PRODUCT BROCHURE

WaveLogic Photonics: Increasing Competitive Advantage with a Fully Instrumented, Agile Photonic System

Today, providers need a more programmable infrastructure that can scale and respond on demand, to meet shifting customer expectations and unpredictable traffic requirements. The photonic layer is the foundation of this programmable infrastructure, leveraging the latest coherent optical technology to deliver maximum scale at the lowest cost per bit. WaveLogic Photonics, Ciena's fully instrumented photonic system on the 6500 Packet-Optical Platform, provides an agile, resilient photonic layer equipped with tools and advanced software applications that abstract complexity, making it fast and easy for operators to make intelligent decisions based on the current state of the network. This provides an edge in quick and simple turn-up and management of services, superior performance with fewer regenerator points, improved network efficiency, and increased service availability and automation for faster time to market.

Deployed by more than 600 operators, the 6500 underpins service, content, and cloud providers; research and education; government; and enterprise networks around the globe. Its popularity hinges on several key factors:

- It can be tailored for an economic fit into a variety of applications
- It very efficiently delivers a wide range of services leveraging packet and/or OTN switching
- It practically scales to elegantly handle step increases in capacity over existing infrastructure

WaveLogic Photonics, designed by the pioneers of coherent optical solutions with deployments since 2008, provides the programmable optical network foundation for this reliable, high-performance system. WaveLogic Photonics is Ciena's fully instrumented, intelligent photonic system composed of WaveLogic coherent optics and flexible line elements that combine with embedded and discrete software tools to offer better automation, control, and visibility to the optical network.

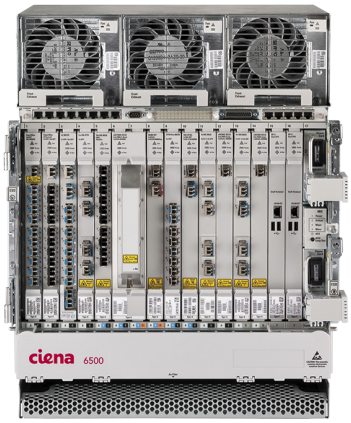

Figure 1. 6500 WDM configuration

Flexibility without Restriction

An important requisite for business success is the ability to photonically interconnect sites quickly and economically to simplify operations of the network and reduce costs, power, and latency associated with regenerators.

A key intelligence component of WaveLogic Photonics is the Domain Optical Control (DOC) software. DOC retrieves network information from the installed equipment and automatically adjusts parameters, reducing error-prone manual operations and accelerating wavelength turn-up. DOC taps into embedded power monitoring information to perform automatic per-channel power control and optimization to continuously maximize system reach and performance in real time. In addition, each amplifier and Wavelength Selective Switch (WSS) has fault monitoring capabilities via many different checkpoints, which are used to simplify system operations. The 6500 uses this information and its built-in intelligence to provide network alarm correlation, helping the operator quickly isolate the fault and take the necessary actions in the best possible timeframe. Finally, contrary to other 'boxed-in' vendor solutions, WaveLogic Photonics leverages DOC to allow for an elegant expansion of the network. Operators are able to expand connectivity to additional sites with in-service network extensions and channel add/deletions.

The 6500 offers the full range of photonic architectures—from passive filters to Colorless, Directionless, Contentionless, and Flexible grid (CDC-F) ROADMs—powering the network to send any service anywhere in the network, dynamically. Flexible grid future-proofs the network by providing the ability to right size channels to take advantage of the economic benefits associated with next-gen higher baud modems (that require more than 50GHz of spectrum). With a flexible grid, reconfigurable photonic layer operators can support a mix of existing and new higher speed coherent interfaces that will be required as the optical network evolves.

The CDC-F solution allows for maximum agility and flexibility in the photonic layer, enabling remote, automated end-to-end service provisioning, eliminating the need to drive to remote sites and insert cards or cabling to fixed direction. It eliminates wavelength routing restrictions that have typically limited operators' ability to quickly turn-up new services once their network reached a certain level of wavelength utilization. The CDC solution allows the operator to handle unpredictable A-Z services or temporary bandwidth demands over the full life of the network. Reconfigurations such as wavelength defragmentation and route optimization are also made possible to scale the network for support of more services. For maximum efficiencies, CDC can operate with the L0 control plane for increased automation of operations as well as for support of automated photonic restoration.

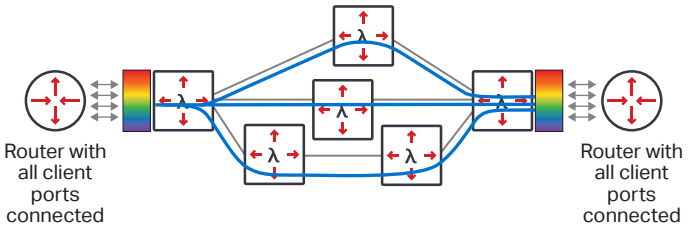

Figure 2. Automated end-to-end service provisioning with a CDC-F infrastructure

To ensure simple and foolproof deployment of this very flexible architecture, Ciena has embedded software intelligence into its CDC solution to offer the following unique operational benefits:

- Accelerated wavelength turn-up and simplified operations through increased automation, reducing the number of site visits, skilled personnel, and test equipment required
- Automatic, real-time system optimization and power-balancing, ensuring maximum system performance and reach
- Automatic system check for faults, ensuring proper system state prior to performing any maintenance activities
- Elegant network expansion with in-service channel additions and network extensions

Smarter, high-capacity coherent technology

As the volume of data traffic on the network intensifies, operators are unanimously moving toward coherent technology for reduced cost per bit and enhanced bandwidth scale. Ease of deployment of these high-capacity wavelengths varies with each solution, however, and directly influences speed of ROI.

WaveLogic Ai: Laying the Foundation for the Adaptive Network
Download application note

Ciena has unique, systems-level expertise and insights into the challenges operators face in scaling their networks. Using this knowledge, Ciena has integrated new levels of visibility into its WaveLogic coherent technology for the ability to accurately engineer the network for optimal capacity and maximum efficiency. These capabilities are integrated in a comprehensive high-capacity portfolio with programmable WaveLogic-enabled hardware tailored to address metro, regional, long-haul, and submarine applications.

Ciena's WaveLogic 3 coherent optical processors enable 100G to 200G-optimized applications through the use of innovative technology such as Soft-Decision Forward Error Correction (SD-FEC), a very robust DSP-assisted receiver, and the integration of DSP in the transmitter (Tx DSP). Ciena's WaveLogic Ai provides unprecedented systems intelligence and programmability to address the increasingly dynamic service requirements of today's on-demand networks. WaveLogic Ai builds upon the best-in-class performance of WaveLogic 3, and uses an advanced, 400G-optimized engine to significantly improve transport economics: driving twice the capacity per channel and three times the distance at equivalent capacity versus 100G/200G solutions.

WaveLogic Ai operates at a selectable baud rate of 35Gbaud or 56Gbaud, providing the ability to trade channel throughput for optical performance and spectrum usage while delivering power and space efficiency benefits over both fixed and flexible grid photonic line systems. A key benefit is that it offers the widest range of tunable capacities in the industry, from single carrier 100G to 400G in 50G increments, with embedded unique, real-time link monitoring capabilities, allowing operators to rapidly determine exactly how much margin is currently present in the network, as well as the optimal capacity they can deploy. Operators can benefit from simplified sparing and forecasting with hardware that can address any application, from high-capacity short-reach metro, to ultra-long-haul and submarine, all while leveraging a pay-as-you-grow approach. Additionally, with Ciena's best-in-class SD-FEC and DSP algorithms, operators can deploy higher capacity channels over longer reaches and eliminate regens from the network.

Ciena's coherent solutions provide previously unattainable network monitoring and efficiencies, with unique, real-time link monitoring capabilities, enabling operators to extract the most efficiency out of their network at any point in the network's life. With these embedded link measurement capabilities, operators can determine exactly how much margin is currently present in the network, as well as the optimal capacity they can deploy. Combined with Liquid Spectrum™ analytics, applications such as predictive link failure now become possible, allowing operators to pre-empt outages with scheduled maintenance activities. Users can access the following critical real-time link measurements:

- Pre-FEC BER, Pre-FEC Q (average, max)
- Tx power level
- Rx total power and channel power
- Maximum, average, and real-time DGD
- PDL (average, max)
- Total Rx and total Tx link dispersion
- Estimated fiber length
- Estimated unidirectional latency
- Effective Signal-to-Noise Ratio (ESNR)

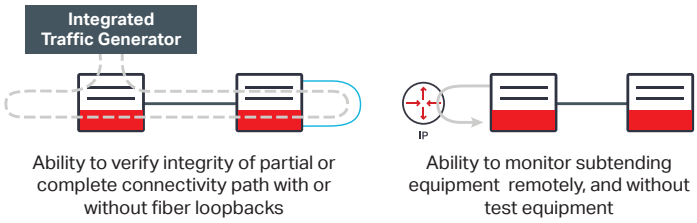

Figure 3. Integrated Test Set for high-capacity wavelengths

Additional WaveLogic Photonics 'smarts' of Ciena's coherent solutions include the continual access and monitoring of physical network parameters, which can be analyzed to provide on-the-spot, route-specific, optimized-link budget engineering to achieve optimal system performance.

Another way Ciena has simplified the deployment of high-capacity coherent solutions is through the integration of test-set capabilities into the transponder equipment, allowing operators to test the complete or partial network path of a given service. The Integrated Test Set (ITS) feature was specifically designed to alleviate, or even eliminate, the need for external test sets for services carried over high-capacity wavelengths—equipment that is costly and complicated at the higher rates. ITS functionality provides several modes of operation. For instance, it supports the ability to remotely loop back far-end equipment located a few thousand kilometers away, and can include subtending equipment such as routers capable of transparent loopbacks. ITS can also be used in conjunction with remote loopbacks to quickly isolate a failure. For muxponder applications, each client port can support an instance of ITS concurrently. For a 10x10G mux, this is equivalent to having ten external test sets running simultaneously, testing ten individual channels. Finally, ITS capability provides a utility to save test results for historical service validation records.

In summary, the networking advantages of Ciena's WaveLogic coherent solutions include:

- Superior reach with fewer regenerator points
- Programmable modulation to quickly adapt and optimize for reach, capacity, and latency
- The ability to operate over any fiber
- Continual access to network parameters for proactive maintenance or system link budget optimization
- Faster/simpler turn-up of wavelengths leveraging ITS capability

Intelligent Line System with PinPoint Advanced Fiber Analytics

Providing unprecedented visibility from the NOC directly into the fiber plant, WaveLogic Photonics also comprises unique PinPoint Advanced Fiber Analytics. PinPoint integrates Optical Time Domain Reflectometer (OTDR) capabilities to transform the way operators monitor and react to fiber degradation or faults in the network.

In the event of a fiber cut, the WaveLogic Photonics system will automatically initiate PinPoint OTDR. The generated trace is available to any remote user seconds after the fault is experienced, enabling the NOC to precisely pinpoint the fault location. The traditional, lengthy troubleshooting step of sending technicians with test sets to either end of the failed span to localize the failure is now completely eliminated; instead, the technician is dispatched to the precise fault location and can promptly execute the repair. This quick turnaround results in increased network availability and reduced outage times.

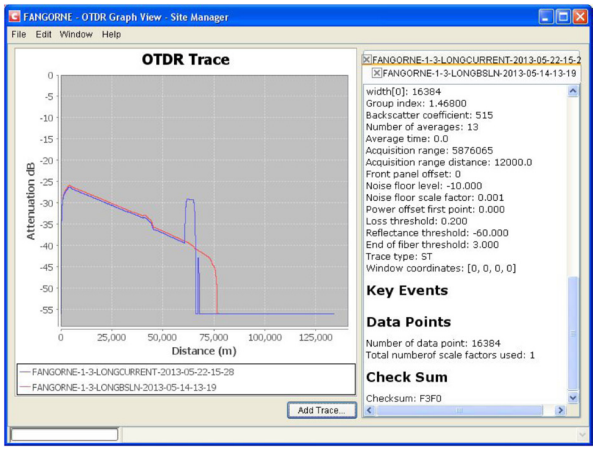

Figure 4. Integrated OTDR benefits in the event of a fiber cut

Another important benefit of PinPoint is that operators can now compare OTDR traces over time. When the line interface modules are initially turned on, the initial OTDR trace is run and set as the baseline. This baseline can be used to compare new traces during fault scenarios to quickly isolate the fiber break, and can also be used post-failure to validate that the fiber repair has been properly effected.

Enabling new levels of proactive fiber monitoring and maintenance, operators can also run PinPoint over traffic-carrying links. The user can leverage this powerful tool to proactively check for fiber degrades or bad repairs and

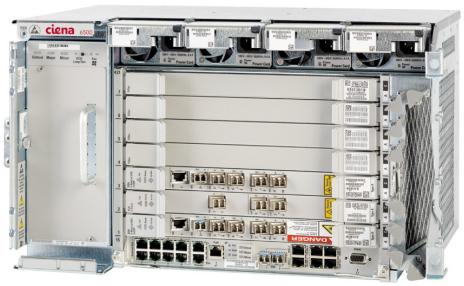

Figure 5. 6500 Hybrid Raman/EDFA configuration

immediately identify potential issues that can be quickly dealt before services are impacted.

Smart Raman

As operators move toward higher-capacity wavelengths, regenerators become increasingly cost-prohibitive and need to be minimized or avoided. At the same time, new coherent modulation schemes increase spectral efficiency of a network, but can carry a significant reach penalty. Raman amplification is an effective tool that addresses these challenges with its ability to:

- Avoid regeneration due to one or few longer (lossier) spans
- Increase un-regenerated service reach

Typically, many operators have shied away from using Raman because it was more operationally challenging to deploy. The high power emanating from the module—along with Raman's use of the fiber plant as the gain medium—creates challenges for turn-up and troubleshooting, as the criteria for connector cleanliness and splice quality are more stringent than what is required for EDFA-only solutions. Ciena has used knowledge gained from its experience during decades of optical deployments to develop an innovative, fully instrumented Raman solution that eliminates the pain points of previous solutions.

First, Ciena has integrated PinPoint OTDR capabilities directly into the Raman amplifier, which greatly simplifies both turn-up and fault isolation procedures. During turn-up, PinPoint provides a quick and controlled turn-up by autonomously testing the fiber plant to detect unacceptable connector and fiber conditions before the amplifier is allowed to turn on. This controlled turn-up process prevents equipment and fiber damage, which could cause additional deployment costs and delay.

PinPoint also allows for rapid, remote fault isolation for Raman applications, again eliminating the need for expensive, dedicated testing devices and remote support staff. PinPoint baseline and in-service traces can also be used to identify and localize high connector losses or reflections and ensure the fiber plant is conditioned for optimal performance.

Ciena's Smart Raman works alongside its next-generation switchable line amplifier module, or XLA. The XLA is a programmable EDFA circuit pack that can be configured remotely to operate in one of two different gain modes for each line-facing direction, High or Low, where each direction can be independently provisioned. With the new XLA, operators need only standardize, forecast, and spare one single circuit pack to meet all their EDFA requirements. With the combination of Ciena's new Raman and XLA, operators can maximize system performance and increase reach by 25 to 40 percent.

The many networking benefits of Ciena's next-generation line amplification solution include:

- Increase in system reach by 25 to 40 percent using Ciena's hybrid Raman/EDFA solution
- Automatic check for dirty connectors or other impediments with Smart Raman not turning on at start-up without 'clean' OTDR results, avoiding connector and fiber plant damage

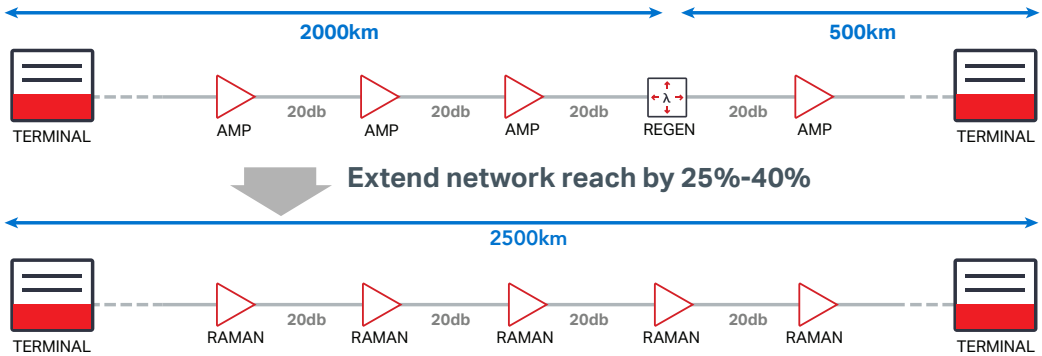

Figure 6. Extending system reach with Ciena smart Raman solution

- Establishment of a start-of-life OTDR baseline with PinPoint to allow for remote, proactive monitoring and maintenance
- PinPoint remote, precise fault isolation, eliminating unnecessary truck rolls and significantly improving repair times

Proven, intelligent L0 control plane

Beyond the integrated software intelligence mentioned thus far, operators using the 6500 have the option of enabling L0 control plane to further simplify operations via improved automation and increased availability. A photonic control plane is an important component enabling a programmable network foundation that can support changing service requirements and the bandwidth-on-demand type of services, at the right cost points.

Ciena's intelligent L0 control plane is a control software that uses real-time network topology to provide automated self-inventory and accelerated service provisioning for faster turn-up of wavelengths, increased automation for efficient planning and operations, and photonic restoration. As illustrated in Figure 7, operators can leverage L0 control plane with L1 (OTN) control plane to increase network availability at lower cost than using OTN alone and guarantee strict customer Service Level Agreements (SLAs) with less deployed equipment. SLAs can range from unprotected to 50ms protection against any number of faults and everything in between. And for unprotected services, L0 control plane ensures Mean Time to Repair guarantees can be met at little additional cost.

Another important benefit is that it facilitates wavelength re-grooming, enabling operators to perform proactive network maintenance in a condensed maintenance window with fewer truck rolls. Wavelength re-grooming can also be used to re-route wavelengths onto shorter, more optimized paths to reduce regenerator ports and service latency and rebalance wavelengths to extend the life of the existing network.

Ciena's L0/L1 control planes leverage more than 15 years of control plane development and optimization based on the world's largest mesh customer deployments, which are associated with Ciena's switching products. This consistent design opens the door to inter-layer control plane communications for expanded network visibility and further restoration optimization down the road.

The networking benefits of Ciena's L0 control plane include the ability to:

- Offer new types of SLAs and improve service availability at low cost with photonic restoration
- Accelerate wavelength turn-up and response to new service requests
- Facilitate proactive maintenance procedures
- Enable a programmable network foundation that can adjust to handle on-demand service requests

Software Control and Automation

Blue Planet® Manage, Control and Plan (MCP) is Ciena's domain controller, which unifies and automates network and service operations across Ciena's multi-layer packet-optical infrastructure. MCP works in conjunction with the OnePlanner Unified Design System to provide comprehensive wavelength planning and management, so that operations teams can quickly plan, provision, manage, and assure services over their entire network, as it evolves. Network planning teams no longer have to rely on manually maintained, outdated spreadsheets. With MCP and OnePlanner, these teams now always have an up-to-date view of their deployed network so they can optimize network utilization, plan for bandwidth growth, and model fiber characteristics.

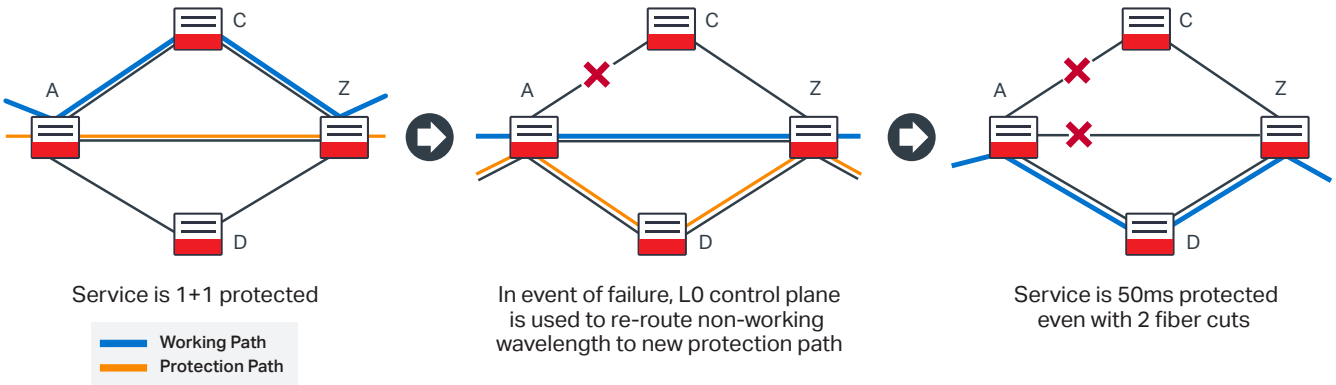

Figure 7. Ciena's L0 control plane increases network availability with less equipment

From a management perspective, MCP automatically discovers a network's elements, configurations, and topology directly from the network itself to ensure an accurate view of what is deployed. MCP's advanced visualization and easy web-based user access enables wavelength services to be provisioned easily with a few simple mouse clicks, eliminating manual, error-prone, hop-by-hop provisioning and ensuring rapid time-to-market and higher customer satisfaction.

Additionally, MCP provides full wavelength service visualization through real-time monitoring and alarm notifications so the Network Operations Center (NOC) can proactively manage the photonic network and ensure it is working at peak performance and utilization. Critical metrics such as power levels, latency, PreFEC, and Bit Error Rate (BER) are readily available from the map for any particular link, wavelength, or channel. Graphs depicting the power levels of a specific service are also available for each intermediate point in the service. In addition to real-time performance management, MCP provides service alarm correlation; an operator can simply select a service to see any/all alarms associated with that service. Node- and link-level alarms are color-coded on the map for easy fault detection and isolation.

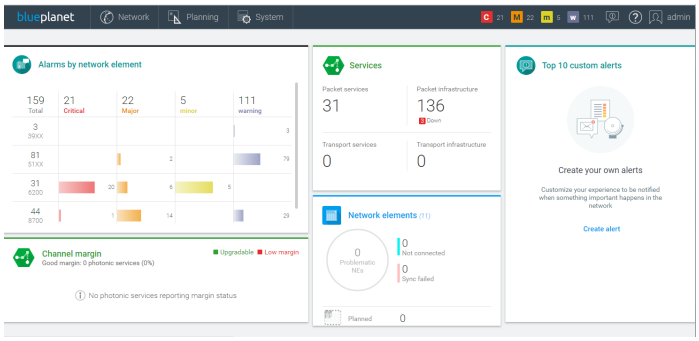

Figure 8: Blue Planet MCP dashboard gives full visibility of network and services

In light of ever-increasing customer bandwidth demands, operators are looking to get the most out of their deployed network infrastructure. OnePlanner can ensure optimal network utilization now and in the future. Network bottlenecks, stranded bandwidth, and fiber aging can easily be identified and remedied before they affect customers. OnePlanner Capture is a critical element in Ciena's comprehensive planning and design tools. Unlike other planning tools—which rely on manually entered data and fiber characteristic estimates—OnePlanner Capture records snapshots of network data directly from the network to ensure network planning activities are based on up-to-date, valid data. Captured parameters include: network inventory, fiber characteristics (ex. per-span fiber loss, fiber type), and wavelength-specific parameters (latency, Polarization Mode Dispersion [PMD], and BER). This detailed photonic data is used to monitor the general health of the network against historical benchmarks to allow network operators to better understand and address the health trends of their network assets. OnePlanner Capture also actively notifies operators of degraded health parameters based on user-defined thresholds, allowing network operators to proactively adjust and account for service fluctuations and avoid service outages.

Learn more about WaveLogic Photonics

OnePlanner works in conjunction with OnePlanner Capture, allowing network planners to access captured data to plan growth and analyze utilization and photonic performance. Completed plans can then be imported directly into MCP, so that the NOC has a comprehensive view of current, as well as planned, resources. Online creation or modification of future services, over the newly planned infrastructure, is integrated within MCP.

To further streamline and automate business processes, Blue Planet MCP offers open REST APIs which allow for ease-of-integration with other backend Operations Support Systems (OSS). Testing of MCP's REST APIs is available to operators, third-party developers, and partners through a web portal to Ciena's Emulation Cloud™, which provides a simulated Ciena network environment. This means that full solution integration can proceed rapidly, without waiting for deployment of physical resources.

Fully programmable and instrumented infrastructure with Liquid Spectrum

WaveLogic Photonics leverages the power of analytics and intelligence to drive advanced software applications to abstract complexity associated with advanced flexible technologies, making it fast and easy for operators to make intelligent decisions based on the current state of the network. Ciena's Liquid Spectrum network solution combines highly instrumented, programmable hardware with advanced software applications to help operators extract the most value from their existing network resources. Value can be quantified as improved efficiency, increased capacity, stronger channel reach, increased service availability, or increased automation for faster time to market.

Integrated as part of Blue Planet MCP, Liquid Spectrum analytics apps leverage the programmability of WaveLogic coherent hardware to precisely match the capacity of a wavelength to the system margin required to traverse a specific path of the network, at any point in time. As an example, operators can mine available network margin and convert it to capacity on demand, allowing them to instantly dial bandwidth up or down, or improve service availability during a disaster recovery situation. Here are some examples of Liquid Spectrum applications that help operators extract the most value from the network:

- Channel Margin Gauge gives operators instant visibility into the efficiency of their networks and lets them know if they can run their deployed optics at higher capacities.
- Planning Tool Calibrator accesses real-time fiber characterization data, which then feeds into planning tools to ensure optimal network designs, without all the manual-link engineering and spreadsheet-checking processes currently in use today.
- Bandwidth Optimizer simplifies and accelerates wavelength turn-up through real-time monitoring and automation, providing users with optimal capacity, spectral assignment, and equipment needs based on service requirements.
- Liquid Restoration increases service availability with the ability to flexibly adjust the transport capacity of deployed coherent optics as needed for optical restoration across any available path in the network.

With Liquid Spectrum, operators can leverage a fully programmable infrastructure with operational simplicity via sophisticated applications, enabling access to new revenue streams and the ability to more fully monetize existing assets.

Summary

WaveLogic Photonics, Ciena's fully instrumented, intelligent photonic system, significantly reduces complexity from an operational perspective, making it fast and easy for operators to respond to service demands. The integration of important test set capabilities such as power monitoring, connection validation, and integrated OTDR further simplifies initial network deployment and ongoing maintenance over time.

Ciena's customers can enjoy the following substantial benefits resulting from WaveLogic Photonics:

- Faster service turn-up
- Reduction of test equipment and operational expenses associated with skilled field personnel
- Reduction in the Mean Time To Repair (MTTR) through effective and rapid remote fault isolation
- Increased network efficiency with new levels of intelligence and programmability
- Network scalability to 400G and beyond
- Increased differentiation via improved network availability

As operators evolve toward a more scalable and programmable infrastructure to meet changing customer expectations, an intelligent agile optical layer becomes a critical requirement to offer the necessary flexibility and resiliency. WaveLogic Photonics provides a competitive advantage in this network transformation with its unique abilities to accelerate service responsiveness for any A-Z traffic demand and scale for growth.

Technical Specifications

OADM/ROADM

Full suite of:

- Passive filters
- 50GHz, 75GHz, 100GHz, flexible grid ROADMs
- Colorless, Directionless, Contentionless ROADMs
- Coherent Select Architecture

Coherent optics

Coherent 400G muxponder (4x100G) with integrated OPS (Optical Protection Switch)

Coherent 400G flexible service transponder (34 client ports) with integrated OPS

Coherent 100GE/OTU4 transponder

Coherent 100G muxponder (10x10G)

Coherent tunability from 100G to 400G in 50G increments

Coherent 200G client card: 2x100GE or 5x40GE/10GE

Coherent 100G client cards: 10x10GE, 10x10G multi-rate, 2x40G+2x10G, 100GbE/OTU4 client

FIPS-certified AES-256 wire-speed coherent 100G/200G encryption solution

Integrated tools and software applications

Photonic Connection Validation tools:

- Automated cable trace verification
- Transponder loopback
- Fiber loss measurements on active/dark fibers

Integrated Test Set support on a per client port basis

PinPoint Advanced Fiber Analytics (Integrated OTDR)

Photonic (L0) control plane

Next-generation amplifier solution

Raman – up to 1W power, with integrated OTDR

XLA – switchable high/low gain amplifier

Service Access Module and Enhanced Service Access Module with integrated OTDR

Real-time Link performance monitoring

Pre-FEC BER, Pre-FEC Q (average, max)

Tx power level

Rx total power and channel power

Maximum, average, and real-time DGD

PDL (average, max)

Total Rx and total Tx link dispersion

Estimated fiber length

Estimated unidirectional latency

Effective Signal-to-Noise Ratio (ESNR)

Liquid Spectrum solution

Channel Margin Gauge

Planning Tool Calibrator

Bandwidth Optimizer

Liquid Restoration

Wave-Line Synchronizer

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