**Introduction**

This white paper analyzes the evolution of metro packet-optical transport systems (P-OTS) in order to meet the changing demands of metro transport networks, driven by continued IP traffic growth, the migration from TDM to packets, and requirements for new services and greater competitiveness. The paper charts the evolution of P-OTS in three phases – P-OTS 1.0 (past), P-OTS 2.0 (present) and P-OTS 3.0 (near future) – and details the key architectural requirements for the next generation of metro transport networks.

**Metro Market Trends**

**Drivers for Metro**

In this section, we examine the key metro trends that are having the greatest impacts on the transport layers:

- **Continued high growth in IP traffic that vastly outstrips growth in operator revenue, including both fixed and mobile broadband.** It is well understood that network traffic growth (particularly IP traffic) far outpaces the growth in associated operator revenue from that traffic. Some recent studies on traffic patterns and growth, including Cisco’s Visual Networking Index and a study from Alcatel-Lucent’s Bell Labs, indicate that traffic in metro networks is growing far faster than in long-haul networks. For operators, this means that reducing the cost per bit (in terms of both opex and capex) is paramount for the metro transport layers. In addition, it means that metro networks need to be able to scale in order to handle the continued traffic demands without having to change out systems and networks.

- **Continuing migration from TDM/Sonet/SDH-based networks to packet-friendly networks.** Long predicted, this trend hit the accelerator in 2012 when global operator spend on legacy Sonet/SDH gear plummeted by 25 percent. The rapid decline in Sonet/SDH spend continued in 2013 with a 28 percent drop. Operators must migrate their transport networks from Sonet/SDH to Ethernet- and IP-friendly networks, as well as create a smooth transition – for themselves and for their customers – from the legacy networks and services to the new packet-focused networks that are built for IP and Ethernet services. P-OTS is the clear beneficiary of this trend.

- **Network stress posed by over-the-top (OTT)/Internet providers.** Telecom network operators face a huge challenge from OTT/Internet companies, including Google, Facebook, Netflix, etc., that provide their services and applications over networks built and operated by telecom network providers. Network operators must increase their capacity to handle the growth in OTT traffic, but there is no corresponding revenue growth associated with the bandwidth increases. Most recently, we have also seen a trend of traditional network operators emulating the efficiency and ingenuity of these Internet competitors in order to better compete. Operator interest in wide-area network (WAN) software-defined networking (SDN) is one example.

- **New revenue opportunities driven by the rise of cloud applications and cloud services delivery.** Cloud services provide new revenue opportunities for network operators that help offset revenue declines in traditional services. However, in order to offer these new services, transport networks need to be re-architected to match the cloud’s flexible and on-demand nature. They must also be highly scalable to accommodate cloud traffic.
Metro Element Needs & Evolution

Metro P-OTS are evolving to address the challenges posed by the trends described above. The top requirements for packet-optical transport are lowering total costs/price, integration with Layer 2/3 packet networks and superior operations, administration and management (OA&M)/management abilities. Heavy Reading sees a clear P-OTS evolution that is currently in its second phase and preparing for a third phase. Figure 1 describes the evolution of metro P-OTS.

Figure 1: Metro P-OTS Evolution

<table>
<thead>
<tr>
<th>PHASE</th>
<th>P-OTS 1.0</th>
<th>P-OTS 2.0</th>
<th>P-OTS 3.0</th>
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</thead>
<tbody>
<tr>
<td>Key Attributes</td>
<td>Hybrid packet/TDM functionalities, but often with separate switching fabrics for each 10Gbit/s-based systems Sonet/SDH requirements dominate buying decisions</td>
<td>The focus of packet-optical shifts from TDM functions to packet functions Hybrid TDM/packet fabrics Pure packet implementations of P-OTS begin to ramp 100G enters the metro</td>
<td>Addition of IP/MPLS functionality to transport Packet-only or packet and optical-only transport become commonplace Multi-layer OAM; ROADM and hybrid SDN support Coherent MSA-based 100G introduced Switched OTN introduced</td>
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Source: Heavy Reading and MRV

Next-Gen Metro Architecture Requirements

In this section, we detail the key architectural requirements for next-generation metro networks, including scalability, full featured packet and optics functionality, and system modularity. These requirements apply to the P-OTS 2.0 phase and, increasingly, as the industry evolves, to P-OTS 3.0.

Scale

Next-generation metro P-OTS needs scalability to handle continued data traffic growth. Optical systems have been moving to 1G and 10G rates for some time now. The newer trend in the metro is the migration to 100G. Heavy Reading forecasts that metro 100G line-side ports will increase at a 78 percent CAGR from 2013 to 2018 – a rate faster than the long-haul 100G market (see Figure 2 on the following page). Mirroring a similar trend in long-haul, metro 40G shipments and revenue are expected to decline as operators favor the greater scalability afforded by 100G.

Full-Featured Packet-Optical Convergence

When Heavy Reading polled operators in 2013 on next-gen packet-optical functionality requirements, operators clearly expressed a dual focus on both the packet and the optics sides of packet-optical. This dual focus stands in contrast to the initial P-OTS 1.0 era, in which much of the focus remained on TDM and Sonet/SDH functionality.
Figure 3 shows the top feature priorities that operator survey respondents selected for next-generation metro transport elements. The figure shows the highest-rated features of a list that contained 13 features.

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>PRIORITY</th>
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<tbody>
<tr>
<td>WDM</td>
<td>Critical</td>
</tr>
<tr>
<td>IP/MPLS</td>
<td>Critical</td>
</tr>
<tr>
<td>100G Line Side</td>
<td>Critical</td>
</tr>
<tr>
<td>ROADM</td>
<td>Very high</td>
</tr>
<tr>
<td>MPLS-TP</td>
<td>Very high</td>
</tr>
<tr>
<td>Native MPLS</td>
<td>Very high</td>
</tr>
<tr>
<td>Switched OTN (Central Fabric or Card-Based)</td>
<td>Very high</td>
</tr>
</tbody>
</table>

When looking at packet features, there is no clear winner, and operators are interested in a breadth of packet capabilities, including connectionless Carrier Ethernet, Multi-Protocol Label Switching, Transport Profile (MPLS-TP) and even higher-layer IP/MPLS. Based on the top showing of IP/MPLS, it is clear that IP/MPLS is set to play a major role in metro transport architectures in the future. The definition of
transport has broadened beyond OSI Layers 0 (WDM) and 1 (Sonet/SDH and OTN), and we will increasingly see Layer 3 (in the form of IP/MPLS) added to transport. Heavy Reading places IP/MPLS as a key defining feature of P-OTS 3.0 equipment.

In addition to packet functionality, operators are most interested in dense WDM (DWDM) optics for their next-generation P-OTS systems. We have already highlighted Heavy Reading’s strong growth forecast for metro 100G. The 100G line rate has become a must-have feature in metro-optical requests for proposals (RFPs), even if operators do not need to deploy 100G on day one. ROADM functionality is also very important to operators for the flexibility it brings to the photonic layer.

OTN grooming and switching is gaining importance in the metro (Figure 3). Although switched OTN is not of interest for all operators, it is a critical requirement for some. The primary drivers for metro OTN are transport network convergence and lower-cost Layer 1 switching for Gigabit and 10-Gigabit Ethernet. Traffic-grooming for 100G transport links is also a driver for operators that are deploying or planning to deploy metro 100G. The top drivers point to operator interest in lowering their cost per bit for transport, by consolidating network layers/elements and by transporting traffic at the lowest effective OSI layer possible.

As device functions have become integrated in P-OTS, universal switching fabrics have grown in appeal. A universal switch fabric can switch any type of TDM or packet traffic natively without requiring encapsulation. Universal fabrics make converged transport systems more efficient by covering all switching options on day 1 of deployment and allowing operators to change the mix of fabric use from TDM to packet over time easily and without additional fabric card investments. Universal fabrics are needed particularly for systems that sit in metro core networks, and vendors are bringing to market systems with universal fabrics that scale to multiple terabits per system.

Figure 4 shows an example of a P-OTS-based converged transport network supporting multiple applications, including enterprise, mobile and cloud, and using multiple packet and optical technologies.
Modularity

A hallmark of metro P-OTS is the breadth of features and functions supported. In this paper, we have discussed connectionless Ethernet, MPLS-TP, MPLS, OTN, 100G DWDM, ROADMs and others. However, few operators will use all these functions together. They will pick and choose the ones they need, and those needs will change over time. One of the key value propositions of P-OTS is that the systems serve as a bridge between the TDM world of the past and the packets world of the future.

Furthermore, different parts of the network will have very different requirements. While 100G DWDM may be required in a metro core application, a metro edge application in that same network may not require DWDM at all.

Operators must be able to choose the features they need for P-OTS without having to pay up front for features that they don’t need today or features that they may never need in their system. System modularity is necessary for P-OTS to deliver on its mission of lowering the cost per bit for transport.

As a modular system, next-gen P-OTS can be deployed as a packet and optical combination or as an optical-only or packet-only system alone. Heavy Reading believes that, increasingly, metro P-OTS will be deployed in packet only or packet and DWDM optics only configurations with no TDM interfaces on the system at all.

As such, metro P-OTS will compete head-to-head with pure play Layer 2/3 switches built for transport applications and will have to be “best of breed” in packet functionality in order to win bids. In fact, we have already seen some early deployments of P-OTS products in packet-only or packet and optics-only configurations.

Evolution of Transport SDN in the Metro

Transport SDN is a hot industry topic and is set to transform both long-haul and metro transport networks. We are at the earliest stage of this network evolution, and there is a lot of confusion surrounding the concept of transport SDN. Based on operator surveys and one-on-one interviews, we believe that network operators seek to achieve the following three primary objectives with transport SDN:

- Multi-domain (i.e., long-haul to metro network) interoperability
- Multi-layer (i.e., OTN to Ethernet to IP layer) interoperability
- Multi-vendor control plane interoperability

These transport SDN objectives relate directly to the operator mandate to lower the cost per bit for transport, particularly on the operations side. Multi-domain, multi-layer and multi-vendor control plane interoperability reduces opex by simplifying operations, automating service and bandwidth provisioning, and automating other network functions such as restoration and protection. To date, all these tasks have been performed manually and, thus, are costly in terms of both labor and time.

The transport objectives are also required to achieve the revenue-generating and services-differentiating promises of SDN, including bandwidth-on-demand, network as a service (NaaS) and wide-scale bandwidth and services provisioning.
In order to make transport SDN’s promises a reality, open standards must be defined and adopted by vendors across the industry. Currently, the transport industry is at the stage of deciding and defining those standards. The ONF has formed the Optical Transport working group to define a create OpenFlow protocol extensions for optical transport networks and define a reference architecture for controlling optical transport networks. The ONF Transport working group is also working closely with the OIF to promote and achieve vendor interoperability.

In addition to the ONF OpenFlow work, there is significant operator interest in the IETF’s Network Configuration Protocol for reading and writing network configurations (Netconf), along with its associated data-modeling language, Yang. Together, the IETF standards form a powerful combination for multi-vendor network configuration.

Finally, there is also a role to play for the IETF’s Generalized MPLS (GMPLS) standard, at least over the next five years. GMPLS has been used for automating single domain optical networks for more than a decade and will continue to be used in combination with new transport SDN standards for any control functions that are best served by a distributed optical control plane.

**Summary & Conclusions**

Network operator pressures are greater than ever to generate new revenue streams while also reducing the cost of providing their services. Operators are in the midst of a transition from the TDM-based services of the past to the packet-based services of the future. Through this transition, the transport network has a key role to play in reducing the costs for transport (in terms of both capex and opex), while also providing the highly efficient and flexible infrastructure on which tomorrow’s services and applications will be built.

P-OTS is rising to meet the transport network challenge, and a new generation of equipment – which Heavy Reading defines as P-OTS 3.0 – is coming to market now. These elements will offer new levels of scale, efficiency, flexibility and modularity as operators continue to adapt to their business demands and customer requirements.