WHITE PAPER

A Framework for IP/Optical Convergence: Building from Existing Networks

The communications landscape is fundamentally changing. Market dynamics associated with changing enterprise cloud as well as residential and data center connectivity are creating new use cases and exciting revenue growth opportunities for Communications Service Providers (CSPs). But from an IP networking perspective, these emerging use cases are also creating new challenges—driving new traffic patterns, the move to virtualized and distributed applications, and the need for higher bandwidth and lower latency connectivity to end-users. Many network providers are currently evaluating IP/Optical convergence as part of their IP network modernization strategy to address these emerging requirements and to achieve a more cost-efficient, resilient and unified network. What are the key elements required to realize the benefits of IP/Optical convergence? There is no 'one size fits all' solution, as architecture evolution needs to start with the CSP's current network reality. While the desired end-state vision is a simpler, streamlined converged IP/Optical network to accelerate service velocity and capitalize on new opportunities possible with 5G, IoT, and multi-access edge computing, there are many unique paths to get there.

What's happening in the market?

Consumer traffic flows are shifting heavily toward the home to support Small Office Home Office (SOHO), gaming, and e-learning. Furthermore, enterprises are accelerating their digital transformation and are moving toward Virtualized Network Functions (VNF) and cloud applications including Software-Defined WAN (SD-WAN) to reduce costs. Deployment decisions for 5G are beginning to pick up as operators evaluate xHaul upgrade options and plan their evolution from 4G to 5G.

These market shifts are driving traffic toward the edge of the network. From an applications perspective, this means computing power will need to move from being centralized to becoming distributed. Applications will continue to become virtualized as they move closer to the edge of the network to reduce latency and improve Quality of Experience (QoE) for end-users. This will require cloud service termination and peering points closer to the edge of the network.

As a result, many service providers are in planning discussions now about the creation of new metro and edge cloud on-ramp access points. They are also exploring new technologies—all so they will be ready to support the new traffic flows and the potentially exponential number of new services they will have to deliver over the next several years. As they look to modernize their IP networks, they are evaluating IP/Optical convergence as part of their strategy. In fact, according to a recent study, 87 percent of providers view IP/Optical convergence as important or critical for their next-generation networks.[1]

Challenges with traditional network designs

Why change? A key challenge of traditional access, aggregation, and metro networks is their static design. Traditionally, separate access and aggregation networks were built to support different service types and Service Level Agreements (SLAs). Moreover, all traffic flows move from the access to the metro in a hub-and-spoke configuration, with all services entering the metro regardless of the end destination.

This architecture makes it challenging to insert applications closer to access and aggregation zones, resulting in the network being too rigid to support next-generation distributed services and

1 Source: Heavy Reading, "IP and Optical Convergence Survey", May 2021, n = 220

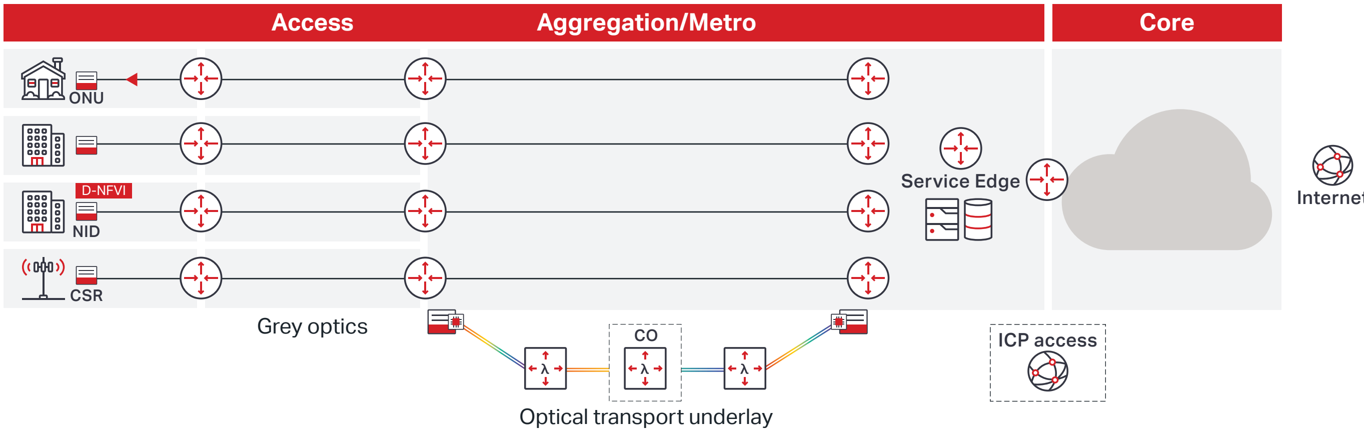

Figure 1. Traditional network design

applications. Furthermore, lack of operational automation and hardware programmability restrict the ability to flexibly move traffic flows as needed. A network evolution that modernizes existing assets with the latest in technology innovation is required.

What Is IP/Optical Convergence?
Read article

The promise of IP/Optical convergence

What is IP/Optical convergence? And what is its role in IP network modernization? At its most basic level, this term refers to the streamlining and simplification of networking layers that include optical (Layer 0) and IP (Layer 3).

There are both hardware and software aspects to IP/Optical convergence, and some or all of these can be employed to achieve network simplification. From a hardware perspective, new technology innovations in coherent Digital Signal Processing (DSP) and the miniaturization of electro-optics are facilitating the integration of coherent optics in router platforms through compact coherent pluggables. Data transport across distance is achieved via photonic line systems, delivering the right flexibility and cost for the specific use case in the network; integrated intelligence in these platforms is important to simplify service turn-up and operations.

Software control, automation, and analytics are no longer nice-to-haves; these elements are needed to enable successful network transformation. Software convergence involves multi-vendor, multi-layer management and resource optimization through a unified interface that enables planning, fault correlation, service resiliency, and capacity optimization.

So why all the hype about IP/Optical convergence? By converging these layers of the network, many CSPs hope to realize a range of benefits: increased operational automation and simplicity, improved service velocity, improved reliability, and reduced total cost of ownership.

Ideal end state: A converged IP/Optical architecture built with next-generation requirements in mind

The future metro network needs to anticipate and respond to dynamic traffic levels, shifting traffic flows, and unexpected service requests. Just as important, this network should serve as the foundation for innovation. It should allow for quick onboarding of new users and applications, and be able to support innovative enterprise services such as end-to-end network slicing and network-as-a-platform. The network must be programmable and easily configurable—with the ability to expose network functionality through standard APIs that developers and end customers can use to create new services and revenue streams.

What does this end vision look like?

With IoT and new 5G applications driving the proliferation of Layer 3 end points, CSPs must evolve their access and aggregation networks from Layer 2 to Layer 3 infrastructure. With this shift, the Layer 3 control plane extends into the access network, requiring a transition to simplified, end-to-end service delivery through Ethernet VPN (EVPN) for single service, and Segment Routing (SR) for single transport. A modern, container-based IP network OS that supports the latest generation of modern control protocols and services enables streamlined operations, including faster upgrades, and faster time to revenue for new features.

A cornerstone of next-generation architectures will be a centralized, SDN multi-layer controller that provides a Path Computation Engine (PCE) and advanced network applications. Streaming data telemetry and network analytics guide the PCE

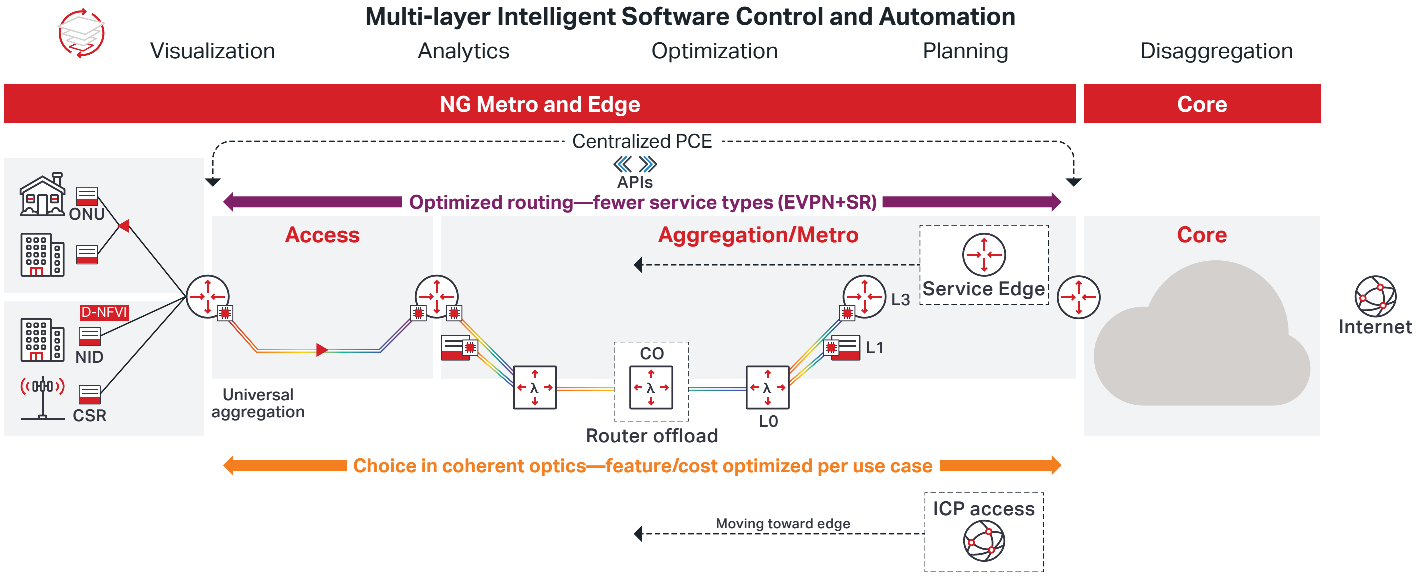

Figure 2. Future mode of operations – ideal end state

and enhance operations. They provide advanced visibility, analysis, and service optimization as well as automated path computation and provisioning, thereby simplifying the user experience. Open APIs expose network functionality to developers to allow for rapid innovation and the introduction of new services. They also enable easy access and integration with third-party devices, which is essential for practical deployment. Advanced IP automation capabilities also result in lower operational cost, shortened time to value, and improved service assurance with reduced Mean Time to Identify (MTTI) and Mean Time to Repair (MTTR).

To support services through a common infrastructure, separate access networks must converge. Depending on service offerings and current network design, this convergence requires a mix of passive and active access technologies such as Passive Optical Network (PON) and Ethernet, as well as the ability to continue to support legacy services such as Time Division Multiplexing (TDM) via cost-effective, compact pluggables. The role of IP/Optical convergence in the access is to support increased capacity while keeping space and energy consumption in check. To this end, integrated coherent optics in IP platforms will start to penetrate this area of the network, requiring access-optimized coherent line systems.

Aggregation and core metro networks must be able to support diverse traffic patterns that may need to transit a large number of hops to get from A to Z. Purpose-built routers supporting stronger performance coherent optics are required for this part of the network. A separate optical transport layer is maintained for ongoing efficient support of existing and new Optical Transport Network (OTN) and high-bandwidth wavelength services.

Finally, an intelligent, flexible Reconfigurable Optical Add/Drop Multiplexer (ROADM) underlay is needed to efficiently handle all bandwidth demands and provide bypass options directly to the core network, support IP traffic offload for increased network scalability, and support network reconfigurability for simple expansion and efficient use of fiber resources.

Taking the above into consideration will allow CSPs to achieve the ideal converged end state that is right for their network environment—a fluid architecture that can quickly adapt to support new traffic flows and simply expand to new cloud on-ramps, maximizing QoE while containing costs for the distributed services and content era.

Network reality and challenges to overcome

It's simple: the biggest challenge CSPs face in moving to the ideal converged IP/Optical end-state architecture is their current network reality. Very few CSPs have the luxury of a clean-slate network environment. Existing transport and service models, deployed hardware assets, and fiber characteristics and availability all play a critical role in any IP modernization strategy. All of these requirements need to be carefully evaluated and addressed.

As service providers move to a common transport and services model, different migration starting points and evolution paths need to be considered based on each service provider's network reality. In some cases, there may be an opportunity for a revolutionary approach, while in others, evolution is required to fit economic requirements. As CSPs evaluate their current landscape of legacy services and transport protocols, there often needs to be a conversation about adaptive evolution of the network. Protocol co-existence and interoperability are key considerations—for example, simultaneous support of Multiprotocol Label Switching - Transport Profile (MPLS-TP) and SR. As the network grows, the business case for simplifying the IP network design—instead of replicating the status quo—becomes stronger.

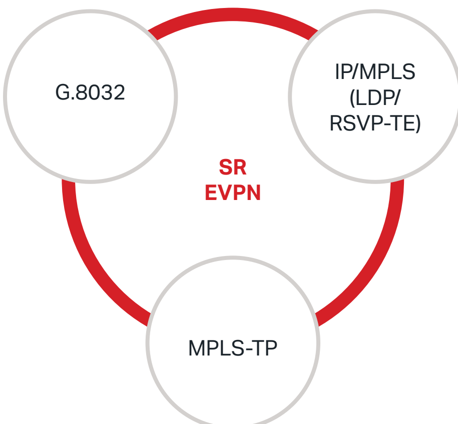

Figure 3. Moving to a common transport and services model

Furthermore, there are several ways to implement control plane and automation in a converged architecture—from 100 percent distributed (in devices), to 100 percent centralized (in controller) with no routing or signaling in the network. Several alternatives exist in between these extremes, and identifying the best evolution path forward is another important consideration.

Finally, specific A-Z traffic flows, fiber characteristics and availability, and existing router and photonic infrastructure assets dictate which coherent technology provides the best choice and lowest total cost of ownership for deployment. First, are the existing routers designed to support the heat dissipation associated with coherent pluggables? With no switch density impact? A negative response to either of these questions may preclude the deployment of coherent pluggables in routers until the new generation of platforms are deployed. In any event, the power, space, and cost savings associated with coherent pluggables can still be realized by deploying these in transport equipment. Is fiber a severely limited resource? If so, performance-optimized embedded optics in transport equipment can prove to be the better technology choice.

Intelligent control and automation

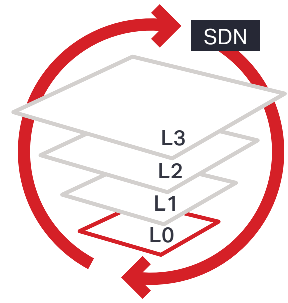

Figure 4. Evolution to centralized multi-layer control

Interoperable QSFP-DD coherent pluggables provide many benefits: they offer the best space and power efficiencies, as well as choice in vendor suppliers. On the other hand, interoperable QSFP-DD pluggables are most limited from a performance perspective. Higher performance and longer reach can be achieved using proprietary coherent plug design implementations. Link engineering performed on the specific network will determine what type of coherent pluggable is required. As an example, network modeling performed on a North America service provider metro network showed that only ~20 percent of optical data paths can be closed with interoperable 400ZR designs, the other ~80 percent require higher performance pluggable or embedded optics. In general, to determine best choice in coherent optic selection, link engineering and business case modeling of different scenarios over a 5–10 year period should be performed.

Phased evolution approach to IP/Optical convergence

Evolving to a converged IP/Optical architecture may seem like an overwhelming task, but there are tangible steps that can be taken in a phased approach to start realizing operational benefits of a modernized metro.

These are the four key activities that a CSP can do to discover its ideal path forward to IP/Optical convergence (ranked from lowest to highest disruption and risk):

1. Network optimization through software: Use centralized multi-layer domain control to optimize service quality, capacity, and network resources across IP and Optical layers. Intelligent multi-layer domain control improves resiliency through enhanced visibility and awareness of shared paths across layers.
2. Technology change: Introduce new, more cost-efficient coherent optic technology, including pluggables, in existing transport equipment or on new 'coherent-designed' routers as they are deployed in the network. Select the coherent optic design that allows for seamless deployment and does not require truck rolls and changes to the photonic layer.

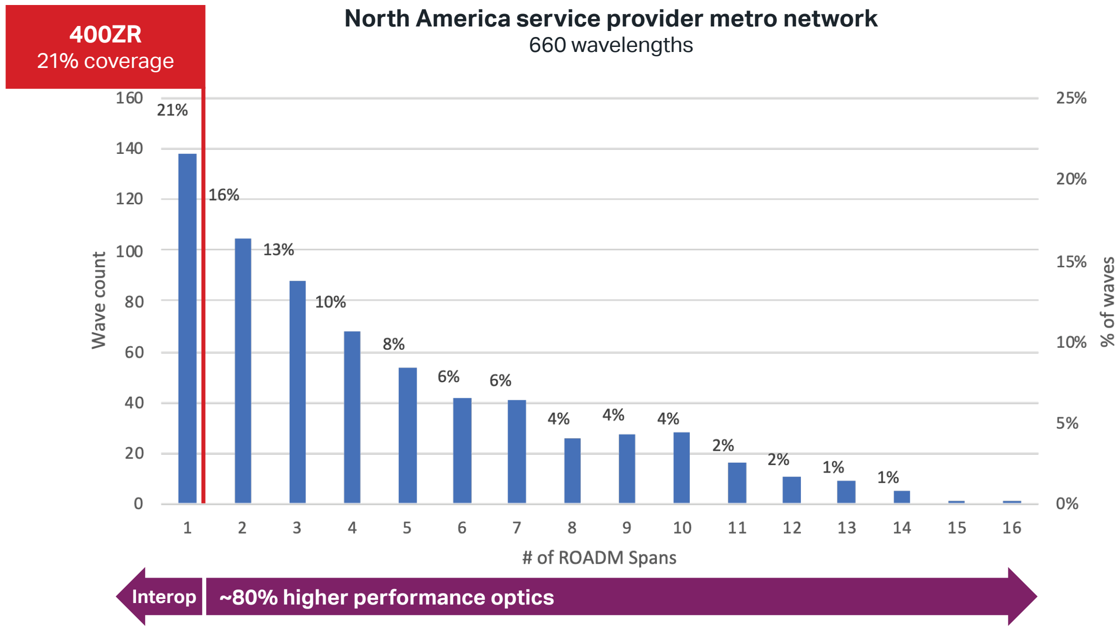

Figure 5. Distribution of traffic demands addressed by different coherent optic choices

3. Photonic layer considerations: As the network expands, select the photonic line system design that is open and flexible enough to support both easy expansion to new sites, as well as new cost-efficient optical technologies that are right-sized to support the capacity and traffic growth requirements of the network.
4. Architecture change: Assess the impact of changing different parts of the network—such as access, aggregation, metro—and start to implement new architecture when appropriate.

CSPs should work with their internal teams to perform a risk/benefit assessment of different options. Both IP and Optical planning experts need to participate in the analysis to expose blind spots that one subject matter expert might not be able to see on their own. Evaluations made using both IP and Optical expertise are more likely to expose hidden pitfalls that may be associated with certain technology or architecture decisions. A partial evolution may be the best approach for some networks. There is no 'one-size-fits-all' approach for architecture evolution—it starts with a CSP's network reality and business objectives.

Ciena's Adaptive Network approach to IP/Optical convergence: Ready for the distributed services and content era

The changing industry landscape is driving the need for a more responsive, automated, and application-driven network. This closely ties to Ciena's Adaptive Network™ vision—a programmable network that uses automation, guided by analytics and intent-based policies, to rapidly scale, self-configure, and self-optimize by constantly assessing network pressures and demands.

Grounded in this vision, Ciena's approach to IP/Optical convergence starts with its Adaptive IP™ approach. Simpler by design—automated, open, and lean—Ciena's purpose-built routers can be used to construct an IP network fabric that performs at scale in next-generation networks. Using the modern, container-based Service-Aware Operating System (SAOS), customers achieve a simpler, automated IP network—from access to metro—that enables customization, rapid innovation, and faster service creation for a quicker time to revenue. Operational agility is facilitated through open software and hardware interfaces supporting modern standards-based protocols, such as SR and EVPN, with a code base that is scalable across physical and virtual platforms—and from access to core. A simpler control plane and software extensibility enables service providers to create a fluid architecture that can quickly onboard new users and applications, and easily redirect traffic flows in new hot-spot locations.

Adaptive IP
Learn more

Ciena's WaveLogic™ Photonics deliver use-case-optimized coherent optical solutions that reduce network complexity and cost while matching customer network requirements. With the broadest range of coherent technology choices, users can select the optics that best match the performance required for a specific networking application, whether this means lower capacity hardened 100G–200G pluggables for access

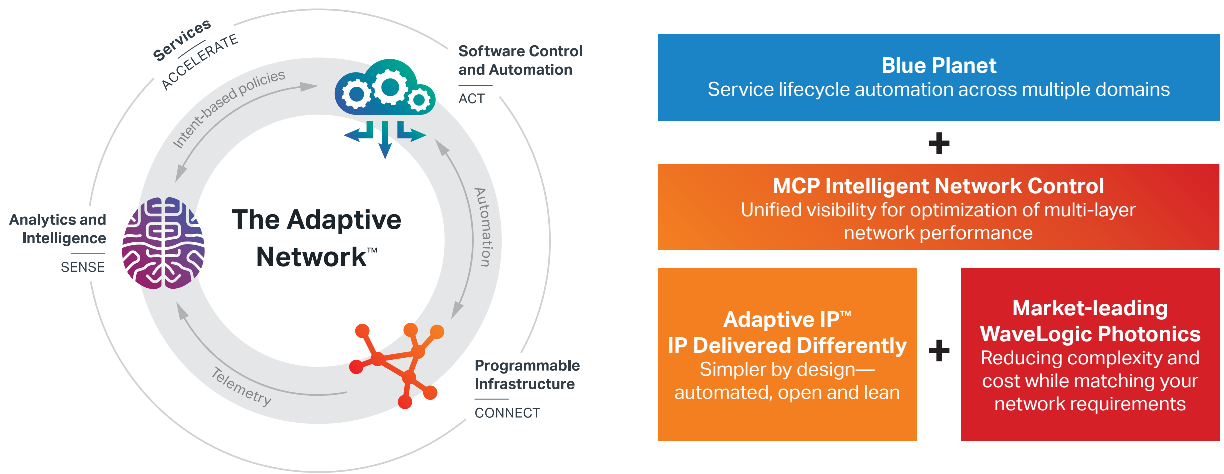

Figure 6. Ciena's Adaptive Network approach to IP/Optical convergence

applications, interoperable 400G pluggables in QSFP-DD form factor for metro DCI applications, high-performance 400G CFP2-DCO pluggables that can operate in existing metro ROADM networks, or maximum performance embedded optics that provide the best spectral efficiency and fiber capacity. Leveraging Ciena's unmatched coherent design and networking expertise, users gain the benefits of lower energy consumption, extended reach that minimizes regeneration, fewer site visits, and a simpler network. Industry-respected link engineering and planning tools enable reliable networks and predictable performance.

Ciena's instrumented optical line systems are designed to operate in fully automated networks. WaveLogic Photonics offer extensive monitoring and real-time networking data that can be exposed to northbound controllers via open APIs. Embedded intelligence in the photonic hardware provides automated system turn-up, fiber characterization, precise fiber fault localization, and real-time, continuous system optimization over the life of the network. Equally important, Ciena offers a range of open, disaggregated line systems to match cost and flexibility requirements for a particular network application, from simple point-to-point systems to fully flexible and reconfigurable ROADM networks.

Ciena's Manage, Control and Plan (MCP), the most advanced multi-layer domain controller in the industry, provides a unified interface for consistent operational workflows across Layer 0 to Layer 3, enabling multi-layer optimization. Integrated with MCP are advanced apps, providing intelligent network control for simplification and automation of the complex tasks required to optimize multi-layer performance. Starting at Layer 3, Ciena's Adaptive IP Apps provide multi-vendor IP/MPLS path- and service-aware performance analytics with an automated PCE for SR Traffic Engineering (SR-TE). These capabilities greatly improve IP service assurance by reducing the time to identify and resolve performance issues. At Layer 0, Liquid Spectrum™ Apps provide real-time analytics and visibility across Ciena's programmable photonic layer and foreign line systems, so that users can respond to dynamic bandwidth demands in real time to increase network capacity and service availability.

MCP Applications
Watch video

For customers looking for software solutions beyond Layer 0 to Layer 3 control, Blue Planet® Intelligent Automation software provides end-to-end service lifecycle automation across multiple domains, as well as across multi-vendor networks.

Ciena also provides professional services with expertise in complex network modernization. From initial strategy development to implementation and ongoing management, Ciena Services experts support customers in every phase of the network lifecycle.

The communications landscape is rapidly changing. New applications and use cases driven by changing enterprise and residential market dynamics, 5G, and the cloud are creating exciting new revenue opportunities for service providers. IP/Optical convergence allows operators to address these new opportunities through a more cost-efficient and resilient IP network. But there is no 'one-size-fits-all' approach to architecture evolution—it starts with the CSP's network reality.

IP delivered differently with Adaptive IP. Market leading WaveLogic Photonics. The industry's most advanced domain controller. Ciena's converged IP/Optical solutions start—and build—from existing networks and evolve to a more streamlined and programmatic infrastructure that can serve as the foundation for innovation in the new distributed services and content era.

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