WHITE PAPER

# THE ROLE OF OTN SWITCHING IN 100G & BEYOND TRANSPORT NETWORKS

## Managing Bandwidth for Long Haul and Metro Network Evolution

Driven by the escalating bandwidth requirements of Internet video, enterprise cloud, and data center interconnect, service providers worldwide have been migrating from 10G to 100G and beyond. Already begun in long haul networks, this migration is now proliferating in metro networks. In addition, many service providers are adopting OTN switching as a more effective technology for grooming lower speed clients onto high speed line interfaces and efficiently managing bandwidth. This white paper examines the benefits of OTN switching together with the added value of next-generation universal switches that combine OTN, packet, and SONET/SDH switching. 100G(+) ADMs are also discussed as a complementary option for smaller sites. Network scenario examples illustrate when a transponder and muxponder, OTN switch, or 100G(+) ADM approach may offer the greatest advantages.

## DRIVING THE ADOPTION OF 100G(+) TRANSMISSION

Video, cloud, and data center interconnect applications are driving significant growth in both metro and long haul traffic. Internet and over-the-top (OTT) video is the biggest driver of bandwidth to consumers, while enterprise cloud applications, including Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), are delivering a similar impact on enterprise bandwidth. Underlying both of these trends is the need to provide significant amounts of interconnect bandwidth between data centers housing cloud and video services.

The adoption of 100G and higher transmission technologies began in long haul networks where the reach and spectral efficiency advantages of 100G outweighed its higher cost relative to 10G. But 100G(+) is now being adopted in the metro to meet the needs of the enterprise cloud and data center interconnect applications and as a service for Internet Content Providers, bandwidth-intensive enterprises, and government customers. According to a recent IHS/Infonetics Survey shown in Figure 1, 100G and above technology accounted for 64% of new installs in 2015 in long haul networks and will grow to 85% in 2018. While in the metro, 100G and above will grow from 24% in 2015 to 57% in 2018.

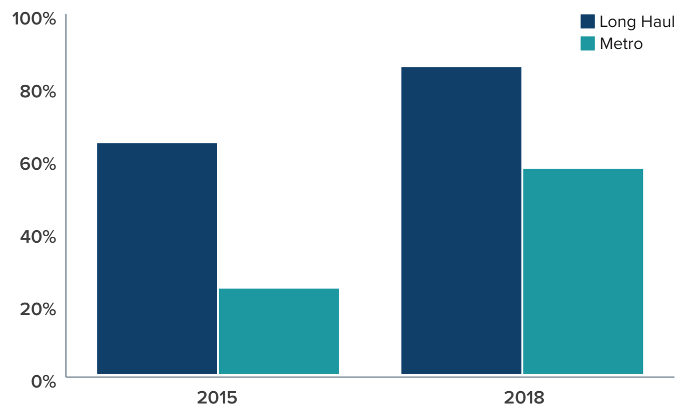


**FIGURE 1** – *100G and Above as a Percentage of New Installs (Source: IHS/Infonetics, 100G+ and ROADM Strategies, Global Service Provider Survey, November 2015)*

## COHERENT-ONLY NETWORKS INCREASE THE NEED FOR FLEXIBLE GROOMING AND AGGREGATION

As operators move to introduce 100G(+) into their networks, they are faced with the question of whether to add 100G(+) to an existing 10G network, to deploy a new network with mixed 10G and 100G(+), or to deploy a new coherent-only network for 100G and beyond without 10G wavelengths. Both of the 100G(+) coherent-only and mixed 10G/100G(+) approaches have their advantages and disadvantages with different results depending on what part of the network is under consideration.

In long haul networks there are significant advantages for deploying a coherent-only network and dispensing with 10G line interfaces and dispersion compensation. These advantages include reach, future-readiness, and spectral efficiency.

- **100G(+) reach** in a coherent-only network can be up to double that of a mixed 10G/100G(+) network with DCMs. The reasons for this difference include non-linear effects such as XPM (Cross Phase Modulation) from 10G and the absence of dispersion, which would have prevented XPM and SPM (Self Phase Modulation) from building up.

- **Future-readiness** drives coherent-only deployment since 10G and DCMs dramatically impact reach as modulation increases beyond 100G to 16QAM for 200Gbps for example.

- **Spectral efficiency** is a driver to deploy a coherent-only network because operators are reluctant to waste 50GHz of spectrum on 10Gbps. An additional advantage of coherent transmission is cost-effective colorless add/drop, which leverages the ability of coherent receiver technology to tune to the required receive frequency.

In metro networks by comparison, the reach advantages of a coherent-only network are less valuable due to the shorter distances. At the same time, fiber is more readily available and the cost of lighting the fiber is lower in the metro, so spectral efficiency is less of a concern than in long haul networks. For these reasons, metro networks are more likely to see mixed 10G/100G(+) solutions. However, on congested metro routes, where fiber availability is an issue or where traffic volumes are high, coherent-only transmission can play a role. Given that the majority of client interfaces are still 10G and below, and realizing the advantages of moving to coherent-only transmission at 100G or above, especially in long haul networks, there is an increasing need to aggregate lower speed client interfaces onto high speed line interfaces.

## BENEFITS AND LIMITATIONS OF MUXPONDER-BASED AGGREGATION

Most of the early 100G(+) networks were built with transponders and muxponders together with ROADMs at the optical layer to provide DWDM multiplexing with flexible add/drop. This solution leveraged the low cost per bit of optical express. Transponders and muxponders still provide the simplest approach to getting traffic on and off a 100G(+) transmission interface. Conceptually, this approach maps one or more client interfaces to a single high speed line interface. Examples of this scenario include a monolithic 100G transponder with one 100G client interface and one 100G line interface, and a monolithic 100G muxponder with ten 10G client interfaces and a single 100G line interface, as shown in Figure 2.

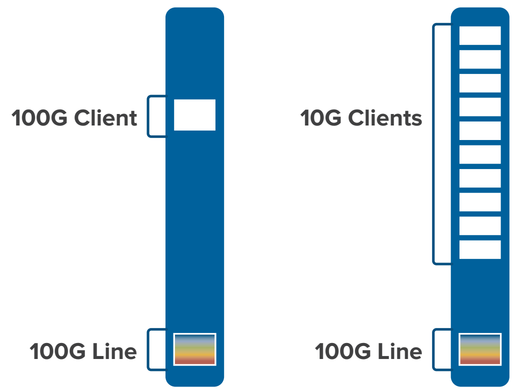


**FIGURE 2** – *Monolithic 100G Transponder and Muxponder*

Next-generation transponders and muxponders are beginning to evolve with separate client and line interfaces on separate modules and with a simplified backplane typically used to provide connectivity between the modules. This approach provides more flexibility than the monolithic transponder and muxponder approach as technology evolution enables multiple line interfaces on a single module for better density and flexi-rate interfaces with the ability to support 100G, 150G, or 200G based on software programmable modulation (QPSK, 8QAM, 16QAM).

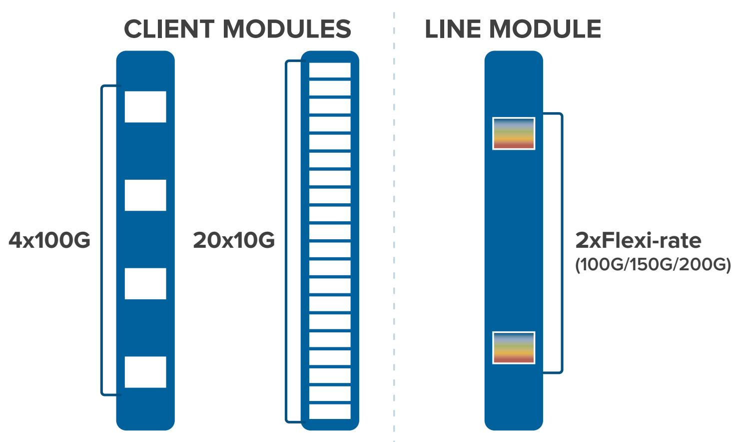


**FIGURE 3** – *Next-generation Flexi-rate Transponder and Muxponder*

For example, the Coriant® hiT 7300 Multi-Haul Transport Platform enables one card with four 100G clients to be paired with one line card configured as two 200G line interfaces or with two line cards each configured as two 100G interfaces. Alternatively, a client card with twenty 10G clients could be paired with one line card configured as two 100G interfaces, or two client cards with twenty 10G ports each could be paired with one line card configured as two 200G line interfaces. This approach enables a wide range of applications to be supported with a limited number of client and line cards while sparing is also simplified.

The key characteristic of the transponder and muxponder approach, whether based on a monolithic transponder and muxponder or separate client and line cards, is that client ports are statically mapped to a single line port and there is no ability to remotely switch client traffic to a different line port or take traffic from one line interface and switch it to another line interface. The advantage of this approach is the simplicity and relatively low hardware cost of muxponders and transponders, which do not require switching hardware or software. Disadvantages include the limited ability to groom traffic from multiple modules onto the same line interface, the inability to remotely reconfigure individual client ports to map to different line interfaces, and the inability to combine add/drop traffic with pass-through traffic from other line interfaces.

Furthermore, most 100G transponder and muxponder solutions have a limited range of client interfaces, typically 100G, 10G, and in some cases 40G. Mapping low speed interfaces such as GbE, 1G/2G/4G Fiber Channel, or SONET/SDH below OC-192/STM-64 typically requires stacking muxponders, with a low speed muxponder aggregating sub-10G clients onto a 10G interface, which feeds into a client port of the 100G muxponder, as shown in Figure 4.

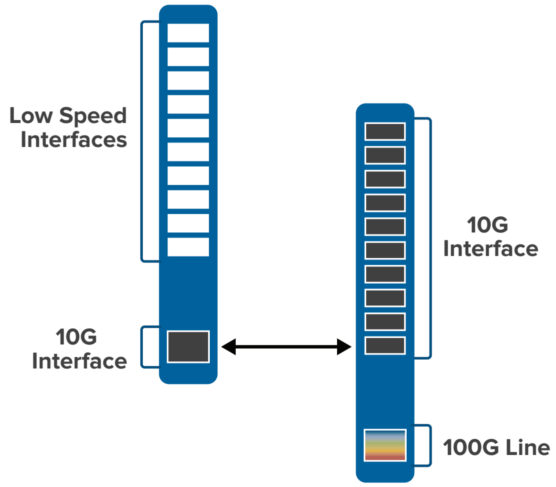


**FIGURE 4** – *Stacked Muxponder Solution for Mapping Low Speed Interfaces to 100G*

The transponder and muxponder approach is likely to have the lowest total cost when the following conditions are met:

- Traffic patterns ensure that A-Z wavelengths will have a high fill rate.
- The client interface speeds are high relative to the line interface speed.
- Traffic patterns are fairly static and predictable.

## THE CASE FOR OTN SWITCHING

OTN switching provides an alternative to the transponder and muxponder approach, although it does not replace the ROADM layer, which is still required for DWDM multiplexing with flexible add/drop and low cost per bit optical express.

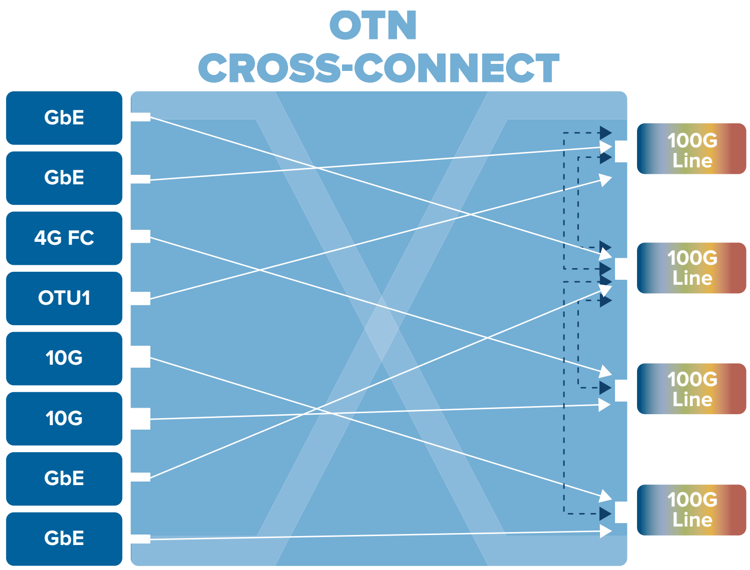


**FIGURE 5** – *OTN Switch with a Mix of Client Interfaces and Multiple 100G Line Interfaces*

An OTN switch enables ODUks (ODU0=1.25G, ODU1=2.5G, ODU2/2e=10G, ODU3=40G, ODU4=100G) and ODUflex (Nx1.25G) to be switched between interfaces, typically via centralized fabrics, mapping any client to any line interfaces and switching pass-through traffic between line interfaces. OTN switches can scale from hundreds of Gbps to tens of Tbps, with the architectural possibility of multi-chassis configurations supporting hundreds of Tbps. As shown in Figure 6, the global market for OTN switching hardware is forecast to almost triple from 2013 to 2019, as operators increasingly deploy the technology to aggregate and virtualize bandwidth on high speed transmission networks.

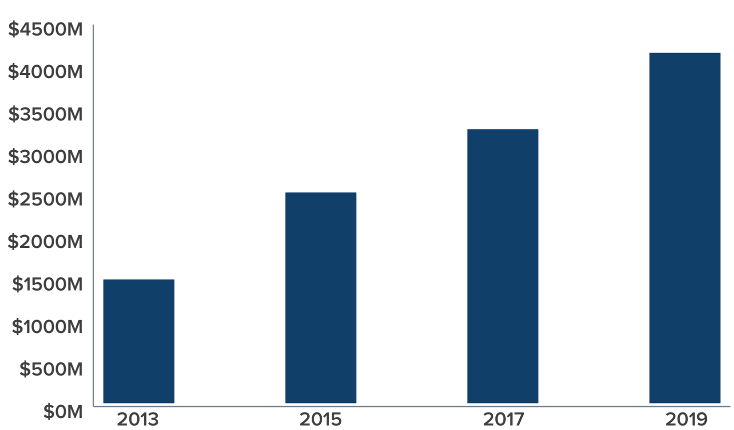


**FIGURE 6** – *Global Market for OTN Switches (IHS/Infonetics, September 2015)*

But what specifically are the advantages of an OTN switching network?

## OTN SWITCH BENEFITS 1: NETWORK COST, SPECTRAL EFFICIENCY, AND LONGEVITY

While an approach based on transponders and muxponders can offer the lowest cost per bit where the client service rates are close to the line interface rate, direct wavelengths have a high utilization rate, and traffic is fairly static and predictable, an OTN switching solution will typically have lower overall costs when these conditions are not met. By combining traffic from different client cards and client speeds with express traffic from other directions, an OTN switch can ensure very efficient utilization of high speed wavelengths. The high speed DWDM line interfaces are the most expensive part of a modern transport network; therefore, the savings in terms of reduced high speed line interface costs is likely to be significantly higher than the incremental cost of adding OTN switching functionality. In a long haul network, an OTN switching solution can offer significant cost savings through a reduction in the amount of 3R regeneration due to fewer wavelengths and the shorter distance these wavelengths have to travel.

A secondary benefit of this efficiency is that an OTN switching solution uses far fewer unique wavelengths, which results in much greater spectral efficiency. This spectral efficiency enables the DWDM network to scale for a longer time period without running into wavelength blocking scenarios and ultimately avoids the cost of having to add DWDM capacity to the network, including the cost of leasing and lighting new fibers.

## OTN SWITCH BENEFITS 2: FLEXIBILITY, OPERATIONAL SIMPLICITY, AND SPEED OF SERVICE DELIVERY

An OTN switching solution offers significant benefits in terms of flexibility, operational simplicity, and the speed with which services can be provisioned. With a solution based on transponders and muxponders, services between a new set of A and Z locations will require new wavelengths involving the deployment, installation, and testing of new equipment. Even when an A–Z wavelength with spare capacity already exists, if low speed client ports are required, a delay may still occur while engineers manually cable a low speed muxponder (i.e., GbE to 10G) to a high speed muxponder (i.e., 10G to 100G).

An OTN switching solution is much more flexible, resulting in lower operational costs and faster service provisioning times. Traffic changes and additions can often be accomplished without having to add new high speed wavelengths. This is especially true for low speed services (GbE, OC-3/STM-1, OC-12/STM-4, OC-48/STM-16, OTU1, 1G FC, 2G FC, 4G FC) where the client service rates are low relative to the line interface rate. Furthermore, low speed services can be remotely switched from low speed client cards to high speed line interfaces without the cabling that is required in the stacked muxponder solution.

## OTN SWITCH BENEFITS 3: NEW SERVICES BASED ON THE ABILITY TO VIRTUALIZE BANDWIDTH

OTN switching together with SDN enables new services by providing the ability to virtualize optical network bandwidth in ways that are not possible with networks based on transponders and muxponders. OTN provides virtualized bandwidth between nodes to the granularity of an ODU0 (1.25Gbps), ODU1 (2.5Gbps), ODU2/2e (10G), ODU3 (40G), or ODU4 (100G). ODUflex provides an ODU that can be sized as a multiple of 1.25Gbps tributary slots in a higher order ODU. OTN switching enables the set of point-to-point connections and bandwidth between these end-points to be reconfigured remotely, as long as the end-points remain physically the same.

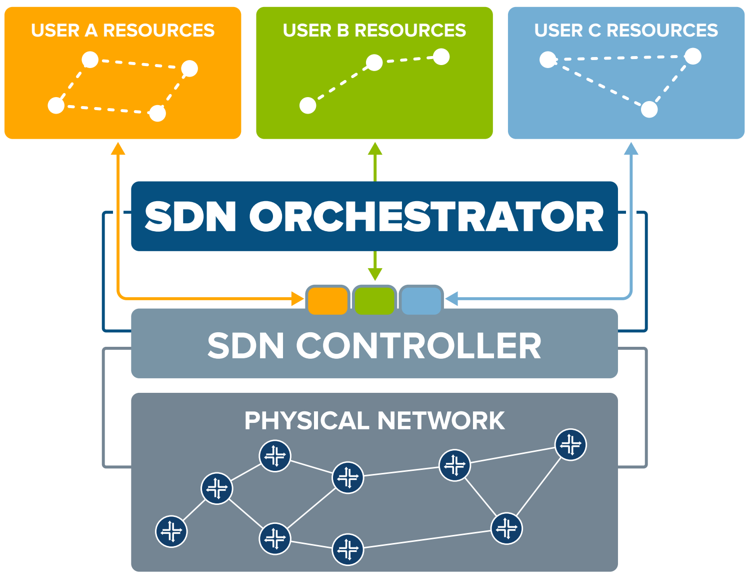


**FIGURE 7** – *Network Slicing with SDN*

The flexible physical infrastructure of OTN switching can be combined with SDN network slicing to abstract physical resources and partition them for different users.

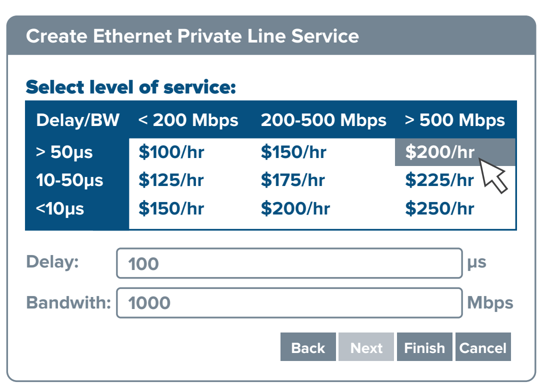


**FIGURE 8** – *Bandwidth-on-Demand*

Once the physical resources have been assigned, an end-user can use Bandwidth-on-Demand applications via open interfaces to reconfigure their assigned resources (either directly or through an orchestrator), thus providing an optical VPN or Network as a Service (NaaS).

## OTN SWITCH BENEFITS 4: PROTECTION AND RESTORATION

Many operators now need to deliver services that can survive multiple simultaneous failures (fiber cuts, interface failures, node failures, etc.). Although optical layer restoration can deliver advantages in terms of simplified planning and the ability to survive multiple failures without requiring additional resources, OTN switching does offer some significant advantages when it comes to protection and restoration.

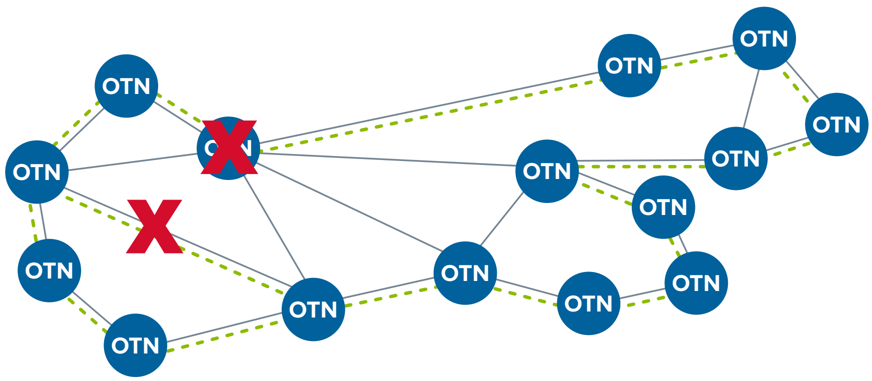


**FIGURE 9** – *Fast Restoration with OTN Switching*

Performing restoration purely in the optical layer typically takes minutes as the lasers need to retune and the amplifiers need to rebalance. OTN layer electrical restoration can be done in hundreds of milliseconds. In long haul networks, OTN switching also performs an OEO regeneration and thus solves the problem of where to put regens to ensure optical layer survivability.

OTN switching enables fast shared protection and restoration schemes, which are harder or even impossible to achieve with a transponder and muxponder solution. These shared protection and restoration schemes can significantly lower the cost of enabling the network to survive multiple failures. In many cases, the optimal solution is to combine OTN-level protection with optical layer restoration, with key decision-making criteria being the traffic matrix, network topology, number of tolerable simultaneous failures, restoration times, and the level of tolerable risk.

## ADDITIONAL BENEFITS OF UNIVERSAL SWITCHING

While the first generation of OTN switches focused on OTN-only switching, next-generation transport switches such as the Coriant® mTera® Universal Transport Platform (UTP) can switch OTN, packet, and SONET/SDH on the same fabrics. With the mTera® UTP, each interface and virtual interface can be software defined for OTN, Carrier Ethernet (Bridging, VLAN cross-connect), or MPLS-TP/VPLS, and the platform can interwork SONET/SDH switching with OTN and packet switching.

Additional benefits of universal switching over and above a pure OTN switch include:

- Router port optimization with VLAN to ODU mapping
- The ability to offer granular and multi-point Ethernet services
- Cost savings from the granularity of packet or STS-1/VC-4 switching and the statistical gains of packet switching
- The ability to mix OTN, SONET/SDH, and packet traffic on the same 100G interface
- Investment protection against changing traffic patterns and client types

Router port optimization is achieved by aggregating sub-wavelength traffic (10G with ODU2, Nx1.25G with ODUflex) from multiple locations onto a smaller number of high speed (100GbE) client ports. This can reduce the number of router ports and modules resulting in significant cost savings.

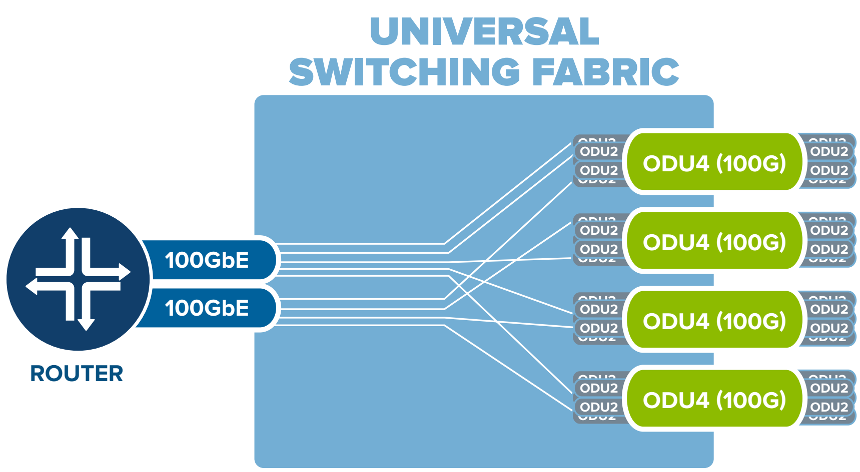


**FIGURE 10** – *Router Port Optimization with VLAN to ODU mapping*

While a pure OTN switch can deliver Ethernet Private Line (EPL) services with uncontended bandwidth based on 1.25G granularity, packet switching can enable more granular services (e.g., 1Mbps increments) in addition to a wider range of Ethernet services including Ethernet Virtual Private Line (EVPL), Ethernet LAN (E-LAN), and Ethernet Tree (E-Tree) services.

| | PURE OTN SWITCH | UNIVERSAL SWITCH |
|---|---|---|
| EPL | ✓ (1.25G granularity) | ✓ (1.25G with OTN or Mbps with packet) |
| EVPL | X | ✓ |
| E-LAN | X | ✓ |
| E-Tree | X | ✓ |

**TABLE 1** – *Ethernet Services Comparison: Pure OTN vs. Universal Switching*

Depending on the location in the network and the traffic matrix, switching at the packet or STS-1/VC-4 level can have efficiency benefits over switching OTN at the ODU0 (1.25G) level or above, as long as one of two conditions are met. Either there must be a lot of client interfaces below 1Gbps or there must be the potential for large statistical gains from multiplexing uncorrelated bursty traffic flows. These conditions are more likely to occur in a metro network versus the long haul network where statistical gains have often already been achieved at the IP/MPLS layer and client interface speeds are likely to be above 1Gbps.

Universal switching platforms such as the mTera® UTP enable OTN, SONET/SDH, and packet switched traffic to share the same high speed interface, with SONET/SDH mapped to ODU2s, packet traffic mapped to ODUflex, and the remaining capacity available for OTN switched traffic, thus making the most efficient use of each high speed interface and the optical spectrum it consumes. In addition, universal switching provides investment protection against changes in traffic patterns and client types. With universal fabrics, and the ability to define in software interfaces and virtual interfaces for OTN, Carrier Ethernet (Bridging, VLAN cross-connect), or MPLS-TP/VPLS, and without impacting the capacity of the switch, operators can easily evolve from OTN to universal switching.

## COMPLEMENTARY ROLE OF 100G(+) ADMS

With a value proposition in-between the low hardware cost of transponders and muxponders and the flexibility of the OTN switch or universal switch, a 100G(+) Add/Drop Multiplexer (ADM) is a small OTN switch with two high speed line interfaces and a number of low speed interfaces (typically twenty 10G ports). The 100G(+) ADM form factor is often similar to two muxponder modules with backplane connectivity between them, although monolithic single card designs and designs with low speed client ports are also possible.

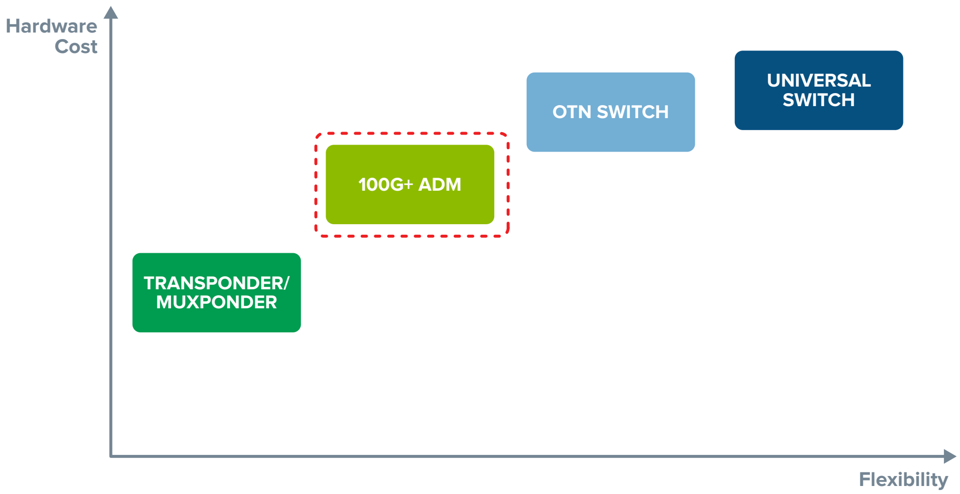


**FIGURE 11** – *Layer 1 through 2.5 Options for 100G+: Hardware Cost vs. Flexibility*

A 100G(+) ADM reduces the cost and complexity of a full OTN switching solution by avoiding the need for fabrics and simplifying the backplane requirements. This solution also reduces footprint and power consumption with 100G(+) ADMs requiring a small number of slots in an existing shelf. However, this approach does not offer the option to grow beyond two line interfaces and, in most cases, lacks the ability to support sub-10G client interfaces.

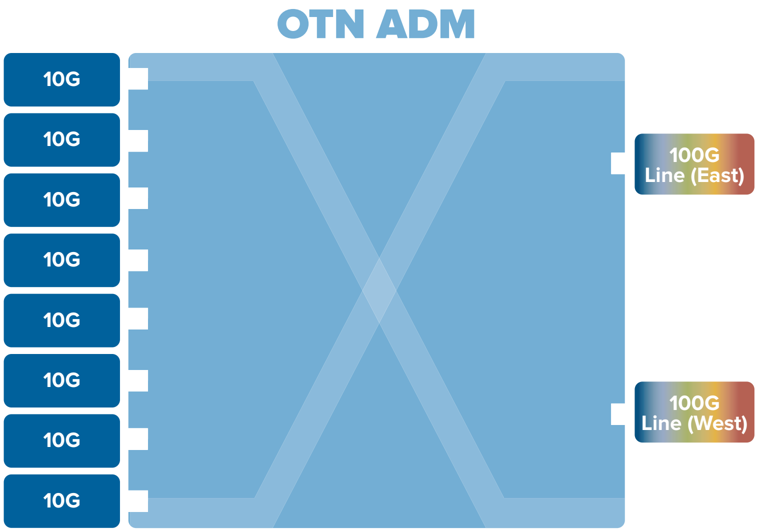


**FIGURE 12** – *100G ADM*

## 100G MUXPONDERS WITH MANUAL 10G PASS-THROUGH

As an option, a pair of regular 100G muxponders can be used as a type of ADM. This solution is implemented by putting short reach pluggables into appropriate client ports, manually patching these ports together, and then manually passing through ODU2s (10G) between the line interfaces as shown in Figure 13.

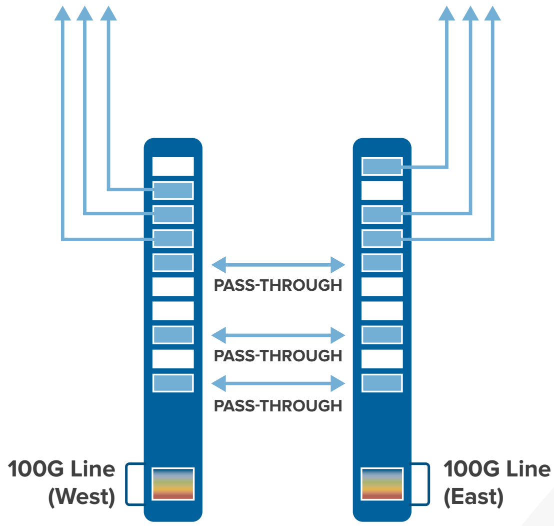


**FIGURE 13** – *Back to Back 100G Muxponders with Manual 10G Pass-through*

In theory for a static network, manual pass-through can provide the same benefits as a 100G(+) ADM solution for lower cost, assuming the cost of short reach interfaces and cabling is lower than the incremental cost of ADM functionality. However, this manual approach adds substantial complexity to the network and careful records must be maintained of all the manual pass-throughs. End-to-end troubleshooting presents a challenge if an end-to-end view is not available in the network management system. Changes to the network require onsite visits with manual changes at multiple locations to add one end-to-end 10G. Moreover, manual patching introduces the possibility of human error.

## NETWORK EXAMPLES

In order to understand the network characteristics that favor OTN switching, OTN ADM, or transponders and muxponders, this section examines network examples to illustrate how each approach may be appropriate for different traffic patterns.

### SCENARIO 1: CONCENTRATED TRAFFIC PATTERN

The concentrated traffic pattern network scenario in Figure 14 shows A–Z traffic that results in a high fill rate for 100G wavelengths between the A and Z locations. In this scenario, a transponder and muxponder and OTN switching or ADM approach would result in the same number of interfaces and wavelengths. The transponder and muxponder solution would, therefore, have the lowest total cost because the incremental cost of the OTN switching/ADM solution would not result in any compensatory efficiency savings.

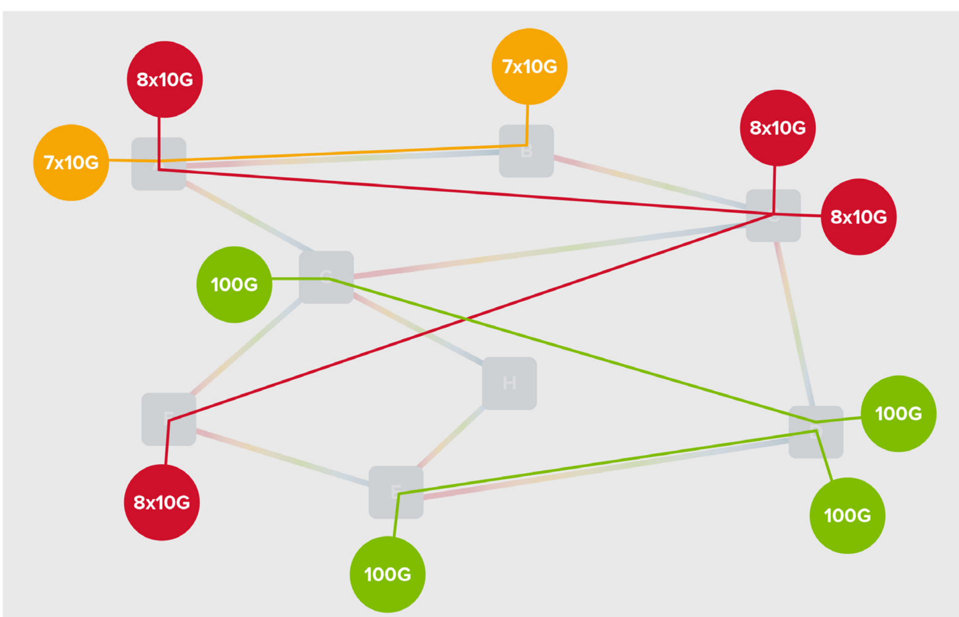


**FIGURE 14** – *Network Example with Concentrated Traffic Pattern*

| | 100G INTERFACES | UNIQUE WAVELENGTHS | LOWEST COST |
|---|---|---|---|
| Muxponder/Transponder | 10 | 2 | ✓ |
| OTN Switching/ADM | 10 | 2 | X |

**TABLE 2** – *Scenario 1 Comparison*

## SCENARIO 2: DISTRIBUTED TRAFFIC PATTERN

In the distributed traffic pattern scenario shown in Figure 15, the traffic volume between any two A and Z locations is much lower. In this scenario, an OTN switching solution has significant advantages in terms of cost and spectral efficiency, especially if there is a mandatory requirement that all line interfaces must be 100G or higher.

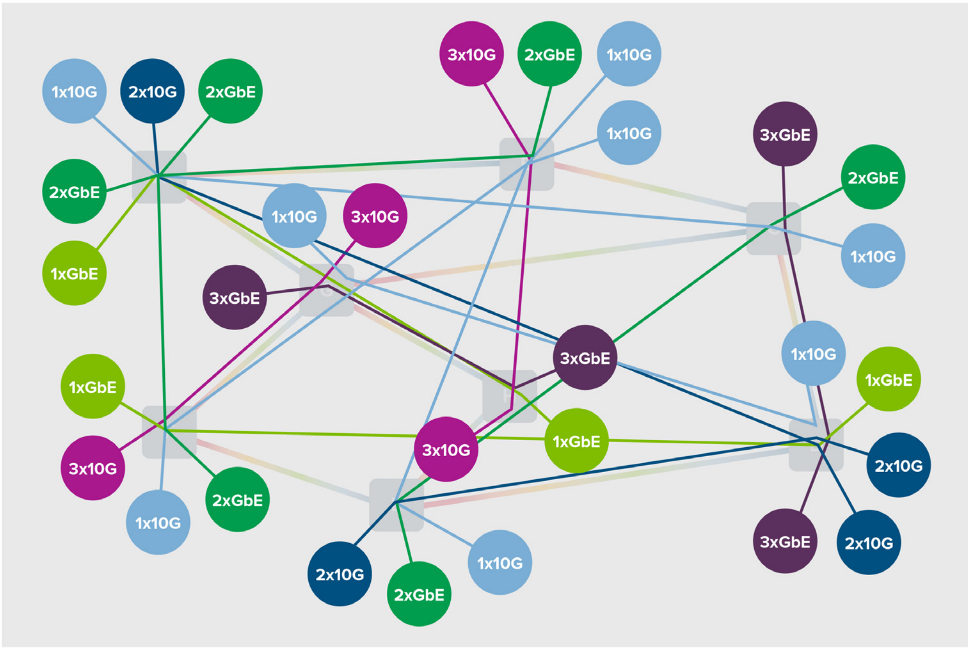


**FIGURE 15** – *Network Example with Distributed Traffic Pattern*

For a line interface requirement of 100G or higher, an OTN switching solution only requires seven point-to-point 100G wavelengths as shown in Figure 16, resulting in fourteen 100G interfaces with a maximum of only a single wavelength used on any span.

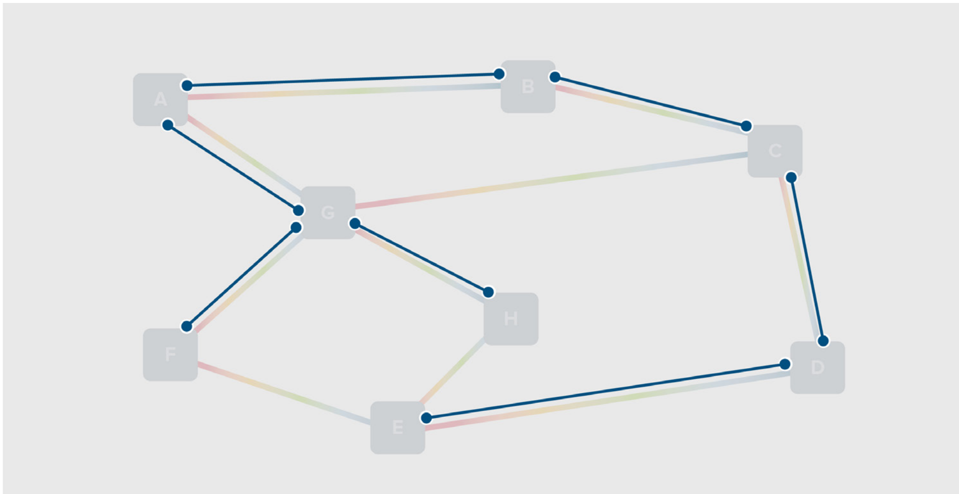


**FIGURE 16** – *100G Wavelengths with OTN Switching*

A point-to-point muxponder solution requires fifteen point-to-point wavelengths with thirty 100G interfaces and up to five wavelengths used on a span, resulting in much worse spectral efficiency. Furthermore, the GbE clients will require a large number of stacked low speed/high speed muxponders.

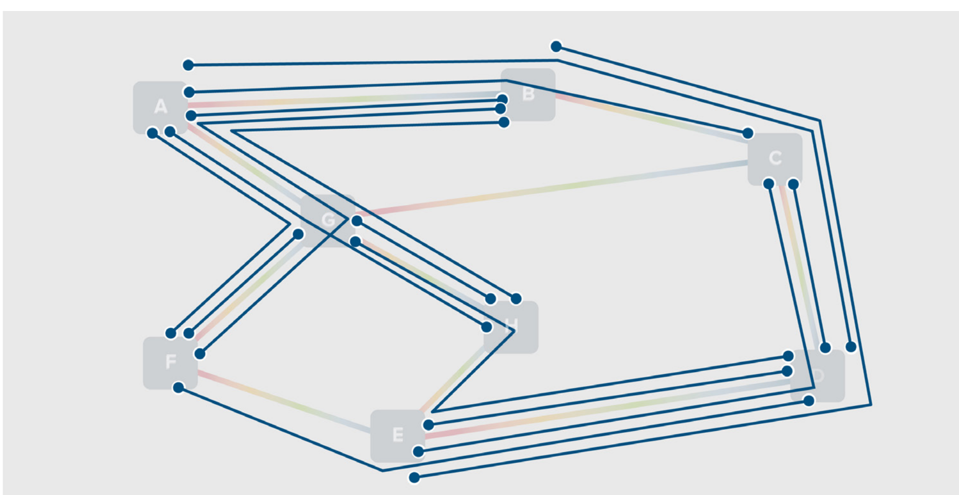


**FIGURE 17** – *100G Wavelengths with Point-to-Point Muxponders*

| | 100G INTERFACES | UNIQUE WAVELENGTHS | LOWEST COST |
|---|---|---|---|
| Muxponder/Transponder | 30 | 5 | X |
| OTN Switching | 14 | 1 | ✓ |

**TABLE 3** – *Scenario 2 Comparison*

In a long haul network, the cost savings of an OTN switching solution is even more pronounced with a reduction in the amount of 3R regeneration due to fewer wavelengths and shorter distances for these wavelengths to travel. In this simple example, a 100G(+) ADM could also be used at all sites other than G. The 100G(+) ADM solution could potentially offer the lowest cost. However, 100G(+) ADMs would not be as efficient if additional 100G line interfaces were necessary in the future at sites that would require 100G(+) ADMs with support for low speed interfaces to avoid stacking with low speed muxponders/ ADMs.

In a network example with much higher traffic loads, an OTN switch would have significant advantages including the ability to support more than two high speed line interfaces and a much larger number and range of client ports. It is also worth noting that as the traffic volumes increase and the fabrics and commons get amortized over a larger number of interfaces, the incremental cost of OTN switching will decrease in relative terms compared to a transponder and muxponder solution or a 100G(+) ADM solution.

## SUMMARY

The evolution of DWDM interfaces from 10G to 100G and beyond, together with the move to coherent-only networks, is leading many operators to adopt OTN switching as an effective solution for grooming lower speed client interfaces and effectively managing bandwidth. While transponders and muxponders can provide an effective solution for a concentrated traffic pattern, OTN switching offers the most cost-effective and spectrally efficient solution when traffic is distributed, to the extent that a muxponder solution would result in poor wavelength utilization. Additional benefits of OTN switching include client interface flexibility, operational simplicity, fast service provisioning times, and the ability to deliver new services based on virtualized bandwidth.

100G(+) ADMs can provide a complementary option for smaller sites where there is a need for add/drop functionality but capacity requirements cannot justify a full-blown OTN switch. Depending on topology and traffic patterns, a combination of transponders and muxponders, OTN and universal switches, and/or 100G(+) ADMs together with a ROADM-based optical layer may prove to be the optimal solution.

In addition to OTN switching, next-generation universal switches such as the mTera® UTP offer significant additional benefits including router port optimization with VLAN to ODU mapping, potential switching efficiencies at the packet or STS-1/VC-4 level, the opportunity to offer a more complete set of Ethernet services, the ability for OTN and packet traffic to share the same high speed interface, and the investment protection to evolve with changing traffic patterns and client types.

## 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.