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White Paper

SDH Network Modernization With Multiservice OTN

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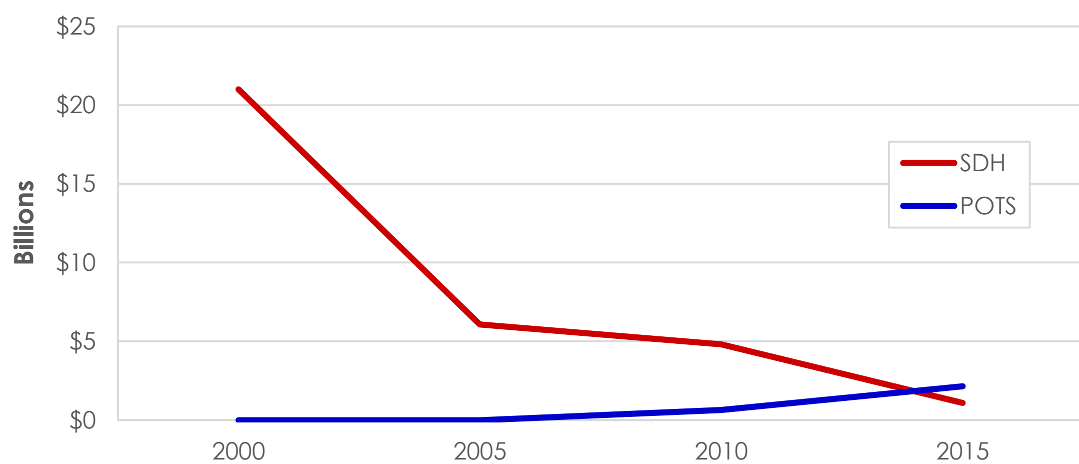
Introduction: State of the Sonet/SDH Market

The end of Sonet/SDH was prematurely declared by the telecom industry so many times over the past 20 years that, when the fall of Sonet/SDH did truly commence in earnest, it went largely unnoticed and unheralded.

The global Sonet/SDH market peaked in 2000 at $20 billion in revenue. During the mid-2000s, Sonet/SDH started on a relatively modest and uneven descent. From 2000-2010, Sonet/SDH spend was in decline, but it also benefitted from the relative immaturity of the Ethernet technologies that were developed to supplant it. It was during this time that many predictions of Sonet/SDH's demise proved premature.

However, the Sonet/SDH decline started accelerating rapidly in 2011, when operators embarked on a rapid migration to Ethernet and WDM at the expense of legacy Sonet/SDH. A significant milestone was hit in 2013, when converged packet-optical transport system (P-OTS) spend exceeded Sonet/SDH spend for the first time in history. And by 2015, Sonet/SDH equipment spend – once the $20 billion workhorse of the global public network – had fallen 95 percent from its 2000 peak. (See **Figure 1**.)

Figure 1: SDH vs. Packet-Optical Transport Revenue (2000-2015)



Source: Heavy Reading

The fall of Sonet/SDH took much longer than most predicted, but today, no one can question that the Sonet/SDH era is nearing its final years.

Operators Must Move Beyond SDH

The current state of Sonet/SDH creates significant challenges for operators. As noted, global spend on new Sonet/SDH was less than $1 billion in 2015 and continues to drop, but this statistic does not take into account the installed base of Sonet/SDH equipment that remains operational today. For example, operators spent $16 billion on Sonet/SDH over the last six years alone. And many operators have Sonet/SDH equipment in their networks going back 15 years or longer, much of it supporting TDM private line services.

This installed Sonet/SDH equipment is aging, meeting or exceeding the 10- to 15-year lifespan for which it was intended. Replacing aging equipment and parts is becoming increasingly difficult and will ultimately become impossible, as equipment suppliers are no longer investing in a market segment that has lost 95 percent of its value. In a segment that has undergone significant consolidation over the years, some suppliers have gone out of business.

The result is that operators maintaining aging infrastructure cannot get new features, have limited or no access to spare parts, and cannot get service on installed gear. In addition, operators see opex go up due to increased faults and service degradation, complex provisioning, high power consumption and large footprint, and the requirement to maintain separate networks: one for newer packet services and another for legacy Sonet/SDH services.

Ultimately, there are two scenarios that force operators to modernize their Sonet/SDH networks:

- Operators are no longer able to obtain the parts or systems required to keep their legacy networks running.
- Operators find that the opex of running and maintaining their legacy network exceeds the capex of deploying a new replacement network.

For operators that need to modernize their legacy Sonet/SDH networks, there are two major technology options available:

- Pure Layer 2/3 packet switching
- Multiservice switched OTN

The remainder of this white paper explores the major migration options and focuses particularly on the drivers for and benefits of Sonet/SDH migration with multiservice switched OTN.

SDH Migration to Layer 2/3 Packet Switching

One of the options for operators migrating away from Sonet/SDH transport is to move directly to packet-based transport using carrier-grade Layer 2/3 switches. A number of technology advancements over the past decade has made Layer 2/3 switching a suitable replacement for Sonet/SDH in a number of applications, and particularly for applications that are exclusively or primarily carrying Layer 2 and Layer 3 traffic.

Mobile backhaul is an application in which packet switching equipment has excelled. The global migration away from TDM-based backhaul to packet-based backhaul occurred over the past six years. In 2010, just 9 percent of cell sites globally were served by Ethernet backhaul (with the remaining 91 percent served by TDM), according to Heavy Reading. At the end of 2015, 79 percent of global cell sites were served by Ethernet-based backhaul networks.

Increasing bandwidth requirements for 3G and 4G, combined with the maturation of technologies that addressed historical packet network shortcomings, were the main contributors. The ITU-T Synchronous Ethernet and IEEE 1588v2 synchronous standards were critical for packet backhaul. Packet synchronization surpassed E1/T1 synchronization in 2012.

Circuit emulation services (CES) was another key advancement that enabled operators to run their TDM services over packet networks. This advancement was important for converged infrastructure applications in which operators wanted to run both packet and TDM services over the same network. CES, once it matured, has proven effective for networks that are predominantly packet-based with a limited amount of TDM services that can be carried via CES.

Carrier Ethernet services is another application in which packet switching equipment has fit well. In the early days of Ethernet, operators required Ethernet services to travel over Sonet/SDH networks due to reliability requirements (i.e., EoS or EoSDH) and OAM features provided by Sonet/SDH, which Layer 2/3 switches lacked. However, carrier-grade reliability and Ethernet OAM functionality – including ITU-T y.1731 – made packet switching suitable for many Carrier Ethernet applications.

Limitations of Packet Switching

Despite technology progress over the past decade, packet switching also has limitations that make it unsuitable for many applications that continue to rely on Sonet/SDH. Below is a summary of the primary limitations of packet switched networks compared to Sonet/SDH.

- Layer 2/3 switching introduces high latency relative to Sonet/SDH that may make it unsuitable for applications that are highly latency-sensitive or have strict requirements for latency guarantees. Latency in packet switched networks is unpredictable and cannot always be guaranteed.
- CES is only an option for lower-capacity circuits, as the technology is limited to T1/E1 and T3/E3 rates.
- Sonet/SDH set the gold standard in reliability with "five nines" uptime and sub-50 millisecond recovery times. Despite its advances, packet switching cannot match the ultra-high reliability of Sonet/SDH networks.
- Shared packet-switched networks are not private like dedicated circuit-switched Sonet/SDH networks, and certain operators and enterprise customers require the security of a private, dedicated connection.
- Finally, some high-value end customers are simply not willing to move away from their TDM services, and forcing a migration to packet-based networks risks losing these customers.

Sonet/SDH Migration With Multiservice OTN

While packet switching has evolved to take on a portion of the burden of legacy Sonet/SDH, it is not always the best option. This section takes a detailed look at another strong option for SDH network migration: **multiservice OTN**. Multiservice OTN comprises two key features:

- The bit-rate transparency of OTN encapsulated signals,
- Universal switching fabrics that can switch all kinds of service types, including TDM- and packet-based services.

We describe both of these multiservice OTN features in more detail below.

Bit-Rate Transparency

OTN is an optical transport standard developed by the ITU-T and first standardized in 1998. It is also known as ITU G.709 and "digital wrapper." While G.709 is the most notable ITU-T standard associated with OTN, other relevant ITU-T standards include G.873.1 and G.872. In OTN, the ITU defined a payload encapsulation, OAM overhead, FEC, and multiplexing hierarchy. The result is a transport standard that includes the benefits of Sonet/SDH (such as resiliency and manageability), but with improvements for transporting data payloads.

OTN is asynchronous, and so does not require the costly and complex timing that Sonet/SDH requires. Yet OTN is a transparent protocol, so it can carry asynchronous traffic such as Gigabit Ethernet, synchronous traffic such as Sonet/SDH, and even a mixture of synchronous and asynchronous, without interfering with the OAM of the client traffic itself.

This bit-transparent transport of the client signal is commonly referred to simply as "transparency." Note that OTN transport is also timing-transparent. OTN's asynchronous mapping transfers the input signal timing to the far end of the connection. This is in contrast to Sonet/SDH, which imposes its own timing on client signals.

Universal Switching

A protocol-agnostic, or universal, switch fabric can process any type of TDM or packet traffic natively, without requiring protocol encapsulation. There are different technologies used for universal fabrics, including TDM-based and cell-based fabrics. These different technologies manipulate the bits differently while they are passing through the fabric chip itself. However, in all instances of a universal fabric, the end function is the same: Traffic entering the switch (whether it is Ethernet, Sonet/SDH, OTN, etc.) exits the switch in the same format. A key benefit is that different service types and different bandwidth granularities can be encapsulated within the same OUT-k channel, which increases bandwidth utilization.

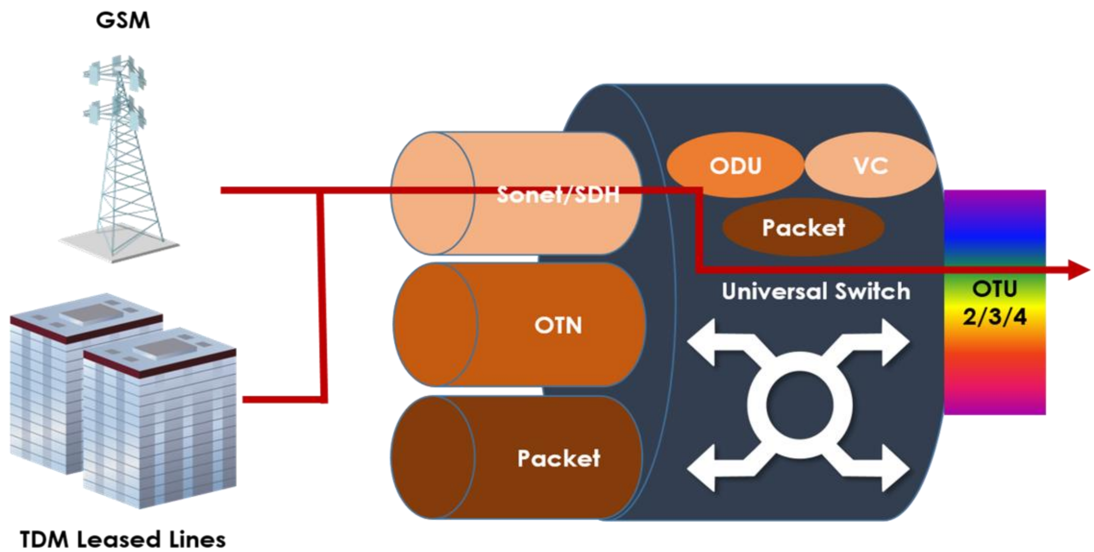
Universal switching fabrics are an important tool in achieving transport network element convergence. Traditionally, operators have deployed multiple boxes to handle separate functions of DWDM transport, Layer 1 circuit switching, and higher-layer packet switching. These have all been managed separately and connected via short-reach interfaces. A converged network element eliminates multiple boxes in a central office and creates capex and opex savings, while also simplifying management. This converged structure is especially efficient in some scenarios, including:

- Networks in which the aggregation and access equipment are 10GigE while the core router is upgraded to 100GigE.
- Very short time to market for end-to-end dedicated line services since there is no need for a UNI connection for different layers. This reduces patch cords and labor.

Universal fabrics make converged transport systems more efficient by covering all switching options on day 1 of deployment, and by allowing operators to change the mix of fabric use from TDM to packet over time easily and without additional fabric card investments.

Figure 2 illustrates a multiservice OTN network using a centralized universal switching fabric combined with universal line cards that carry any service type – including Sonet/SDH, OTN, and packet-based services.

Figure 2: Universal Switching Fabric Carrying Multiple Traffic Types



Source: Huawei and Heavy Reading, 2016

Primary Benefits of Multiservice OTN

OTN brings several benefits to operators that are looking to migrate away from legacy Sonet/SDH networks. Below we discuss the primary advantages of multi-service OTN transport and switching, as well as several applications that are best suited to those advantages.

Guaranteed & Ultra-Low Latency

Network latency is any kind of delay that occurs in data communications over a network. Latency in transmission has many sources, including hops through the various elements along a route and the transmission medium itself.

Latency over optical fiber is ultimately dictated by the speed of light traveling through that fiber and the distance over which the signal travels. Photonic devices along a fiber route – including fiber amplifiers and photonic-layer switches – each add latency to a transmission, but it is minimal, measured at 5 ns per device.

Beyond the photonic layer, higher-layer processing is required in optical transmissions for functions including OAM, multiplexing and grooming, and switching. Here, Layer 1 is always the best choice from a latency and overhead perspective. As a Layer 1 protocol, OTN adds very little overhead and latency to transmissions compared to Layer 2 Ethernet and Layer 3 IP networking protocols. Layer 1 switching provides up to 1,000 times lower latency than Layer 2 switches or Layer 3 routers, and also guarantees full line-rate performance with no oversubscription.

In addition to low latency, OTN also provides a high consistency of latency across different data rates, as well as high consistency across different client protocols, such as Gigabit Ethernet or Fibre Channel, for example.

In addition to the amount of network latency in a transmission, the variation in latency is another important factor that operators must consider in offering services. TDM networks – which includes Sonet/SDH and OTN networks – create fixed latency in the transmission, which is also guaranteed for the operators and for their end customers. Guaranteed and predictable latency is important for high-value services, such as leased lines, and for certain applications, such as video.

By contrast, Layer 2 (Ethernet) and Layer 3 (IP) packet networks not only have greater latencies, due to greater processing, but latency is also unpredictable. Variability in latency is a problem in packet switched networks particularly during peak traffic times, during which latency can increase to 10 times to as much as 100 times compared to low traffic times.

High Scalability With Guaranteed Bandwidth

Two key aspects make OTN highly scalable when compared to legacy Sonet/SDH. The first relates to 100G transmission. While both Sonet/SDH and OTN standards exist at 2.5G, 10G, and 40G data rates, there is no 100 Gbit/s standard for Sonet/SDH. Of the two protocols, only OTN has been standardized up to 100 Gbit/s transmission (ITU-T OTU4). For this reason, OTN switching took off in the core network when operators began migrating to 100G, and as 100G has started moving into metro applications, we are seeing concurrent adoption switched OTN in metros.

Second, OTN signals ride on DWDM wavelengths, so OTN is scalable at the DWDM level. This makes OTN suitable for high-bandwidth applications are that also high-growth applications, such as financial trading applications and high-definition video such as HDTV and 4K video. For these applications, as bandwidth needs increase, operators can quickly upgrade capacity by adding an additional OTN-based wavelength on the existing system.

Beyond scalability, an additional benefit of OTN is guaranteed bandwidth. As a connection-oriented, TDM-based protocol, OTN inherently also provides guaranteed bandwidth for end customers, meaning that a customer that orders a 10 Gbit/s service over an OTN network will always receive a 10 Gbit/s signal. This can be particularly important for private line customers, and for wholesale customers who are paying for a set amount of capacity and need to be assured that they will always receive exactly what they are paying for.

High Security

Two aspects make OTN an ideal fit for operators that require high security. First, OTN over DWDM enables operators to dedicate a full channel/wavelength for individual customers. Thus, an end customer can put all of their traffic on a private wavelength (or multiple private wavelengths) without sharing capacity with other customers.

The second security benefit of OTN is Layer 1 encryption. Layer 1 encryption secures data as it travels between end locations, such as between two data centers, or between a data center and an enterprise location. Encrypting Layer 1 for the in-flight portion of a transmission ensures that information contained in all of the layers above Layer 1 is also encrypted. This is because the encrypted payload of a Layer

1 OTN frame contains all of the payload and header information of every layer that is being carried over that wavelength.

Layer 1 encryption also has benefits of extremely low latency compared to higher-layer encryption techniques. For example, 100G optical encryption adds less than 150 nanoseconds of latency to a transmission, whereas a 10 Gbit/s Ethernet transmission adds several microseconds (while providing one tenth the bandwidth). IPsec encryption adds even greater latency, measured in milliseconds – roughly 10,000 times greater latency compared to OTN encryption.

Highest levels of data security are a requirement for government applications, as well as for financial services applications. Enterprises across verticals are becoming increasingly concerned with data breaches, so security is really a growing requirement across industries.

Figure 3 provides a summary of certain verticals and applications across the key attributes of OTN that were discussed in this section.

Figure 3: Requirements for Verticals

Segment/ Application	Ultra-Low Latency	Guaranteed Latency	Guaranteed Bandwidth	Security	High Bandwidth
Government	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM
Financial services	HIGH	HIGH	MEDIUM	HIGH	HIGH
Private line	MEDIUM	HIGH	HIGH	MEDIUM	
Wholesale		HIGH	HIGH	MEDIUM	HIGH
Video	HIGH	HIGH			HIGH

Source: Heavy Reading

Smooth Network Migration

Lastly, a smooth migration is one of the most important requirements for any Sonet/SDH network modernization project. If the migration is not carefully executed, there will be service interruptions due to incompatibility between the new network and the old Sonet/SDH network. Here, the MS-OTN universal switching fabric provides an advantage by enabling a site-by-site migration from the old Sonet/SDH. The MS-OTN equipment can support all Sonet/SDH services and can fit in the old Sonet/SDH network without requiring changes to other sites. With MS-OTN, potential mistakes can be located easily and service interruptions can be avoided.

Migrations using IP and other packet-based equipment, by contrast, are more complex. Typically, in these cases, a new packet network must be built before the Sonet/SDH offload takes place, requiring extra fiber and space for the new sites and introducing risks for service interruptions and delays.

Some vendors propose a third option – a mixed network that consists of both SDH equipment and separate, switched OTN elements. This option is proposed by vendors that don't have multi-service capabilities within their OTN systems. However, this architecture also raises compatibility issues between the new network and the old.

We close this white paper with a look at four network operators from different regions of the world that faced various challenges with their aging SDH networks and ultimately selected multiservice OTN for their SDH modernization. **Figure 4** highlights these SDH modernization success stories.

Figure 4: Operator SDH Modernization Success Stories

Operator	Challenges & Requirements	Multiservice OTN Benefits
Tier 1 Operator, Americas	SDH equipment from more than 10 vendors, with some equipment reaching end of life. Resource system was more than 20 years old and 30 percent inaccurate. Operator was also running out of CO space.	Migrating to multiservice OTN, operator was able to reduce opex by 20 percent and reduce CO space by 40 percent. Operator also improved network restoration times and simplified network planning.
Tier 1 Operator, India	3G subscribers increasing rapidly, but legacy SDH network was unsuitable for 3G/LTE migration. SDH required high opex, a large number of fibers, and provided limited bandwidth.	Operator reduced capex by 55 percent, and each single site was given exclusive bandwidth that did not affect other sites.
Tier 1 Operator, Europe	Massive network of old SDH equipment, entering end of life, with frequent faults, lack of spare parts and high power consumption. Legacy SDH network provided insufficient bandwidth for growth requirements and was too costly.	Multiservice OTN saved 70 percent of CO floor space and reduced power consumption by 60 percent compared to legacy SDH network. Also, only 10 percent of the original SDH network investment was required to update the network with multiservice OTN.
Tier 1 Operator, Europe	More than 9,000 sets of SDH equipment from multiple suppliers, and much of it more than 10 years old. Operator faced high opex, high rent, high power consumption and low OAM efficiency.	Migrating to multiservice OTN saved more than 35 percent on both capex and opex compared to legacy network. Operator also increased capacity and scalability, enhanced service availability and improved OAM efficiency.

Source: Huawei, 2016

Conclusion

The current state of Sonet/SDH is creating a major challenge for major operators globally. For the past decade and longer, operators have been building out packet-centric networks to support the rapid growth in in data traffic and services on their networks. Equipment suppliers responded to operator demand by refocusing their R&D and investments on packet network equipment, while eliminating investments in and support for legacy Sonet/SDH.

The problem today is that many of the services remaining on legacy Sonet/SDH networks – such as high-value and high-availability leased line traffic – are unsuitable for a packet network migration. Compounding the problem is the fact that much of the Sonet/SDH infrastructure is past its intended lifespan and in need of replacement now.

Enter multiservice OTN as the solution for migrating these high-value, high-availability applications from the aging Sonet/SDH networks on which they operate without sacrificing the features that are needed. Heavy Reading believes that multiservice OTN offers the following key benefits for SDH modernization:

- Predictable latency that can be guaranteed for network operators, and for their end customers
- Ultra-low latency from Layer 1 transport that can be orders of magnitude lower than Layer 2 and Layer 3 networks
- Ultra-high scalability from WDM that can deliver 200 Gbit/s per channel today and 80 channels or more per fiber
- High security from dedicating separate OTN channels to each customer, combined with the ability to encrypt all in-flight traffic at Layer 1
- The ability to efficiently combine legacy Sonet/SDH, OTN and packet traffic on a single network infrastructure using the universal switching fabric in multiservice OTN equipment.
- The ability for operators to migrate their customers away from TDM private lines at a pace that is comfortable for those customers, and without forcing on customers a drastic change.

Heavy Reading believes that these features, in combination, make multiservice OTN a compelling choice for operators facing SDH modernization.