White Paper

Optical Transport Networks (OTN) Test
by Reza Vaez-Ghaemi, Ph.D.

Introduction

The increasing need for residential triple-play, wireless broadband, and IP business services continues to drive the demand for network expansion in core metro networks. Managing CAPEX and OPEX are extremely important for the successful introduction and sustainability of this expansion. Ethernet and DWDM have been important ingredients in cost reduction over the last several years, delivering superior cost performance compared to legacy SONET/SDH technologies in many cases.

However, Ethernet and DWDM lack some key characteristics necessary for carrier-grade performance and management in metro core networks. Optical Transport Network (OTN) technology delivers superior reach, transparent transport of client signals, and powerful switching and management capabilities. This white paper provides an introduction to OTN technology and focuses on test and measurement applications for OTN-related field deployment.

Optical Transport Networks

Increasing need for bandwidth and lower cost-per-bit has driven the demand for Ethernet- and DWDM-based solutions in metro and core/long-haul networks. In long-haul networks (Figure 1), the reduction of regenerators and transponders constitutes a significant component of cost savings. In comparison to wavelength-based solutions, SONET/SDH systems require costly Optical Electrical Optical (OEO) conversion. However, SONET/SDH-based systems deliver critical functions necessary for network performance, availability and manageability. Although DWDM systems eliminate the need for costly OEO conversion, they lack some of the aforementioned functions.

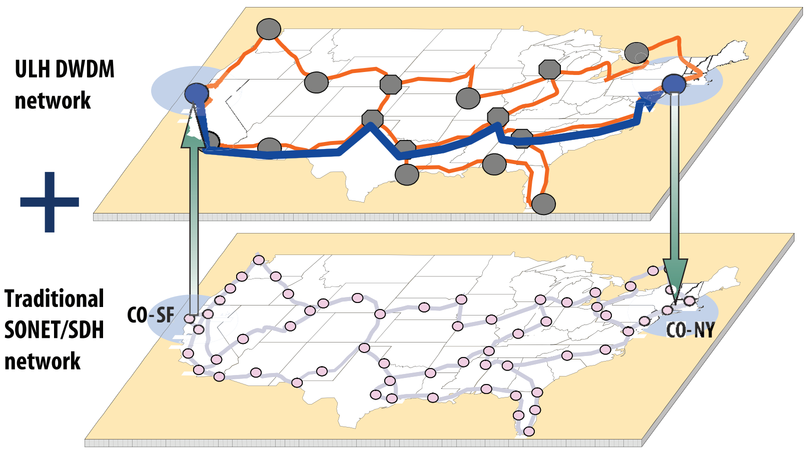

Figure 1: Optical Transport Networks

Optical Transport Network (OTN) technology delivers these critical functions. Forward Error Correction (FEC) algorithms improve the reach of transmission links, helping to reduce regenerators and/or optimize spectral efficiency. Additionally, an OTN “Digital Wrapper” includes many layers and components known from SONET/SDH, but at an enhanced performance level.

OTN uses the same layering concept as proven in other Transport networks and introduces three or more sublayers: Optical Transmission Section (OTS), Optical Multiplexing Section (OMS), Optical Channel (Och), plus G.709 sublayers (Figure 2). A client-server model is applied between sublayers of the OTN. Each sublayer offers well defined services to its client layers and each sublayer has its own layer management functions, including fault, performance and configuration management.

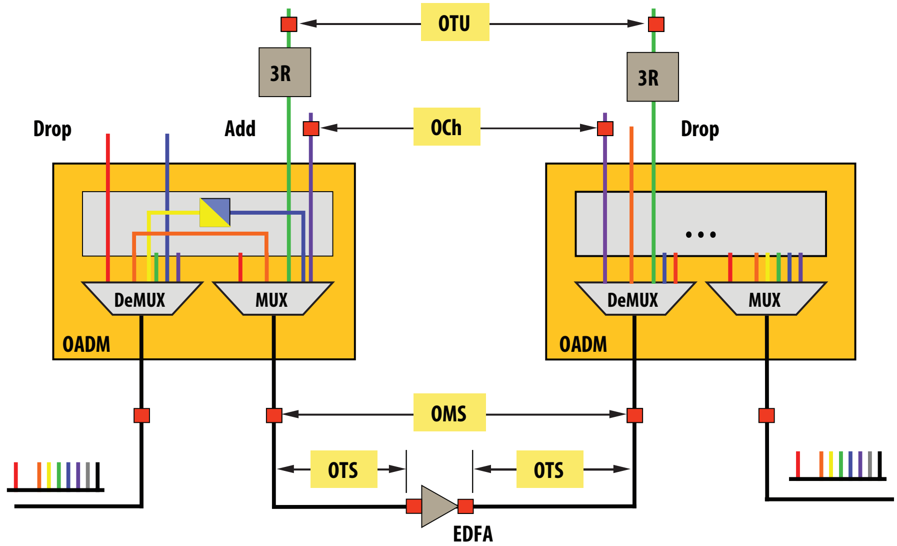

Figure 2: OTN Hierarchy

An OTN frame (Figure 3) consists of the mapped transparent client, the extensive overhead (OH) which is used for operations, administrations, monitoring and provisioning (OAM&P) and the FEC. As with SDH/SONET, the quality of transmission is monitored by multiple parity checks and the corresponding reactions of the OTN elements.

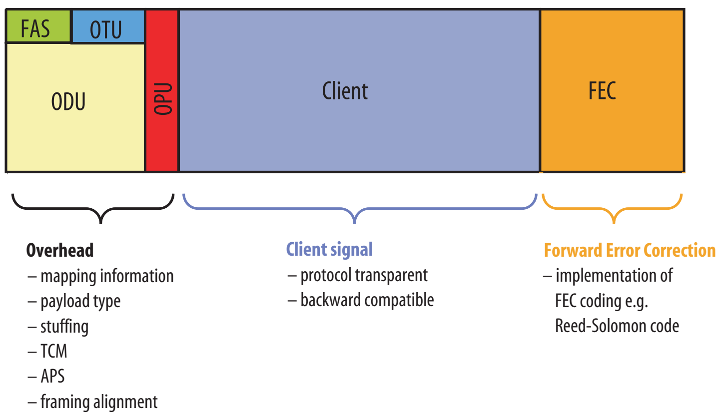

Figure 3: G.709 Frame Format

OTN Field Deployment and Test

Proper deployment of OTN in the field requires various tests to:

– Verify proper turn-up of OTN client signals
– Monitor OTN signals and clients inside OTN signals
– Check proper operation and configuration of OTN network elements

Depending on the test application, the test can be operated in an end-to-end terminate mode, single-ended terminate mode with a loopback on the far-end (Figure 4), or monitoring/through mode. The most important test functions for field deployment are:

– Signal integrity
– Forward Error Code (FEC) function
– Client mapping/demapping
– Alarms response

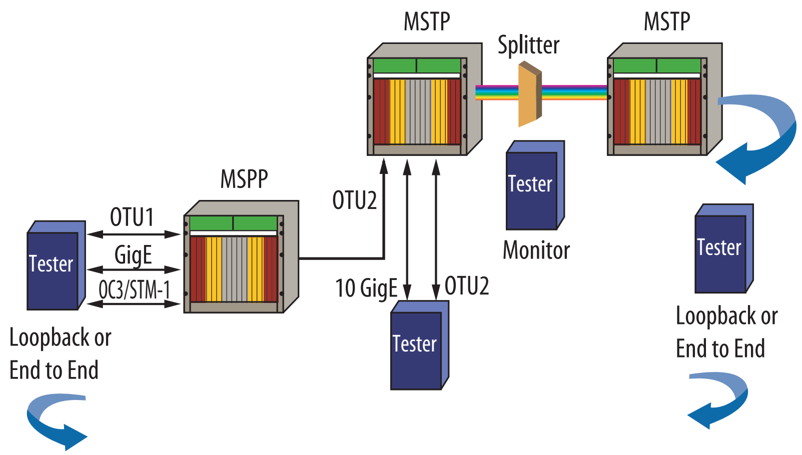

Figure 4: OTN Field Test Applications

Signal integrity test

Verification of optical power parameters and link synchronization to OTN signal line rates (Table 1) are the most important and basic tests. Optionally, users may consider testing clock deviation and jitter tolerance/generation.

Link synchronization test shall be performed ahead of optical power test. An optical attenuator can be used in series with the device under test (DUT). While measuring bit error rate (BER), the applied optical signal is continuously attenuated until the threshold of the OTN receiver is reached.

Clock deviation is tested by applying an OTN signal and verifying the signal integrity in presence of varying frequency offset up to maximum limit. Maximum Tolerable Jitter (MTJ) and intrinsic jitter characterize the performance of receiver and transmitter of OTN device under test, respectively.

Interface	Line Rate (Gbps)
OC48/STM16	2.488
OC192/STM64	9.953
OC768/STM256	39.813
10GigE LAN	10.313
10GigE WAN	9.953
OTU1	2.666
OTU2	10.709
OTU2e	11.049/11.095
OTU3	43.018

Table 1: Transport interfaces and line rates

FEC test

If errors occur on a 10.7 Gbps line in any area of the frame, the receiver of the DUT is able to correct up to 8 symbol errors per subrow or, in other words, 512 errors per OCh frame. In order to verify FEC, a number of error patterns are inserted in subrows of the transmitted signal then transmitted through an OTN device under test.

As the name suggests, when inserting correctable FEC errors, the DUT should still be capable of correcting these errors. This test can verify the correct installation of network element in the field.

To perform DUT's error detection capabilities, uncorretable FEC errors shall be applied. Here, it is not possible for the errors to be corrected by the DUT. When inserting these errors, alarms by the DUT can be expected when the DUT is operating correctly.

Client mapping/demapping

The OTN's framing structure allows for the mapping of different traffic types of client signals into Optical Channel Payload Units (OPUs), including SONET/SDH and Ethernet (Figure 5). The G.709 specifies guidelines for synchronous and asynchronous mapping. With asynchronous mapping, rate differences between the client and the OPU are adjusted through "stuffing."

To check the mapping capability of the DUT, an input client signal (for example OC192/STM64) with varying offset (allowed deviation ± 20 ppm) is transmitted then mapped into the OPU by the DUT. Proper mapping of the client signal can be verified by checking on alarms/errors. The demapping function is checked in a similar way in other direction.

In addition to client frequency offset check, various payload tests can be performed. A simple method for payload test uses a "bulk" pseudo random bit sequence (PRBS) directly applied to OTN payload. Alternatively, one can insert a test pattern with an appropriate mapping/encoding scheme such as PCS.

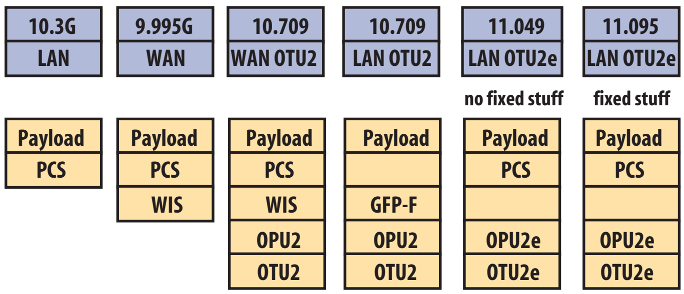

Figure 5: 10G Ethernet and OTN Mapping

Alarms response

Depending on signal input failures and degradation, an OTN network element will generate alarm responses in the up and downstream direction to deliver information on the line quality to neighbouring network elements. OTN provides a multi-layer maintenance interaction (Figure 6) similar to a SONET/SDH system. In monitoring test applications, it is necessary to identify present alarms such as SM-BIP or PM-AIS. Optionally, an OTN tester can be used to apply various alarms to the device/network under test, and verify proper response in the up and down-stream direction from device under test. For example, the detection of a LOF at the network element input will force an OTU-AIS on the output in forward direction, and also an OTU-BDI on the output in backward signal.

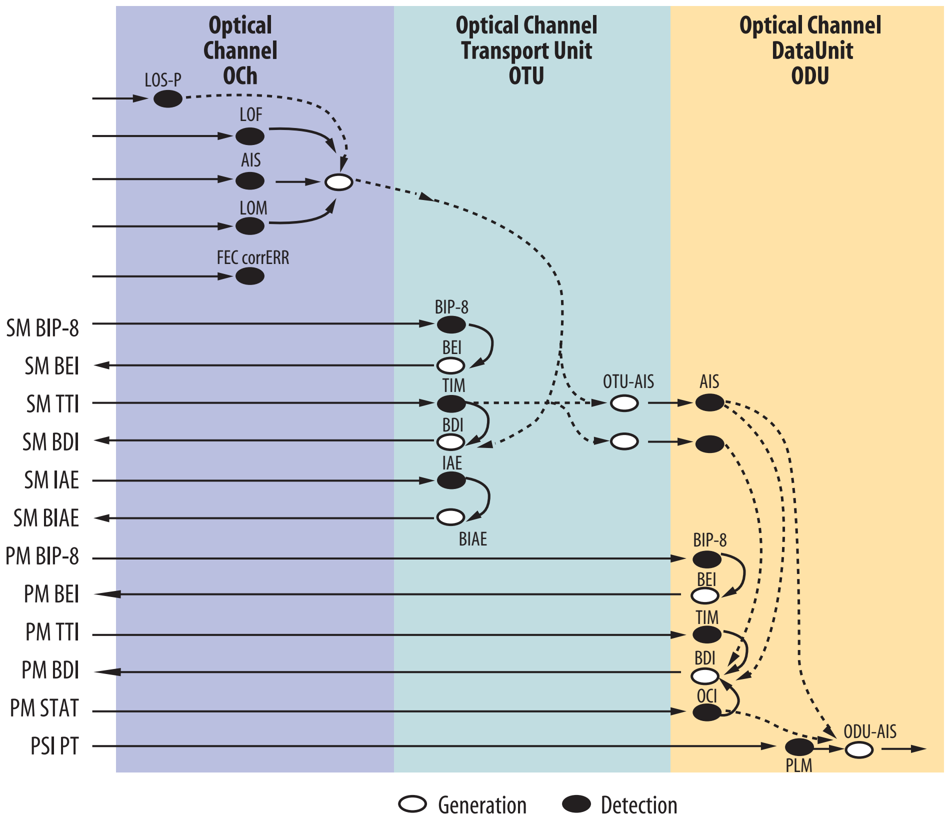

Figure 6: OTN Maintenance Interaction

OTN Standards (ITU)

Transport Plane

Management aspects of OTN elements	G.874
Network Architecture	G.872
Structures and bit rates	G.709/Y.1331
Equipment	G.798
Jitter and Wander Performance	G.8251
Error Performance	G.8201
Physical	G.959.1
Maintenance	M.2401

Control Plane

Automatic Switched Optical Network	G.8080/Y.1304
Distributed Connection Management	G.7713/Y.1704
Generalized Automatic discovery	G.7714/Y.1705
ASTN Routing	G.7715/Y.706
Data Communication Network	G.7712/Y.1703

Abbreviations

APS	Automatic Protection Switching
BDI	Backward Defect Indication
BEI	Backward Error Indication
BIP-8	Bit Interleaved Parity-8
DUT	Device Under Test
DWDM	Dense Wavelength Division Multiplexing
FAS	Frame Alignment Signal
FEC	Forward Error Correction
GbE	Gigabit Ethernet
GFP	Generic Frame Procedure
IAE	Incoming Alignment Error
IP	Internet Protocol
MFAS	Multi frame Alignment Signal
NE	Network Element
OADM	Optical Add Drop Multiplexer
Och	Optical Channel
ODU	Optical channel Data Unit
OH	Overhead
OMS	Optical Multiplexing Section
OPU	Optical channel Payload Unit
OTM	Optical Transmission Module
OTN	Optical Transport Network
OTU	Optical channel Transport Unit
OTS	Optical Transmission Section
PM	Path Monitoring
PSI	Payload Structure Identifier
SDH	Synchronous Digital Hierarchy
SM	Section Monitoring
SONET	Synchronous Optical Network
TCM	Tandem Connection Monitoring

Test & Measurement Regional Sales

NORTH AMERICA	LATIN AMERICA	ASIA PACIFIC	EMEA	WEBSITE:
TEL: 1 866 228 3762	TEL: +55 11 5503 3800	TEL: +852 2892 0990	TEL: +49 7121 86 2222	www.jdsu.com/test
FAX: +1 301 353 9216	FAX: +55 11 5505 1598	FAX: +852 2892 0770	FAX: +49 7121 86 1222	

April 2008 30149255 001 0408 OTN.WP.ACC.TM.AE