers may choose to use fixed optics when commissioning new hardware, and tuneables for maintenance and individual upgrades.

Step 2: Remote End Installation

At some point after the central office installation, an engineer is sent to Apex Business Park to complete the installation at the remote end. Tuneable lasers will always be used in the remote end, but the only instructions this engineer needs are:

- Take the tuneable SFP+ and insert it into the CPE device, or perhaps simply plug in the CPE device because the SFP+ is already fitted in the CPE.
- Patch port 3 on the MDU to the newly installed SFP+ in the CPE.

At this point, no further intervention is needed by the engineer. The remote end SFP+ will power up and start a scanning process. The

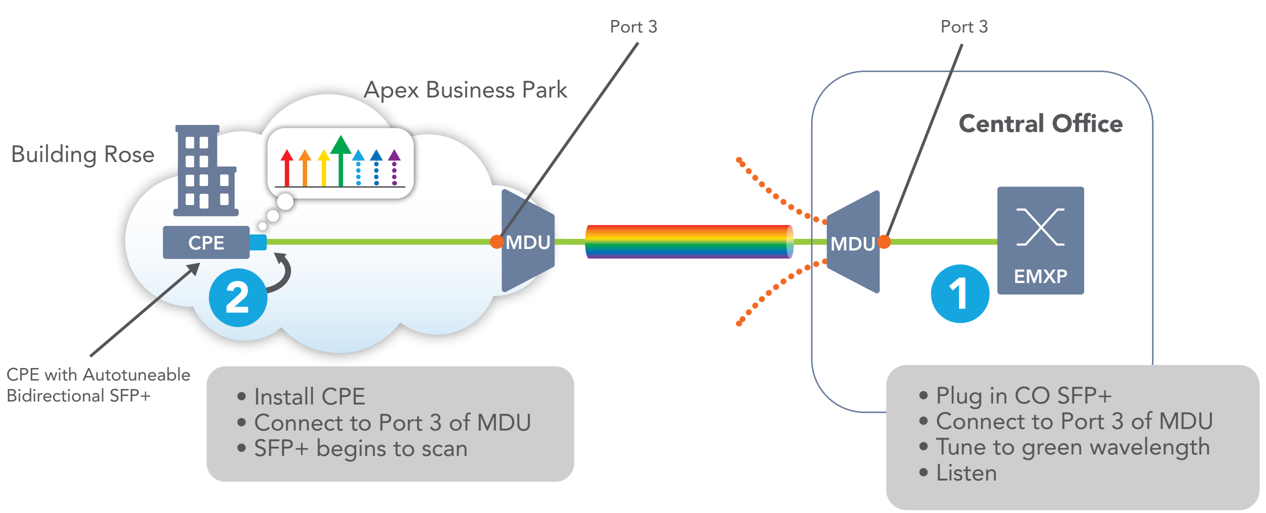

Figure 4: Wavelength Scanning-based Auto-Lambda Installation

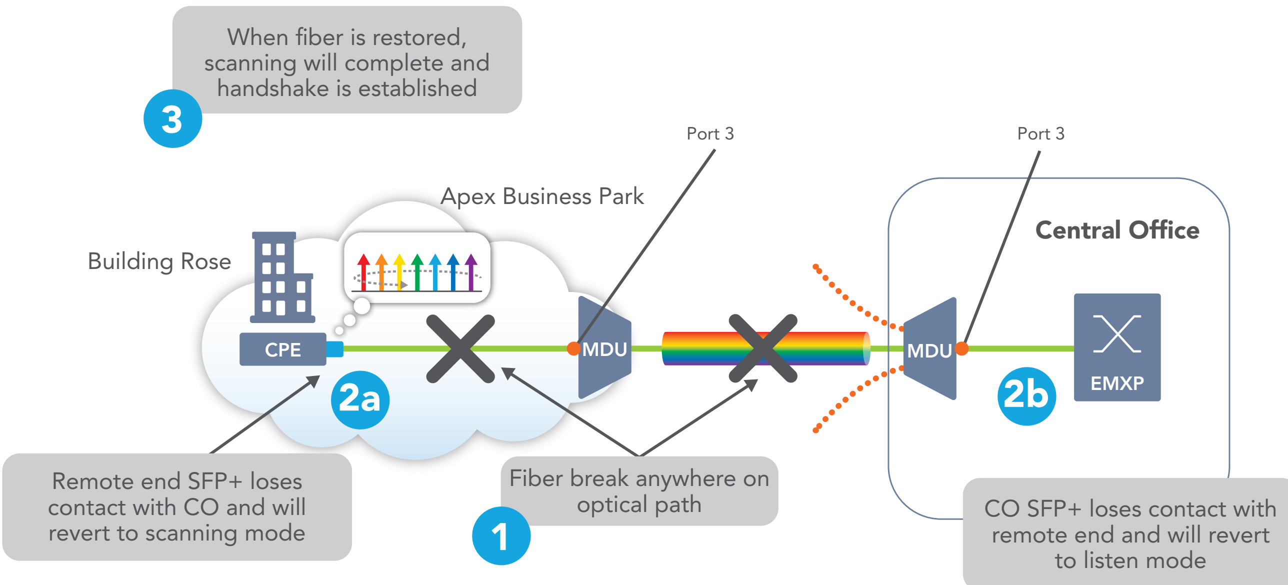

Figure 5: Wavelength Scanning-based. In the Event of Fiber Break, Both Ends Enter Initial State

scan begins at one end of the C-Band, and the remote end SFP+ will send a signal into port 3 of the MDU.

Figure 4 suggests that the scan begins at the red end of the spectrum, and so red, then orange, then yellow, and then green are tried. When green is transmitted, the filter configuration of the optical plant allows the signal to reach the central office port 3, and the EMXP in the central office will activate its transmitter and complete a handshake process that stops the scanning in the remote end SFP+. This scanning is totally automatic.

The network operations center engineer will typically confirm to the installation engineer that the installation is complete. Note that this confirmation action can be automated with a simple script – for example, to send an SMS text message to the engineer confirming successful installation.

Failure Conditions and Handling

In any access network, failure conditions can arise for various reasons, including equipment malfunction or accidental misconfiguration. The autotune protocol for the wavelength scanning-based option of Auto-Lambda is designed to minimize the impact of these failure conditions. For example:

Fiber Break

Figure 5 shows that, in the event of a fiber break at any point in the optical pathway, both ends of the link will be forced to return to their initial configurations. In other words, the central office SFP+ will be in standby mode, while the remote end SFP+ will scan across the C-Band, waiting for a signal in return. During the scanning process, only the green wavelength will be allowed through the fiber plant, which ensures that the scanning does not impact other services on the fiber. When the fiber is repaired, the scanning will complete and the green wavelength will be reestablished.

Remote End SFP+ Failure

In the event of a failure in the SFP+ in the remote end device, an engineer will be sent to replace the SFP+ module. The central office SFP+ will switch to standby mode once an optical signal is lost. When the new, tuneable SFP+ in the remote end is installed, the scanning process will initiate and installation will complete as normal.

Central Office End SFP+ Failure

In the central office, the service provider has two options, as described above: they can use a tuneable SFP+ or a fixed-wavelength SFP+. If a tuneable SFP+ in the central office fails, the replacement tuneable module will go into standby mode upon installation. This will force the remote end SFP+ into scanning mode, which will initiate the autotuning process.

If a fixed SFP+ is used, then the replacement must use the same wavelength as the original failed SFP+ module. When this replacement is installed, it will go into standby mode and await light to arrive from the remote end to complete the installation process. If a different, fixed SFP+ is inserted by mistake, the EMXP in the central office will see that there is a mismatch between the expected wavelength and the installed SFP+ wavelength and will signal this to the management system as an error. Until the SFP+ is replaced, this incorrect wavelength will be blocked by the MDU in the central office, so that the handshake between each end cannot happen. More importantly, an incorrectly chosen fixed-wavelength SFP+ will not interfere with other wavelengths operating over the optical plant.

Remote End Equipment Failure

In the event of hardware failure and replacement in the remote end, it would be common to swap out an entire unit, as opposed to individual SFP+ or chassis parts. In this case, the affected SFP+ modules will go into standby mode. When the replacement chassis is powered up at the remote end, the SFP+ will go into scanning mode and will autotune as usual.

Central Office Equipment Failure

In contrast to the remote end, central office equipment will most likely be replaced on a port-by-port or a slot-by-slot basis unless a major failure occurs. Upon failure or removal of the affected card, the remote end SFP+ modules will be placed in scanning mode. When the new equipment is brought up in the central office, it will go into standby mode and await a signal from the remote end.

Summary

In this paper, we have described Infinera's Auto-Lambda technology, which includes two different approaches to autotuneability within optical access networks. Based on a simple, passive optical plant in the form of the Infinera XTG Series solution, coupled with innovations in the Infinera XTM Series, the two methods are simple and robust. Most importantly, Auto-Lambda minimizes the operational complexity of large-scale optical access network deployment, enabling network operators to roll out networks quicker and more cost-effectively to support the proliferation of WDM-based optical access in new fiber-deep network architectures and applications.

Global Headquarters
140 Caspian Court
Sunnyvale, CA 94089
USA
Tel: 1 408 572 5200
Fax: 1 408 572 5454
www.infinera.com

Asia and Pacific Rim
Infinera Asia Limited
8th floor
Samsung Hub
3 Church Street
Singapore 049483
Tel: +65 6408 3320

Europe, Middle East, Africa
Infinera Limited
125 Finsbury Pavement
London EC2A 1NQ,
United Kingdom
Tel: +44 207 065 1340

Customer Service and Technical Support
North America
Tel: 877 INF 5288
Outside North America
Tel: 1 408 572 5288

For more information
Contact Us
infinera.com/contact-us

infinera®