WHITE PAPER

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THE CASE FOR CONVERGED PACKET OPTICAL PLATFORMS

Delivering Significant Savings, Space Reductions, and Faster Revenues

A number of trends are driving network operators to complement WDM optical transport with packet transport technology, primarily in the metro and more recently in long haul networks. These trends include the demand for more bandwidth and greater agility with key applications including Ethernet and cloud connect services, fixed broadband aggregation, mobile backhaul, and SONET/SDH migration.

While the cases for both packet transport and WDM technologies are compelling, this white paper explores the case for deploying converged platforms that integrate both technologies into a single network element as an alternative to independent platforms and highlights key benefits including reduced CapEx, reduced OpEx, and the potential for increased revenues through faster installation and provisioning.

WHAT IS A CONVERGED PACKET OPTICAL PLATFORM?

For the purposes of this white paper, a converged packet optical platform is one that at a minimum integrates packet transport switching technology with full featured WDM interfaces (i.e., OTN Forward Error Correction, performance monitoring) and a WDM optical layer including ROADM technology. Common additional capabilities might include transponders/muxponders, SONET/SDH switching, OTN switching, and an ASON/GMPLS control plane. More advanced functionality might include packet optical convergence at the electrical layer with agnostic fabrics, hybrid OTN/packet switching, and/or universal switching with OTN, packet, and/or SONET/SDH supported on the same hardware and defined in software.

Minimal Requirements	Packet Transport Switching with WDM Interfaces Optical Layer including ROADM
Common Additional Capabilities	Transponder/Muxponder OTN Switching SONET/SDH Switching ASON/GMPLS Control Plane
Advanced Functionality	Agnostic Fabrics Hybrid OTN/Packet Switching Universal Switching

TABLE 1 – Converged Packet Optical Platform Definition

EVOLUTION OF PACKET OPTICAL

Packet transport offers a more granular and cost-effective alternative to traditional transport technologies while now benefiting from carrier class OAM and protection. Integrating packet transport switching and WDM optical layer technologies into the same platform offers the potential of reduced CapEx and OpEx and faster time to revenue. As a result, the packet optical transport systems market is forecast to grow from $2B in 2015 to almost $5B in 2020 as shown in Figure 1.

The concept of integrating packet switching and WDM technologies is not new. Over the past decade, transport equipment vendors have integrated packet switching into WDM platforms to varying degrees, while packet switching vendors have added WDM interfaces and even WDM filters into their packet switching and router platforms, again to varying degrees. However while promising CapEx and OpEx savings, these approaches typically required a compromise relative to best-in-class optical and best-in-class packet while simultaneously running into organizational barriers erected by packet and transport silos within many network operators. In the meantime, the market has evolved driven by both network and operator demands as well as the evolution of packet optical technology.

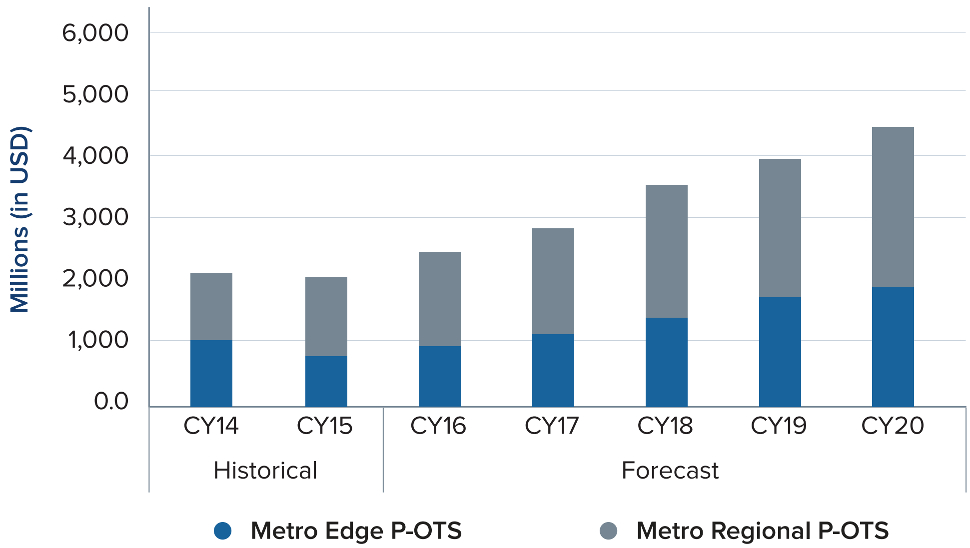

FIGURE 1 – Global Packet Optical Transport System Market (Source IHS, March 2016)

NETWORK AND OPERATOR DEMANDS

Demand for bandwidth has continued to grow dramatically driven by video, cloud, and data center interconnect. Ethernet-based enterprise and wholesale services have continued to grow strongly often at the expense of legacy TDM-based services with traffic volumes forecast to grow from 5 Tbps in 2015 to over 18 Tbps in 2020, though ASPs have dropped to temper market growth to a still healthy 10.7%, according to Ovum's September 2015 Ethernet Services Forecast Report: 2015-2020.

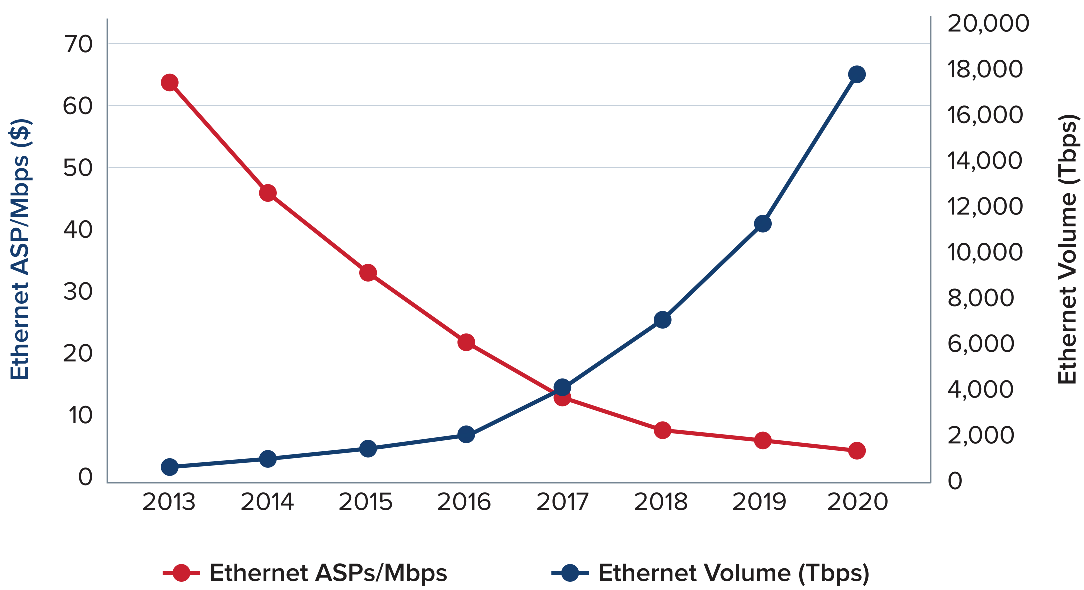

FIGURE 2 – Global Ethernet Service Traffic Volumes (Source: Ovum, September 2015)

In addition, mobile backhaul has migrated from TDM and ATM to Ethernet and IP interfaces with backhaul speeds set to evolve from 1 Gbps per cell site with 4G to 10 Gbps per cell site with 5G. Network operators are also faced with the challenge of how to migrate their networks away from SONET/SDH equipment with very high support costs, and packet transport represents one of the key options for this migration.

Agility has also become a key enabler of competitiveness with faster service development, installation, and service provisioning all key requirements. To address this, many operators are starting to deploy SDN and NFV technologies while reconfiguring organizational boundaries including breaking down the silos for packet and WDM technology.

PACKET OPTICAL TECHNOLOGY

On the technology side, transport-oriented packet switching technologies including Carrier Ethernet and MPLS-TP have been standardized and matured. 50 ms protection has been enabled by technologies including Recommendation ITU-T G.8031 VLAN protection, Recommendation ITU-T G.8032 Ethernet ring protection, and RFC 6378 MPLS-TP protection. Carrier class OAM now includes 802.1ag and Y.1731 for Ethernet together with OAM for MPLS-TP as defined in RFCs 6427, 6428, and 6345 and ITU-T G.8113.1 and G.8113.2 in addition to RFC 2544 and Y.1564 for Ethernet service testing. Packet switching scalability has also evolved from hundreds of Gigabits/s to multiple Terabits/s.

On the optical side, interface technology has evolved from 10G to 100G and beyond with the adoption of coherent receiver technology, polarization multiplexing, and advanced modulation including QPSK, 8QAM, and 16QAM. Meanwhile, the optical layer has evolved with ROADM becoming mainstream and technologies including flexi-grid and colorless, directionless, and/or contentionless add/drop providing new levels of optical layer flexibility.

Network management has also evolved with SDN providing an architecture for multi-domain, multi-layer control with open APIs enabling new services and new levels of agility. The MEF Lifecycle Service Orchestration architecture takes this to the next level by defining standardized interfaces for multi-domain orchestration for Carrier Ethernet and IP services.

THE BENEFITS OF CONVERGED PACKET OPTICAL

Integrating both a packet transport switching layer and WDM optical layer into the same network element can deliver significant benefits in terms of reduced CapEx, reduced OpEx, and increased revenues.

CapEx Savings	Reduced number of line interfaces with efficient grooming Low cost per bit optical pass-through Eliminated transponders and short-reach interconnect pluggables Reduced common equipment (shelves, processors, fans, etc.) Reduced router CapEx
OpEx Savings	Footprint savings of up to 30%~50% Power consumption savings of up to 40% Fewer NEs to install, manage, and maintain Simplified troubleshooting and planning
Increased Revenues	Faster time to revenue Faster installation Faster service provisioning New Ethernet services

TABLE 2 – Benefits of Packet Optical

CAPEX SAVINGS

Packet transport can reduce CapEx in a number of ways. First, electrical switching can deliver significant cost savings by reducing the number of high speed line interfaces in a WDM transport network, as described in the Coriant white paper The Role of OTN Switching in 100G & Beyond Transport Networks. Second, the cost per bit of packet switching hardware is likely to be significantly less that SONET/SDH hardware and comparable to OTN switching hardware costs. Third, the granularity and statistical multiplexing of packet switching technology can result in significant additional cost savings where traffic is bursty or can benefit from greater granularity than that offered by OTN containers. In a Coriant real-world metro network study, packet switching was able to deliver CapEx savings of over 60% versus a pure OTN switching solution.

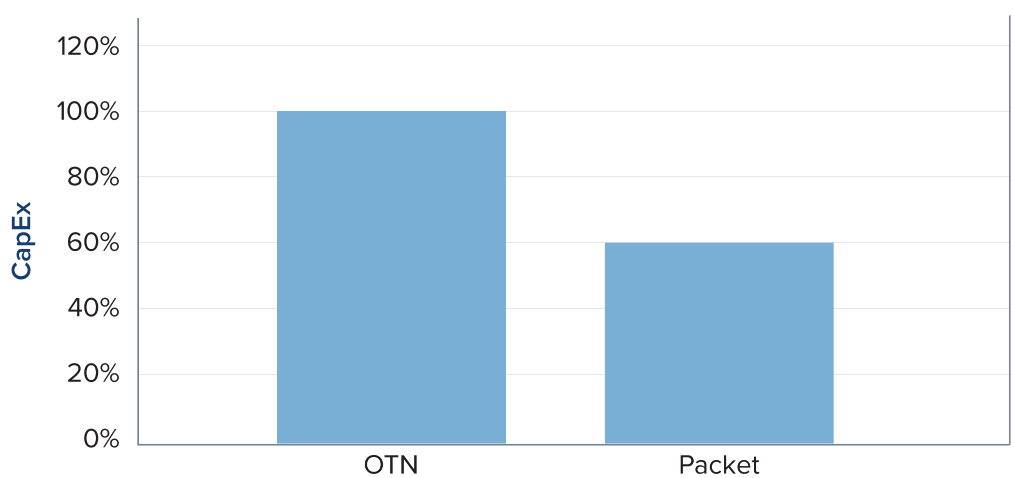

FIGURE 3 – Recent Coriant Metro Network Study

WDM optical transport technology can also deliver significant cost savings. Once traffic is multiplexed into a lambda, switching the traffic optically is an order of magnitude more cost-effective than switching it electrically. By only dropping traffic to the electrical layer when necessary and optically expressing traffic where possible, significant cost savings can be achieved.

By integrating the packet switching and optical layers into the same network element with full featured WDM interfaces on the packet hardware, short-reach interconnects between the packet switch and the transponder/muxponder in the DWDM equipment and the transponders/muxponders themselves can be eliminated. Consolidating packet switching and DWDM into the same shelf can reduce the cost of common equipment including the shelves, control processors, fans, and power supplies resulting in an overall savings of up to 25%.

The final opportunity for CapEx savings is not on the packet or WDM equipment but on the routers. By grooming traffic from multiple locations onto a smaller number of high speed router ports, router slots and ports can be used more efficiently. In addition, packet traffic that does not need IP processing can be off-loaded from the router layer onto the packet optical layer, which typically offers a significantly lower cost per bit.

OPEX SAVINGS

By eliminating the need for separate transponders/muxponders and consolidating DWDM modules and packet switching in the same shelf, the total footprint required can be reduced substantially relative to separate systems. For example, rather than deploying two 5RU shelves, one for optical and one for packet, a single 5RU shelf could be deployed with footprint savings of 50%, though 30% may be a more typical figure for less simplistic scenarios. Likewise, the elimination of transponders and short-reach interconnects together with a reduction in common equipment can have a similar impact on power consumption with reductions of up to 40%.

Packet transport with familiar TDM-like provisioning and OAM can deliver its own operational savings. However, a converged platform further reduces operational costs with fewer network elements to install, manage, and maintain. This is especially true where a single multi-layer network management system can provide end-to-end service discovery, provisioning, and troubleshooting with consistent tools and workflows across both packet and optical transport technologies. Additional operational benefits include a simplified DCN with fewer IP addresses, faster multi-layer troubleshooting and planning, and guaranteed packet optical interoperability.

INCREASED REVENUES

Converged packet optical can also deliver increased revenues by offering faster time to revenue, improving customer retention, facilitating new customer wins, and enabling new services. Revenues for new services and customers can be realized months sooner with faster installation and service provisioning.

Time to service readiness can also be a key factor in winning new customers and retaining existing ones. Finally, packet optical may enable new service offerings in terms of service speeds (i.e., 100GE), scope (EVPLAN, E-Tree, etc.), and/or geographic coverage, depending on the current network architecture and service offerings.

KEY APPLICATIONS FOR PACKET OPTICAL

METRO APPLICATIONS

A wide range of applications are driving packet optical in the metro. These applications include:

- **Business and Wholesale Ethernet Services**: MEF-defined EPL, EVPL, EPLAN, EVPLAN, E-Tree, E-Access, and E-Transit services offer speeds ranging from Mbps delivered on a 10 Mbps access circuit to 100 Gbps based on 100GE or LAG-aggregated 10GEs.

- **Mobile Backhaul**: With 4G driving the evolution of mobile backhaul to packet interfaces and 1 Gbps to the cell site and 5G expected to drive cell site bandwidth to 10 Gbps, the combination of packet and optical will be critical to delivering these bandwidth increases cost effectively.

- **Fixed Broadband Backhaul**: Massive bandwidth growth is being driven by video and enabled by the adoption of high speed broadband access technologies including G.fast DSL, NG-PON/NG-PON2, and DOCSIS 3.0/3.1. Optical technology is key for delivering this bandwidth cost effectively while packet technology plays a key role in enabling the cost-effective delivery of IP TV including special interest niche programming.

- **SONET/SDH Migration**: As discussed previously, SONET/SDH MSPPs are a legacy technology with a high cost per bit for packet traffic and often very high support/care costs with a risk of end-of-life notification as vendors struggle to source older components. Many network operators are now looking at migration strategies with packet transport, packet optical, and universal switching all valid options.

- **Router Optimization**: By grooming traffic from multiple locations onto a smaller number of high speed router ports, router slots and ports can be used more efficiently resulting in significant CapEx savings.

- **Data Center Interconnect**: Applications for packet optical include enabling Carrier Neutral Providers (CNPs) and Internet Exchange Providers (IXPs) to offer enterprises and smaller Internet Content Providers (ICPs) cloud connect services interconnecting servers in different data center facilities and providing access to Cloud Service Providers (i.e., Amazon AWS, Microsoft Azure).

LONG HAUL APPLICATIONS

While the integration of packet switching and optical has been primarily deployed in the metro, a number of applications are starting to drive increased adoption of this approach in long haul networks. This adoption of packet transport in long haul is being accelerated by universal switching, which enables OTN and packet switching on the same physical hardware as defined by software. Key long haul applications include:

- **Business and Wholesale Ethernet Services:** The ability to offer more granular and multi-point Ethernet services with aggregated handoffs leveraging the economics of statistical gain
- **Data Center Interconnect:** Providing a more flexible architecture that can dynamically adapt to changing traffic patterns and workloads as well as offering Network as a Service (NaaS) to key DCI customers

COMPARISON WITH ALTERNATIVES

This section compares a converged packet optical solution with the most common alternatives.

CONVERGED PACKET OPTICAL VS. SEPARATE PACKET AND OPTICAL PLATFORMS

The first comparison is between a single integrated packet optical platform and separate packet and WDM optical platforms, either from two different vendors or a single vendor.

<table>
<tr><th rowspan="2"></th><th colspan="2">Separate Packet and WDM</th><th rowspan="2">Converged Packet Optical</th></tr>
<tr><th>2 Vendors</th><th>1 Vendor</th></tr>
<tr><td>Eliminated Transponders/ Muxponders & Short-reach Interconnects</td><td colspan="2">Possible if packet equipment has full featured DWDM interfaces (high speed, FEC, PM, etc.)</td><td rowspan="2">✓ (~25% CapEx reduction)</td></tr>
<tr><td>Reduced Common Equipment</td><td>x</td><td>x</td></tr>
<tr><td>Footprint</td><td>Higher</td><td>Higher</td><td>Lower (-30%)</td></tr>
<tr><td>Power</td><td>Higher</td><td>Higher</td><td>Lower (-40%)</td></tr>
<tr><td>Platforms to Install and Manage</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>Management Systems</td><td>2</td><td>Vendor-dependent</td><td>1</td></tr>
<tr><td>Supplier Relationships</td><td>2</td><td>1</td><td>1</td></tr>
</table>

As discussed previously, typical advantages of an integrated platform include reduced CapEx with shared common equipment and eliminated transponders and short-reach interconnects, though packet platforms with full featured DWDM interfaces may also eliminate transponders and short-reach interconnects.

While the most obvious OpEx advantages include reduced footprint and power consumption, additional OpEx advantages include fewer platforms to install and manage, a single end-to-end management system, and a single vendor relationship to manage. Although, the single management system and single vendor relationship advantages could also exist with two separate platforms from a single vendor.

Furthermore by deploying converged packet optical across the network, the network will be more prepared for changes in traffic patterns compared to separate platforms when packet switching is only placed at those locations required to be optimized for initial traffic conditions. On the other hand, proponents of separate platforms might argue that multiple platforms provide best-in-class technology at each layer without compromise, or they might assert that using slots with a backplane or fabric access for optical layer technology is wasteful since the modules do not use the backplane or fabric.

PACKET TRANSPORT VS. TRADITIONAL TRANSPORT APPROACHES

This second analysis compares packet and universal switching with common transport alternatives including transponders/muxponders (i.e., no switching), OTN switching, and SONET/SDH switching.

	Traditional Transport Approaches			Packet Optical Approaches	
	Muxponder/ Transponder	**SONET/SDH**	**OTN Switching**	**Packet Switching**	**Universal Switching**
Cost per Gbps	$	$$$$	$$	$$	$$+
Granularity	ODU0 on client side Lambda on line	STS1 (50G) VC-4 (150G)	ODU0 (1.25G)	Mbps	ODU0 STS1/VC-4 Mbps
Max Interface Speed	100G+	40G	100G+	100G+	100G+
Statistical Gain	x	x	x	✓	✓
Multi-Point	x	With integrated packet switching in some platforms	x	✓	✓
Aggregated Handoffs	x		Only if routers support channelized OTN interfaces	✓	✓
Hard QoS	✓	✓	✓	With Policing and CAC	OTN mode or Policing and CAC
Non-Ethernet	✓	✓	✓	With Circuit Emulation	✓

While transponders/muxponders may offer the ability to transport non-Ethernet protocols and the lowest cost per Gbps in terms of the port card itself when used to carry packet traffic, they suffer from limited granularity, no statistical gain, and no support for multi-point services. Furthermore with a distributed traffic pattern, muxponders will require more interfaces than a switched solution resulting in higher costs and more limited flexibility.

OTN switching is the closest alternative to packet switching for the electrical layer in transport networks. Offering advantages in terms of transparency and simplicity, OTN switching provides support for non-Ethernet protocols, transparent timing, and hard QoS without the need for complicated QoS mechanisms (policing, signaling, CAC, etc.). However, it suffers from more limited granularity, offers no statistical gains, and cannot support multi-point to multi-point services or aggregated handoffs to standard router interfaces.

In comparison, SONET/SDH is now a relatively expensive legacy technology with a maximum interface speed of 40G (STM-256/OC-768). Furthermore, it cannot offer the granularity or statistical gains of packet technology, though like OTN, it does offer simplified hard QoS.

An alternative that combines the best of both packet and OTN switching is universal switching as supported on the Coriant® mTera® Universal Transport Platform (UTP). With only a small incremental premium relative to a pure packet or pure OTN switch, it is possible to define each interface and virtual interface for OTN, Carrier Ethernet (Bridging, VLAN cross-connect), or MPLS-TP/VPLS in software and to interwork SONET/SDH switching with OTN and packet switching. Additional benefits of universal switching over and above a pure packet transport switch include:

- The ability to support non-Ethernet protocols including SONET/SDH and Fiber Channel natively
- The ability to map traffic to OTN for transport over the core network with simplified hard QoS and transparency
- The ability to extend virtual packet switching to remote OTN muxponders
- The ability to mix OTN, SONET/SDH, and packet traffic on the same high speed (100G+) interface
- Investment protection against changing traffic patterns and client types

In a recent real-world study of a Tier 1 operator’s national and pan-European backbones, universal switching demonstrated CapEx savings of between 35% and 45% over pure OTN switching with the savings coming from both reduced numbers of 100G line interfaces and more efficient use of router ports.

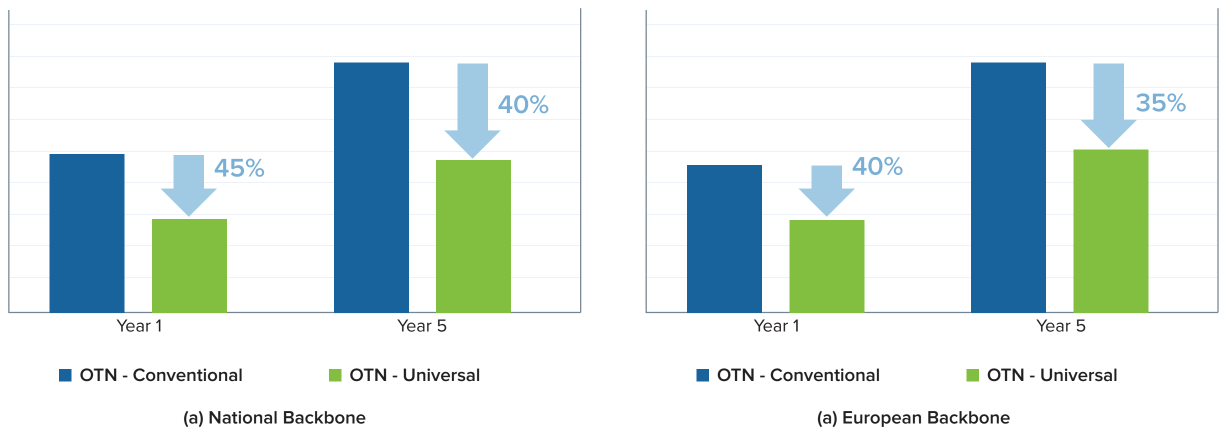

FIGURE 4 – Tier 1 Long Haul Network Savings with Universal Switching

CORIANT PACKET OPTICAL PORTFOLIO

A pioneer in offering converged packet optical solutions with the introduction of the first generation of packet switching cards in 2007 for the Coriant® 7100 Packet Optical Transport Solutions, Coriant offers industry-leading converged packet optical solutions from the metro edge to the core that are widely deployed in both large and small operator networks across the globe.

	CPE/NID	Metro Edge	Metro	Metro Core	Core LH/ULH
Packet	7090	Coriant 7100 Nano/Pico			Coriant mTera
Optical					hiT 7300

FIGURE 5 – Coriant Packet Optical Transport Portfolio

In the metro, the 2RU Coriant® 7100 Pico™ Packet Optical Transport Platform can combine up to 400 Gbps of packet switching with support for WDM including fixed WDM and ROADM based on the Coriant® Pluggable Optical Layer, while the Coriant® 7100 Nano™ Packet Optical Transport Platform can combine up to 1.2 Tbps of packet switching per shelf with multi-degree ROADM or fixed WDM. In core networks, the mTera UTP can combine 12 Tbps of universal switching including packet, OTN, and SONET/SDH with flexi-grid ROADM-on-a-blade.

Complementing the 7100 Series and mTera UTP converged platforms, the Coriant® 7090 Packet Transport Solutions provide cost-effective packet transport for CPE/NID and metro edge applications that do not require converged packet optical. As an alternative for long haul networks, it is possible to combine universal switching and Coriant CloudWave™ Optics in the mTera UTP with long haul amplifier and ROADM technology in the Coriant® hiT 7300 Multi-Haul Transport Platform while managing both platforms as a single network element.

SUMMARY

With a wide range of applications including business and wholesale Ethernet services, mobile and fixed broadband backhaul, and SONET/SDH migration driving increased adoption of both packet transport technology and WDM optical transport, network operators are faced with the question of whether to deploy independent systems for packet and WDM or a converged platform for both. Advantages of a converged platform include potential CapEx savings of up to 25%, power consumption reductions of up to 40%, and footprint reductions of over 30%. Moreover end-to-end multi-layer provisioning can enable faster revenues and more satisfied customers.

ABOUT CORIANT

Coriant delivers innovative, dynamic networking solutions for a fast-changing and cloud-centric business world. The Coriant portfolio of SDN-enabled, edge-to-core transport solutions enables network operators to reduce operational complexity, improve utilization of multi-layer network resources, and create new revenue opportunities. Coriant serves leading network operators around the world, including mobile and fixed line service providers, cloud and data center operators, content providers, cable MSOs, large enterprises, government agencies, financial institutions, and utility companies. With a distinguished heritage of technology innovation and service excellence, forged by over 35 years of experience and expertise in Tier 1 carrier networks, Coriant is helping its global customers maximize the value of their network infrastructure as demand for bandwidth explodes and the communications needs of businesses and consumers continue to evolve. Learn more at www.coriant.com.