OTN – What is it and Why is it Important?

Technical Level 1 (Basic)

by Stuart Whitehead
Senior Product Marketing Manager
Field Test Solution

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Background

The core of most telecom operator networks today is SDH/SONET (Synchronous Digital Hierarchy/Synchronous Optical NETwork), which has always offered good fault management, performance monitoring, predictable latency, a protection mechanism and, of course, synchronization. This very stable network has become the expected minimum in performance objectives for network operators today and is often described as having "five 9s" (and higher) performance, meaning at least 99.999% up time.

Ethernet is often discussed as a replacement for SDH/SONET, but the two technologies are different in every way. The reason for the difference can be tracked back to the original design requirements where SDH/SONET was designed to carry voice, while Ethernet was designed to carry data. However, as with all companies, cost efficiency always has to be considered. While Ethernet allows for greatly improved cost points, in comparison to SDH/SONET it lacks in the areas of fault management, performance monitoring, protection mechanisms and predictable latency and jitter. Due to the cost benefits of Ethernet, many operators have looked at and in some cases have switched parts of their network to Ethernet-based systems, but this has often meant having to manage two independent (or nearly independent) networks, reducing the cost benefits of Ethernet.

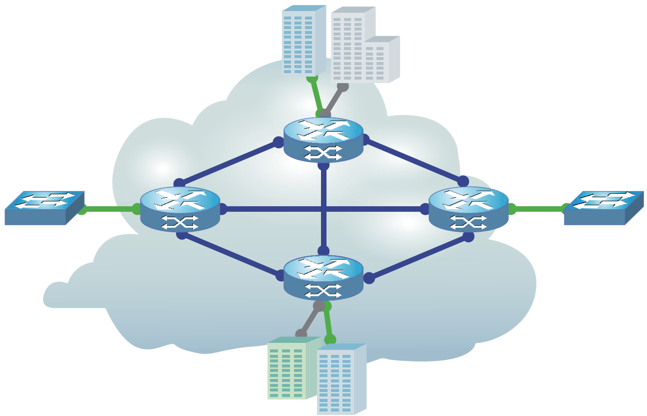

Figure 1. Simplified Network

Many operators are now looking into or have already implemented a P-OTS (Packet-Optical Transport Systems) network supporting integration of ROADM/WDM (Reconfigurable Optical Add/Drop Multiplexer/Wavelength Division Multiplexing) and L2 (Layer 2) switching as well as SDH/SONET. The combination of circuit-based TDM (Time Division Multiplexing) and packet-based Ethernet standards that can be transported over the network is a logical step forward for any operator. A P-OTS network can carry flexible payloads within a common transport framing, such as MPLS-TP (MultiProtocol Label Switching–Transport Profile), PBB-TE (Provider Backbone Bridges–Traffic Engineering) and OTN (Optical Transport Network), with the latter being able to carry SDH/SONET.

Benefits of P-OTS

There are many benefits for operators combining all technologies over a single network, such as optimizing the network structure, which includes dynamic control of services across the network, dynamic real-time bandwidth allocation for on-demand services and minimizing layers within a network, which reduces complexity and cost.

Concerns about P-OTS

Today, P-OTS is a combination of technologies. This means operators still have to manage multiple systems when configuring or maintaining a single circuit. Increased complexities as well as concerns about interoperability between equipment vendors and increasing customer demand for more bandwidth-sensitive services all contribute to operator cost. Engineers need to be trained in multiple technologies, which the training can be complicated and still maintain expertise across multiple technologies is quite difficult.

The Solution

Making OTN the underlying P-OTS technology carrying Ethernet, MPLS-TP, PBB-TE, SDH/SONET or other traffic on top of it solves many issues. Although extending OTN from the Core network to the Metro network or even to the customer edge solves the above concerns, it has only become possible recently with the newer OTN standards.

OTN as we understand it today was first defined by the ITU-T (International Telecommunication Union Telecommunication Standardization Sector) in the G.709 standard in 2001 for the Submarine and Core markets. It was designed to transport TDM circuits over long distances by providing GFEC (Generic Forward Error Correction) but hadn't achieved large network rollouts until recently. From 2009 to 2012, the standard underwent major enhancements introducing areas allowing it to extend further into non-Core markets. Many operators are now looking to utilize the benefits of OTN in their Metro and Access networks. New rollout requirements are migrating OTN from the Core network to the total network, quickly increasing its market presence.

Many engineers now see OTN as the best transport solution because it offers the best of both worlds: fault management, performance monitoring, and protection mechanisms coupled with low entry cost point and ability to support current infrastructure. It is very important for network operators to have the ability to continue using their existing infrastructure, allowing them to migrate current customers from legacy SDH/SONET and PDH/DSn (Plesiochronous Digital Hierarchy/Digital Signal number) networks to Gigabit Ethernet and Fibre Channel (used in data centers) and operators of Metro to Core networks must be able to supports all technologies, both future and legacy.

Overview of Different Technologies

The following technologies have a common goal of being able to route packet technologies (Ethernet) across a network in a deterministic way while providing a stable system with management and fault-finding abilities. Technologies such as SDH/SONET, which is connection-oriented, are very deterministic in routing and quality but they are also very inflexible with regards to upgrades or network changes. Standard Ethernet (non-carrier grade) is at the other end of the spectrum; it is connectionless and offers very flexible routing across the network because the network elements determine the routing, making it non-deterministic in both path and quality. For modern networks, the most important feature is the ability to be deterministic, ensuring that quality is maintained across the network even when carrying packet-based technologies, such as Ethernet.

PBB-TE was designed to provide the deterministic connection-oriented features of TDM to carrier-class Ethernet. It achieves this by using both PBB (Provider Backbone Bridges) often called MAC-in-MAC and VLAN (Virtual Local Area Network) technologies to identify the traffic. The management system is responsible for routing the traffic streams through the network utilizing point-to-point connection paths and the OAM (Operations, Administration and Management) protocol. The management system also creates a backup route supporting the ability to switchover if required.

MPLS-TP is an extension of the MPLS (MultiProtocol Label Switching) protocol suite and was designed to provide deterministic carrier-class services over MPLS networks. The Transport Profile allows connectionless traffic to be encapsulated making it connection-oriented. MPLS-TP creates LSP (Label-Switched Paths) to transport the traffic across the network as well as utilizing OAM information, including information like APS (Automatic Protection Switching).

OTN is based on a fixed frame size with three key areas: the Overhead section, the Payload section, and finally the FEC (Forward Error Correction) section. The network routes these OTN frames across the network in a connection-oriented way. Much like a SDH/SONET frame, the Overhead carries the information required to identify, control and manage the payload, which maintains the deterministic quality. The Payload is simply the data transported across the network, while the FEC corrects errors when they arrive at the receiver. The number of correctable errors depends on the FEC type. The most common is GFEC described in the G.709 standard, which can identify 16 symbol errors and correct 8 symbol errors per frame.

The roots of OTN come from an SDH/SONET background, while both PBB-TE and MPLS-TP are adaptations of Ethernet networks, but all allow a more optimal and deterministic way of transporting data across a Core network and in many cases across Metro or Access networks.

Market Trends

Most operator networks have completed several incremental steps as the technologies have advanced, although some engineers argue that it would be better technically to complete a total network technology change. The commonly discussed reasons for incremental steps are (naturally) cost, as well as infrastructure, customer disruption and churn.

The network is naturally trending from SDH/SONET to all IP (Internet Protocol) is still happening with the major changes shown in Figure 2.

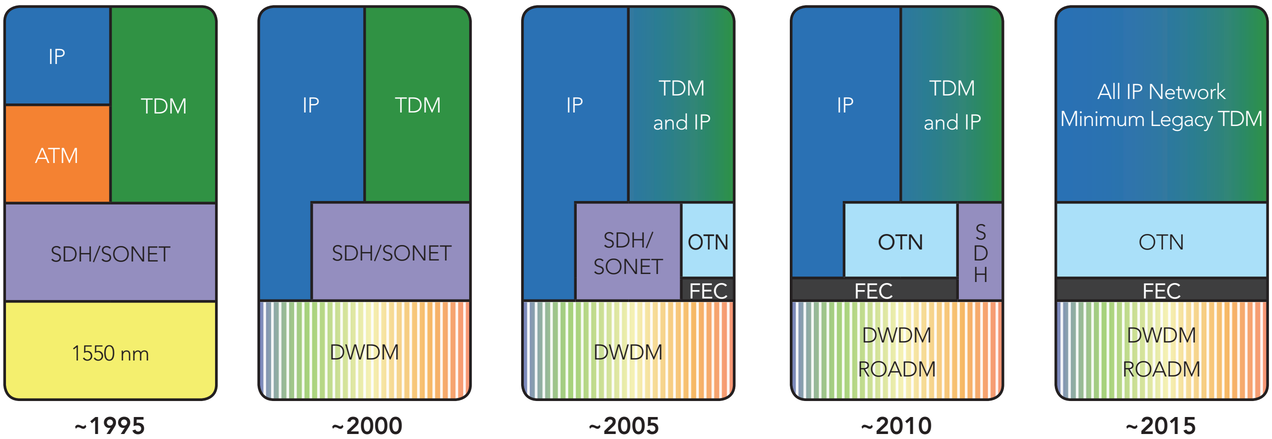

Figure 2. Network Technology Trend

Although OTN has been moving for some time to become the most used transport technology in operator Core networks, it is also important to note how quickly it is moving into Metro networks. Historically, the Metro network was a sub-rate of the Core but this is starting to change as operators are required to minimize RTT (Round Trip Time) by placing services closer to customers. Services that must be closer to customers are replicated across operator networks and include video servers, cloud solutions (requiring real time or close to real time updates), etc. Such replication massively reduces Core network traffic demand.

With this in mind, many operators are now upgrading their traditional TDM Metro networks to P-OTS networks, which of course are more often than not taking advantage of OTN and its latest updates. A recent Heavy Reading survey looking at operator revenue clearly shows movement from TDM to P-OTS. It also shows the reduction in revenue generated from the network from 2008 to 2018 (Figure 3). While the total revenue in 2008 is about 30% more than the 2018 projection, the network bandwidth requirements are significantly larger.

Worldwide Metro P-OTS and SONET/SDH Revenue, 2008 to 2018 ($M)

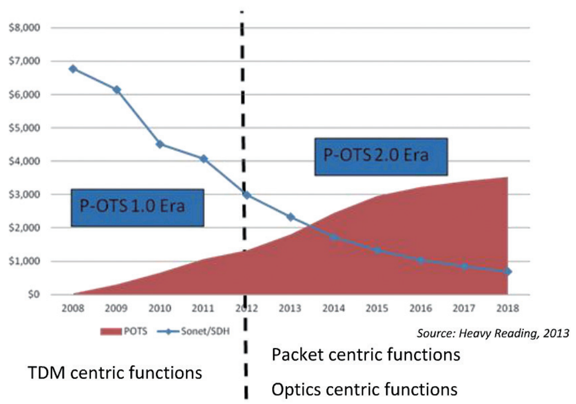

Figure 3. Movement of P-OTS into the Metro Network

Many (if not all) market experts are predicting a large increase in P-OTS and OTN networks to support the large increase in data requirements within operators' Metro networks.

- Light Reading completed this webinar titled "Redefining Packet-Optical Transport with SDN and 100 GbE", which discusses many areas including the Heavy Reading figures above.
- Dell'Oro Group reported here by Lightwave predicts 15% compound growth over the next 5 years and operator Metro network spending will overtake Core.
- Infonetics reported by Lightwave predicts the OTN switching segment will grow at 20% compound until 2018, and grew by 37% in 2013.

Summary

Many networks will change not only in the underlying technology but also in the location and density of data to be carried as we move from TDM to P-OTS. Of course, this will happen in different phases around the world and there will be significant change globally as we all demand greater access to not only reliable and fast data connections but also to extremely low-latency networks. This combination of high throughput requirements and low latency will drive operators away from traditional networks transporting everything across the Core to networks requiring regionally deployed network assets (data centers, video streamers, etc.).

Further Reading

White Papers in this series:

OTN – What is it and How does it Work?

Technical Level 2 (Engineer)

How OTN works; Breaks down and explains the five major frame sections written for engineers, but readable by all.

OTN – The Deep Dive into Details that Make it Tick (Coming soon)

Technical Level 3 (OTN Engineer)

All you need to know about OAM, TCM, FTFL and FEC written for OTN engineers, but readable by anyone with a keen interest in OTN technology.

Free OTN Wall Poster

Many of the above details are shown in an A1 wall poster.

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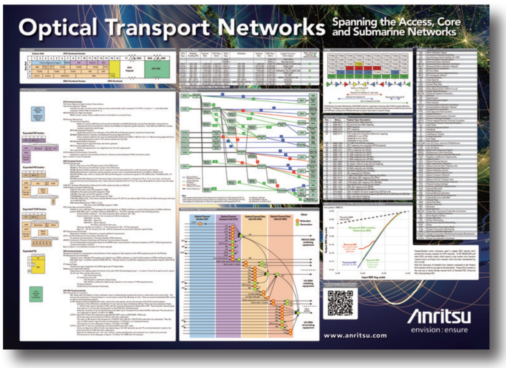

References

ITU-T G.709 (Interfaces for the Optical Transport Network)
http://www.itu.int/rec/T-REC-G.709

List of Acronyms

Acronym	Definition
APS	Automatic Protection Switching
DSn	Digital Signal number
FEC	Forward Error Correction
GFEC	Generic Forward Error Correction
IP	Internet Protocol
L2	Layer 2
LSP	Label-Switched Paths
MAC	Medium Access Control address
MPLS	Multi-Protocol Label Switching
MPLS-TP	MultiProtocol Label Switching – Transport Profile
OAM	Operations, Administration and Management
OTN	Optical Transport Network
PBB	Provider Backbone Bridges
PBB-TE	Provider Backbone Bridges – Traffic Engineering
PDH	Plesiochronous Digital Hierarchy
P-OTS	Packet-Optical Transport Systems
ROADM	Reconfigurable Optical Add/Drop Multiplexer
RTT	Round Trip Time
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Networking
SONET	Synchronous Optical NETwork
TDM	Time Division Multiplexing
VLAN	Virtual Local Area Network
WDM	Wavelength Division Multiplexing

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● United States
Anritsu Company
1155 East Collins Blvd., Suite 100, Richardson,
TX 75081, U.S.A.
Toll Free: 1-800-267-4878
Phone: +1-972-644-1777
Fax: +1-972-671-1877

● Canada
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

● Brazil
Anritsu Eletrônica Ltda.
Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - São Paulo - SP - Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

● Mexico
Anritsu Company, S.A. de C.V.
Av. Ejército Nacional No. 579 Piso 9, Col. Granada
11520 México, D.F., México
Phone: +52-55-1101-2370
Fax: +52-55-5254-3147

● United Kingdom
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

● France
Anritsu S.A.
12 avenue du Québec, Bâtiment Iris 1- Silic 612,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

● Germany
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

● Italy
Anritsu S.r.l.
Via Elio Vittorini 129, 00144 Roma, Italy
Phone: +39-6-509-9711
Fax: +39-6-502-2425

● Sweden
Anritsu AB
Kistagången 20B, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00
Fax: +46-8-534-707-30

● Finland
Anritsu AB
Teknobulevardi 3-5, FI-01530 VANTAA, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

● Denmark
Anritsu A/S
Kay Fiskers Plads 9, 2300 Copenhagen S, Denmark
Phone: +45-7211-2200
Fax: +45-7211-2210

● Russia
Anritsu EMEA Ltd.
Representation Office in Russia
Tverskaya str. 16/2, bld. 1, 7th floor.
Russia, 125009, Moscow
Phone: +7-495-363-1694
Fax: +7-495-935-8962

● United Arab Emirates
Anritsu EMEA Ltd.
Dubai Liaison Office
P O Box 500413 - Dubai Internet City
Al Thuraya Building, Tower 1, Suit 701, 7th Floor
Dubai, United Arab Emirates
Phone: +971-4-3670352
Fax: +971-4-3688460

● India
Anritsu India Private Limited
2nd & 3rd Floor, #837/1, Binnamangla 1st Stage,
Indiranagar, 100ft Road, Bangalore - 560038, India
Phone: +91-80-4058-1300
Fax: +91-80-4058-1301

● Singapore
Anritsu Pte. Ltd.
11 Chang Charn Road, #04-01, Shriro House
Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

● P.R. China (Shanghai)
Anritsu (China) Co., Ltd.
Room 2701-2705, Tower A,
New Caohejing International Business Center
No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

● P.R. China (Hong Kong)
Anritsu Company Ltd.
Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

● Japan
Anritsu Corporation
8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-1221
Fax: +81-46-296-1238

● Korea
Anritsu Corporation, Ltd.
5FL, 235 Pangyoyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 463-400 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

● Australia
Anritsu Pty. Ltd.
Unit 21/270 Ferntree Gully Road, Notting Hill,
Victoria 3168, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

● Taiwan
Anritsu Company Inc.
7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

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