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WHITE PAPER

Technology Innovation for Web-scale Data Center Interconnect

The Rise of the Data Center

The proliferation of Internet-connected devices has created a global culture in which content is king, and is demanded and consumed anywhere, at any time. In response to this demand, Internet Content Providers (ICPs) have had to create more data centers to house this sought-after content. The data center is where the content lives. In addition, the instant nature of some services and applications, and users' expectation that content be delivered instantaneously and with high quality, have led ICPs to aggressively pursue innovative ways to interconnect data centers more effectively and push them farther into metropolitan areas, closer to the end-user. Other content that does not require instantaneous delivery, such as email and Web pages, can be delivered by more distant data centers. The unprecedented proliferation of mobile devices like smartphones and tablets and new, Over-The-Top (OTT) services such as streaming video and online music and gaming has fueled the creation of data centers in suburban and rural areas as well.

Moreover, natural disasters, the increased use of digital records, and government regulations have pushed enterprises to create data centers for data back-up and mirroring applications as part of Business Continuity/Disaster Recovery (BC/DR) plans. These data centers are sometimes located within close proximity of each other for synchronous applications, or they can be hundreds or even thousands of kilometers apart for asynchronous applications. Multinationals have been creating data centers across the globe to provide a quick and secure data stream to conduct their operations for R&D teams, sales, support, billing, and back-office functions. This data center growth is further accelerated by the increased use of cloud and virtualization tools.

The demand for data centers shows no signs of slowing. A recent report from research firm Ovum states that—in terms of number of data centers—the top 20 global cities have over 2,200 data centers; some cities have more than 100 data centers within their metropolitan boundaries In total, there are more than 6,000 data centers worldwide.[1]

Over the past few years, a new business model has proved to be very lucrative in this content-driven data center market. Companies are building data centers in key locations to offer a broad set of services to anyone who needs to house compute and storage resources. These companies, often referred to as Carrier Neutral Providers (CNPs), offer rack space, power, security, and even cross-connect services to different data centers, public cloud providers, and network service providers.

Evolution of the Data Center

Typical data centers house three different sets of equipment:

- **Compute devices (servers) –** Fast compute platforms needed by apps to process data, such as navigation applications calculating the quickest route between two end-points. These compute platforms can also run cloud-based applications such as data processing, billing, and Customer Relationship Management (CRM).
- **Storage devices –** High-capacity disk arrays that process data saved or accessed by applications, such as emails, online photos, and videos. Storage arrays are also used to back up enterprise data (data duplication or mirroring) to protect the enterprise information assets from natural disasters or data corruption.

1 "Opportunities for Optical Data Center Interconnect: Market landscape, sales forecast, and competitive analysis", Ovum, April 2015.

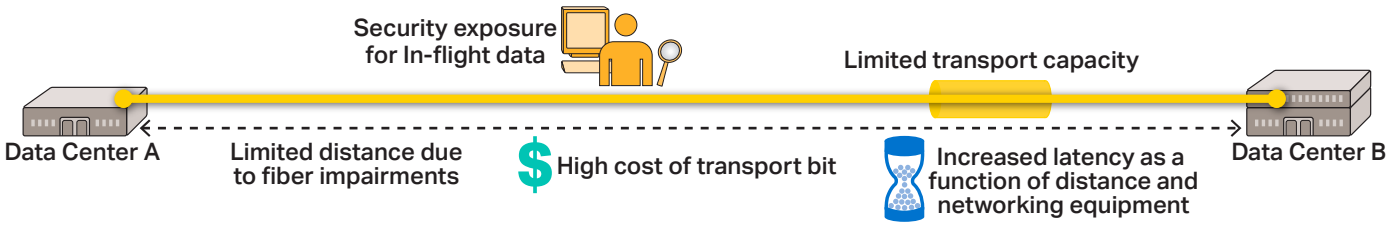

Figure 1. Challenges between data centers

- **Network or 'telecom' –** This equipment is used to route traffic within data centers, between servers, and storage arrays. Other telecom equipment connects the data center to the outside world. Connecting data centers is a crucial task to enable the compute and storage functions to serve the apps. Without adequate connectivity, there is no app since the network increasingly sits between an end-user and their content! Data centers underpin the cloud. The cloud is only as good as the network that interconnects the data centers.

In addition, virtualization is affecting the practical functions of the traditional data center. With today's technologies, two or more physical data centers can act as a single logical data center, sharing the load and dividing tasks to minimize operating expenses and maximize performance. For example, two relatively close data centers in a large city, where real estate is at a premium, can act as one virtual data center, eliminating the need to build new facilities.

To support today's shifting traffic patterns (resulting from requests for data), bandwidth increases, and the proliferation of apps, most data centers are undergoing a major overhaul. Specifically, Data Center Interconnect (DCI) has quickly become a key enabler for ensuring the successful implementation of upper-layer applications.

DCI Challenges

The following paragraphs summarize the technical and physical challenges in connecting data centers (Figure 1):

- **Distance Limitations –** Data centers often require a connection with minimum latency to maintain a proper flow of information and synchronization between the server sending the information and the storage device saving it. When data centers that need to be connected are far apart, the latency increases as a function of the distance between the data centers and the network equipment that interconnects them. While choosing the shortest physical route can minimize fiber-induced latency, software- and equipment-induced latency must be kept to a minimum with proper design practices.
- **Capacity –** Very often, the aggregate size of application data sets entering or leaving the data center can be very large—hundreds of Gigabits, or even terabits—so the networking equipment connecting to the data center must be capable of providing reliable, high-capacity connections that can be scaled to higher rates as required.
- **Security –** Information stored in data centers, such as financial transactions, personal records, and corporate data, is often business-critical and confidential, creating a requirement to ensure data center network connections are trusted, reliable, and secure—often requiring network encryption.
- **Operations –** Manual network operations are labor-intensive, complex, slow, and can be highly error-prone. Minimizing manual operations by automating frequent and recurring tasks is an operational imperative. Turning up a connection between two data centers should be rapid and reliable, and managing this connection should not require ongoing manual operational tasks.
- **Cost –** With expected traffic growth between data centers approaching 30 percent CAGR, network costs must grow at a much slower rate if a data center is to remain financially viable into the future.

Overcoming DCI Challenges with Technological Innovation

DCI is at the heart of cloud networking. It mandates high scalability, efficiency, reliability, and security to ensure quick access to content across the cloud's building blocks. The latest technology breakthroughs (Figure 2) in hardware and software have overcome DCI challenges.

- **Overcoming distance limitations with Digital Signal Processing (DSP) –** Fiber impairments such as chromatic or polarization mode dispersion—that have long been roadblocks to implementing high-bandwidth connectivity over long distances—are no longer an issue. Breakthroughs in DSP technology have allowed networking equipment providers to introduce packet-optical platforms capable of automatically and intelligently compensating for these

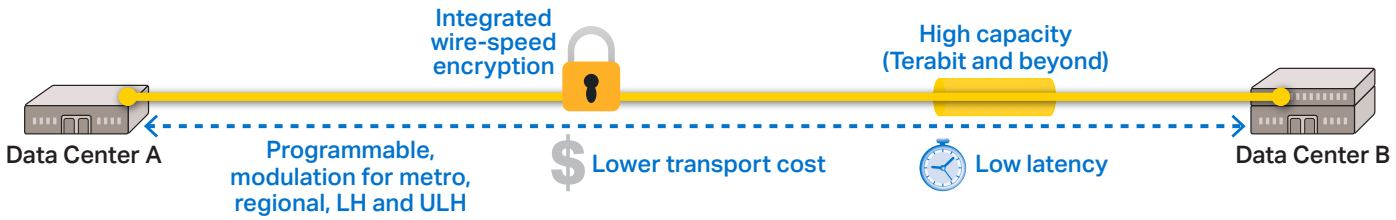

Figure 2. Technology innovation for DCI

fiber-optic transmission effects, allowing large data flows to be carried over several thousands of kilometers over different fiber types, without compromising speed for performance. Today's optical interfaces can be programmed to provide the optimum modulation schemes for different deployments scenarios.

- **Overcoming capacity limitation with coherent optics–** Coherent optics paved the way to successful transmission of data at 40 Gb/s and beyond, over almost any distance. Coherent detection created a major increase in transport capacity, a key requirement for today's DCI. However, not all coherent solutions are the same, so they do not all deliver the same performance. Ciena's WaveLogic 3 family of coherent chipsets provides best-in-class optical processors to increase optical performance through use of spectral shaping, soft Forward Error Correction, and Ciena's own analog-to-digital conversion techniques.
- **Overcoming latency limitation with high-performance and ultra-high-speed optoelectronics –** Sophisticated hardware design, optimized software engines, innovative Forward Error Correction (FEC) schemes, and high-performance optoelectronics have significantly reduced network equipment-related latency. Minimizing latency is a key factor in the successful implementation of numerous data center-related applications such as data mirroring.
- **Overcoming security exposures with wire-speed inflight encryption –** The ever-increasing rate of data breaches has put significant emphasis on ensuring that data is safe wherever it resides, be it at rest or in flight between data centers. While disk encryption and stringent rules for access of stored data are widely deployed to protect data from intruders, today's networking equipment offers inflight data encryption, allowing increased data protection from the moment data leaves one data center to the moment it enters another data center over the interconnecting network.
- **Overcoming manual operations with programmable automation –** Data center networks are constantly changing, resulting in traffic trends that are difficult to predict, given the spontaneous access to the resource pool by a wide variety of users and applications. Operational tasks can be automated through the use of APIs and associated applications. End-users can create custom applications that execute bandwidth increase requests, set up new connections between two end-points, modify an existing connection, and perform many other tasks required in daily data center-to-data center operations, without any intervention.
- **Overcoming cost increases through application-optimized platforms –** Today's latest optical platforms are meticulously designed and purpose-built around DCI applications. Simple planning, ordering, and installation allow data centers to be interconnected faster. Full programmability allows data center operators to design and build applications for their specific operational needs. High speed in a small footprint connects data centers with the lowest cost per bit. Small footprint and low power consumption directly and positively impact operating costs, while modularity allows scaling to multiple terabits of transport capacity without massive hikes in CAPEX/OPEX.

Raising DCI to Web-scale Proportions
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Ciena's DCI Solutions

The aforementioned Ovum report[1] provides a testament to Ciena's leadership in the total DCI market, which reached $2.5 billion in 2014 and is projected to grow at 10.5 percent CAGR from 2014 to 2019, surpassing $4.2 billion in 2019. The following highlights Ciena's solutions:

6500 Packet-Optical Platform (Figure 3) – A key platform with a successful track record serving as the cradle of numerous technological innovations such as coherent optical processing. The 6500 offers best-in-class switching and transport for all DCI applications, including:

- One platform for switching, DWDM, transport, and photonics
- Multiservice support including Fibre Channel and native digital video protocols

Figure 3. 6500 Packet-Optical Platform

- Single platform for 10G/40G/100G DWDM transport over any distance (metro to submarine)
- Flexible modulation (BPSK, QPSK, 8QAM*, 16QAM) for best application fit
- Packet capabilities (aggregation, switching, OAM)
- Multiple form factors (6500-2, 6500-7, 6500-14, 6500-32) for an optimized application fit
- Wire-speed encryption

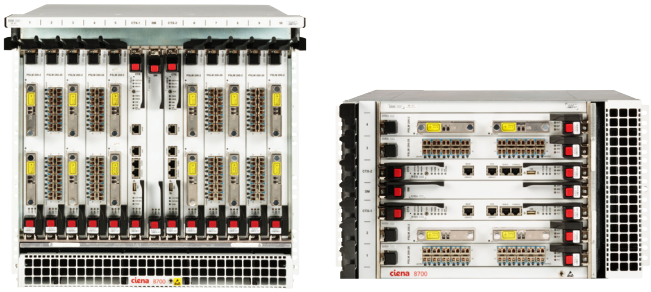

Figure 4. 8700 Packetwave Platform

8700 Packetwave™ Platform (Figure 4) – A multi-terabit packet-over-coherent DWDM platform combining the best of the metro network with the best of the data center. The 8700 provides cost-effective, packet-aware aggregation and switching that facilitates the interconnections of today's data centers. Features include:

- Programmable multi-terabit packet-over-coherent DWDM switch
- 4-slot (800 Gb/s) and 10-slot (2 Tb/s)
- Compelling economics
- Twice the 10GbE density (fastest-growing port speed)
- Half the power and space, significantly reducing ongoing operational expenses related to energy and real estate
- Single programmable platform integrating Ethernet, MPLS-TP, and 100G WaveLogic 3 Nano DWDM optics
- Zero-Touch Provisioning (ZTP) that eliminates manual operational tasks related to system turn-up
- Massive scalability (400G-ready)
- Rich set of packet OAM tools and capabilities to proactively and reactively maintain the overall health of the packet network

Figure 5. Waveserver stackable interconnect system

Waveserver™ stackable interconnect system (Figure 5)– The latest addition to Ciena's field-proven DCI solutions, designed from the ground up to address web-scale DCI applications at any distance. Waveserver was built on two key principles, WaveLogic economics and web-scale IT, to create a stackable interconnect system with the aim of providing simple yet programmable web-scale DCI solutions. The Waveserver extends the IT practices currently used in servers toward the networking function, where the attributes of programmability and openness are now part of the tool set.

Features include:

- Breakthrough high capacity (up to 400G client + 400G line) in a compact, 1RU footprint
- Flexible line interfaces, with QPSK, 8QAM*, and 16QAM, for the highest capacity at any distance from metro to long-haul requirements
- Runs Linux, similar to a data server, but to set up connections manually or automatically via open APIs
- Communicates with Ciena or third-party applications via open REST API access
- Simple to install and operate, requiring little to no technical support. Personnel familiar with installing and turning up data servers will have no issues installing the Waveserver system
- Anytime, anywhere management via mobile devices
- Offers an open development and test environment so end-users/developers can create, test, and fine-tune their own applications

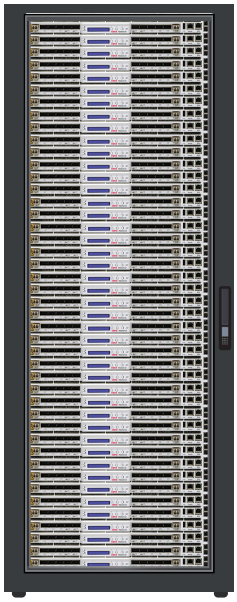

Figure 6. Modularity and stackability

- Enables new economics for cost of transport, such as lower cost per transported bit; lower cost per bit per rack; low power consumption; compact, space-saving design; and scalable modular architecture
- Achieves a new level of scalability—its 1RU footprint provides the modularity for rack-and-stack deployments, as shown in Figure 6

Waveserver complements Ciena's market-leading DCI solutions. With its flexible line interfaces, Waveserver can be used for metro, regional, or long-haul DCI scenarios, and it satisfies web-scale needs, such as high capacity, small footprint, and programmability. It is designed around the requirements of data center operators such as ICPs, CNPs, enterprises with data centers (for example, data mirroring, data recovery, backup sites, and private/hybrid cloud), government, and military, as well as any other deployment scenario that requires two data centers to be interconnected.

Learn more about Ciena's new Waveserver

Ciena Emulation Cloud

The openness and programmability of Waveserver cannot be fully leveraged until a data center operator can create an application. To this end, Ciena is introducing the Emulation Cloud (Figure 7), an open application development environment designed to help data center operators, application developers, IT teams, and other third-party developers create, test, and fine-tune customized applications. The Emulation Cloud will be extended strategically across Ciena's product portfolio going forward.

Ciena's Emulation Cloud is hosted in a cloud environment, accessible via the public Internet and open to all registered users. Ciena provides all the required tools, functionalities, and support to ease the development of web-scale applications such as code samples, documentation, online tutorials, and other educational materials. Data center operators can leverage Ciena's Emulation Cloud to develop unique and customizable operational tools tailored to their specific requirements without investment in the IT infrastructure. It also allows them to innovate, experiment, and test new service models with dramatically lower entry and exit costs. In addition, it accelerates service velocity by creating tools for multi-vendor/multilayer networks, de-coupled from individual vendor equipment implementations.

Why Choose Ciena?

Ciena is the current leader in the DCI market, as highlighted by recent industry market share reports.[1] Ciena's successful track record, coupled with its technological innovations, allow data center operators to deploy scalable, efficient, and cost-effective solutions they can trust. The benefits include:

- **Simple operations and fast turnaround.** Through designed operational simplicity, Ciena's solutions enable a hassle-free and faster execution of DCI projects. Easy planning, fast ordering, and quick delivery with rapid turn-up and intuitive management are all significant contributors to lower operational costs and faster execution velocity.
- **Easy integration with back-office tools for task automation.** Northbound interfaces and REST APIs allow data center operators to automate labor-intensive manual tasks to significantly reduce maintenance windows and free staff from repetitive, error-prone tasks.

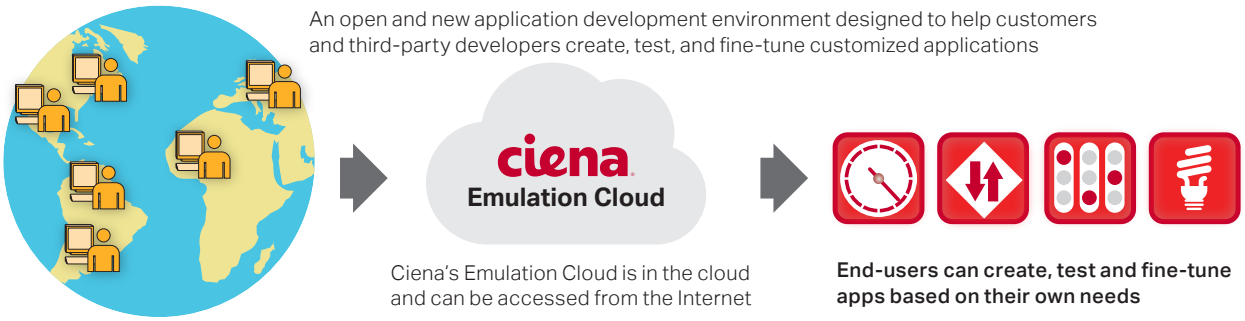

Figure 7. Ciena's Emulation Cloud

- **Peace of mind for traffic growth.** High capacity, flexible modulation, and seamless scalability to multiple terabits allow data center operators to meet today's and tomorrow's traffic growth needs without massive injections of CAPEX or network disruptions related to ongoing capacity increases.
- **Easy development of unique and customizable operational tools.** Leveraging Ciena's Emulation Cloud and platform-embedded APIs, data center operators can develop unique and customizable operational tools tailored around their specific requirements, without investment in physical hardware.
- **Reduced recurring/operating costs.** Optimized designs with low power consumption and compact footprints allow data center operators to reduce electricity, cooling, and real-estate costs. Simple product architecture also leads to lower management, sparing, licensing, and training costs.
- **High availability.** Ciena's DCI solutions leverage field-proven technologies, trusted by customers around the world across various industry segments, to carry mission-critical traffic. Ciena has deployed over 75 million kilometers of coherent networking worldwide, equivalent to 98 round trips to the moon. Ciena's reputation for delivering high-reliability networks allows data center operators to eliminate worries about link quality and capitalize on the resulting high availability as a competitive differentiator.
- **Highly flexible.** Ciena's solutions were designed and built to be flexible for the various connections and interfaces (protocol, rates), modulation schemes, deployment scenarios (over existing photonic line, protected, un-protected), and capabilities (packet aggregation and switching), allowing data center operators to embrace their growing web-scale needs.

Summary

Today's society has evolved into a global culture where content is consumed on demand and end-users expect to be able to access content anywhere, at any time, with high quality. The network is at the heart of this evolution to a web-scale world, playing a crucial role in connecting data centers with new benchmarks in operational simplicity, scalability, and viable business economics. Ciena's solutions, rooted in the company's industry leadership in DCI applications, enable data center and network operators to accelerate deployments, reduce operating costs, and raise the level of flexibility and efficiency dictated by today's web-scale operational paradigm.

* Future feature

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