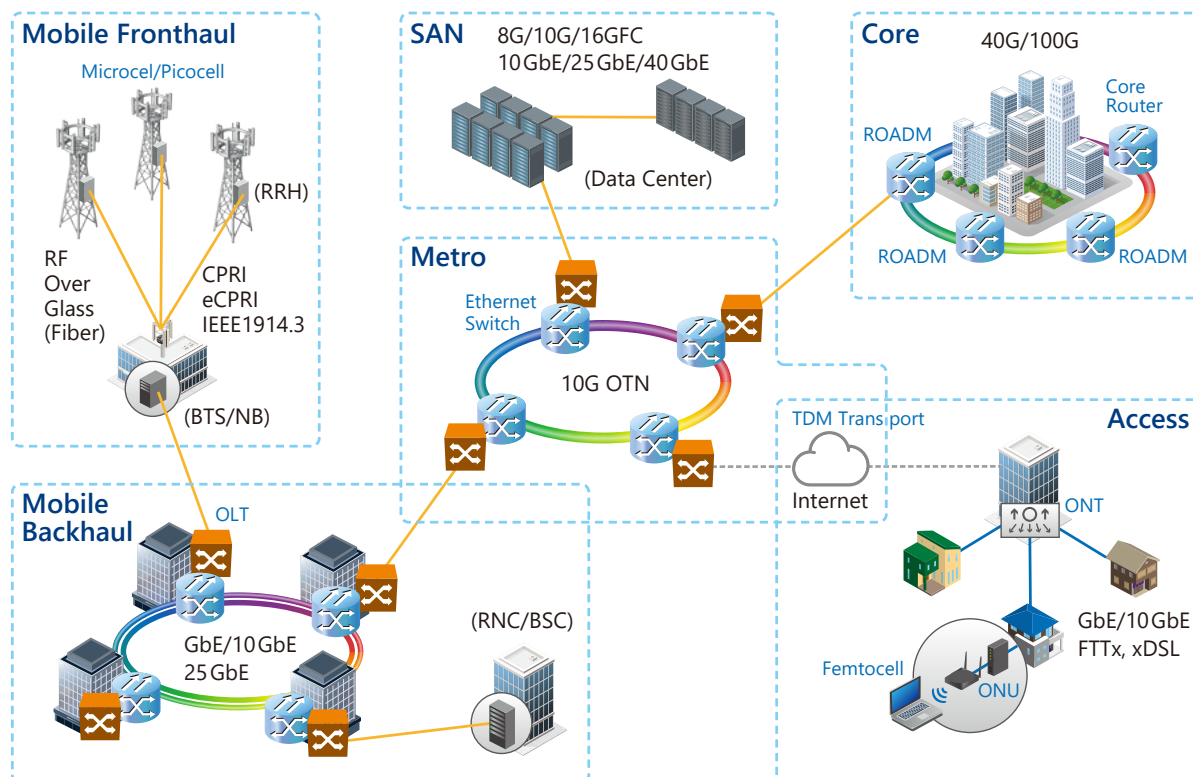


OTN — What Is Important to Test

Background

Telecommunication operators are increasingly adopting Optical Transport Networks (OTNs), moving them closer to end users. OTN is a communication protocol that has evolved from voice data multiplexing and provides stable communication with low latency. The International Telecommunication Union (ITU) has been developing this protocol to handle high-speed data communications such as 100 Gigabit Ethernet and Fibre Channel, in addition to voice data.

With the rapid growth of data centers and the resulting need to handle enormous amounts of data, OTN has become indispensable as a large-capacity, low-latency, and highly flexible communications infrastructure. The telecommunications industry is undergoing a shift toward programmable and flexible network architectures. Furthermore, operators are facing the increasing demand for high-speed communications in both the residential and commercial sectors due to the widespread use of cloud computing and Artificial Intelligence (AI), Internet of Things (IoT), and online services. Therefore, the expectation for the OTN technology is rising more and more.



The Network

One of the advantages of OTN is its ability to support long-distance data transmission. A function for detecting and correcting errors that occur during optical signal transmission (Forward Error Correction, FEC) enables extremely low Bit Error Rates (BER), guaranteeing stable communications even in mission-critical fields such as finance and medicine. OTN also enables wide-bandwidth and large-capacity data transmission. It supports high-speed communications with data rates over 100 Gbps, while multiple data streams can be integrated and transmitted in batches for efficient network operation. In particular, when combined with wavelength division multiplexing (WDM) technology, it offers excellent scalability and flexibility, making it capable of handling future increases in demand. When implemented with optical amplifiers and signal regeneration equipment, stable communications over hundreds to thousands of kilometers are possible, making it ideal for building global backbone networks. OTN also supports the efficient use of bandwidth and flexible service delivery. Variable rate transmission and bandwidth control functions enable optimal service configuration according to user needs and contribute to the optimization of network resources. In addition, the programmable transport layer greatly increases flexibility in service deployment and network operations.

Another major advantage of OTN is its ability to integrate diverse communication protocols. Different types of data, such as Synchronous Digital Hierarchy/Synchronous Optical Network (SDH/SONET), Ethernet, and Fibre Channel, can be efficiently handled by a single optical network, simplifying interconnections between different types of networks. This facilitates interconnection between different types of networks. In addition, OTN supports excellent fault management capabilities and operability, enabling fault detection and isolation by segment in the event of a failure, as well as rapid recovery. This makes it easier to provide quality assurance based on service level agreements (SLAs).

The OTN frame structure allows direct association with network segments. Understanding this segmentation of the network allows engineers to quickly identify problem areas and the extent to which the problem may affect the operator's customers. Figure 1 shows the frame structure of OTN.

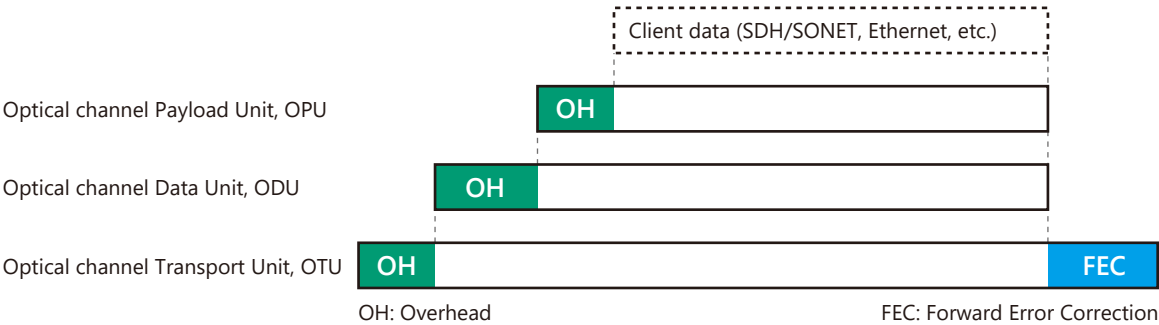


Figure 1 OTN Frame Structure

As shown in Figure 2, the network can be divided into the following logical sections, based on the OTN frames.

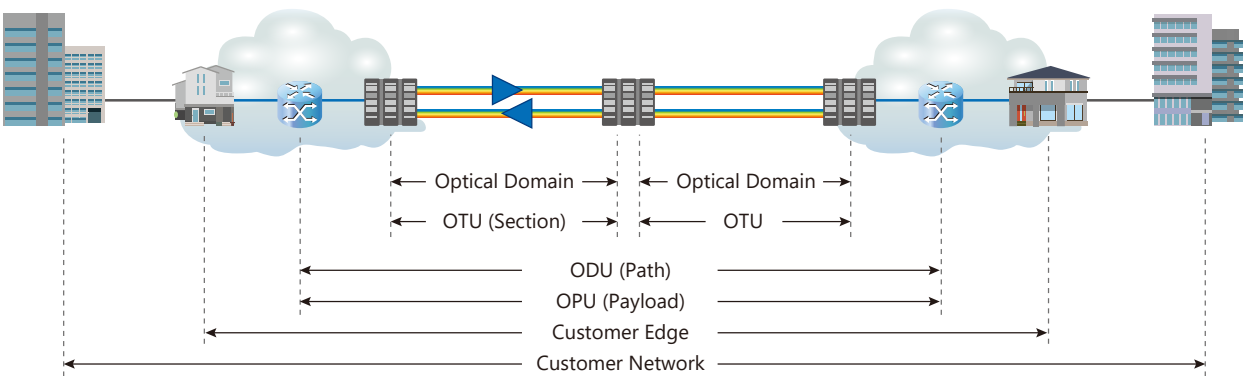


Figure 2 OTN Segmentation

These sections are typically represented by major physical network sections within the network. An OTU section is a section transmitted by optical signals and may pass through an optical amplifier along the way, especially in long-distance networks. The OPU/ODU section is the transmission section for the OTN client signal, and the metro section is often the end point or path terminus for the OTN.

Testing the OTN Layer

Since the OTN is a transport layer, it is important to be able to test all the standard OTN layer alarms and errors. One way to achieve this is to use a Pseudo Random Binary Sequence (PRBS) in the payload and measure how many bit errors occur. This is commonly referred to as the Bit Error Rate Test (BERT).

Although the BER is a good indicator of possible issues affecting a telecommunications operator's customers, it is even more important to also test the higher layers to ensure comprehensive testing and to obtain detailed information about the higher layers through which the customer's traffic flows. Some of the more traditional BERT methods for testing OTN networks are described in the following three sections ("Errors are reported in several ways," "Understanding TCM," and "Standard BER testing"). For an explanation of the more advanced testing required for OTN client signaling, refer to our Application Note ["OTN – Advance Testing and Dividing the Network"](#).

Several Ways to Report Errors

It is possible to confirm whether a network element is responding correctly to an error by inserting a tester with two ports between the two network elements and monitoring the signals.

Figure 3 shows the connection of the tester with dual-port 10 Gbps for an OTN network. Placing the tester in the signal line in pass-through (or pass-through with overwrite ability) mode supports this type of testing. Pass-through is a function that transmits the received signal as is. Pass-through with overwrite ability allows overheads to be rewritten (to insert errors or alarms).

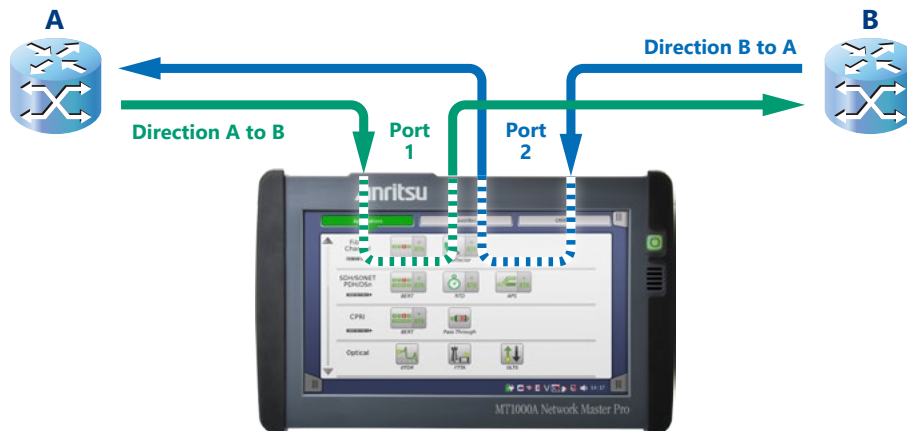


Figure 3 Connection of a 10 Gbps Dual-Port Tester for Monitoring Signals

When the tester is configured as shown in Figure 3, it can observe traffic in both directions and determine whether one network element is responding correctly to error conditions.

For example, if a Section Monitoring - Alarm Indication Signal (SM-AIS) is inserted in the direction from A to B, as shown in Figure 4 (top), the network element in the other direction should report back Section Monitoring - Backward Defect Indication (SM-BDI). Note that both are on the Section Monitoring (SM) layer. If a Path Monitoring - Client Signal Fail (PM-CSF) error is inserted in the direction from A to B, a PM-BDI error will be reported back from B to A in the opposite direction. In this case, since the SM layer is part of the OTU layer, the problem is likely in the core network. For this reason, it is necessary to focus on the different layers mentioned above. On the other hand, the PM layer, being part of the ODU layer, is often directly related to alarms and errors on end-user lines.



Figure 4 Alarm Injection and Detection in Pass-Through Mode BERT

Understanding TCM

The release of OTN led to major enhancements to Tandem Connection Monitoring (TCM) compared to the implementation of the SDH/SONET (Synchronous Digital Hierarchy/Synchronous Optical Network). One of the main differences is that TCM has been extended from a single layer to a six-layer system, allowing connection monitor signals to be set for each operator, even when signals are transmitted through multiple operators. An example is shown in Figure 5.

To monitor the OTN's end-to-end communication, Operator A configures TCM1 with sender information (source address point identifiers, SAPI), destination information (destination address point identifiers, DAPI), and errors/alarms. When passing through the networks of Operator B and Operator C along the way, TCM2 and TCM3 are set for the sender information, destination information, and errors/alarms in their networks, respectively.

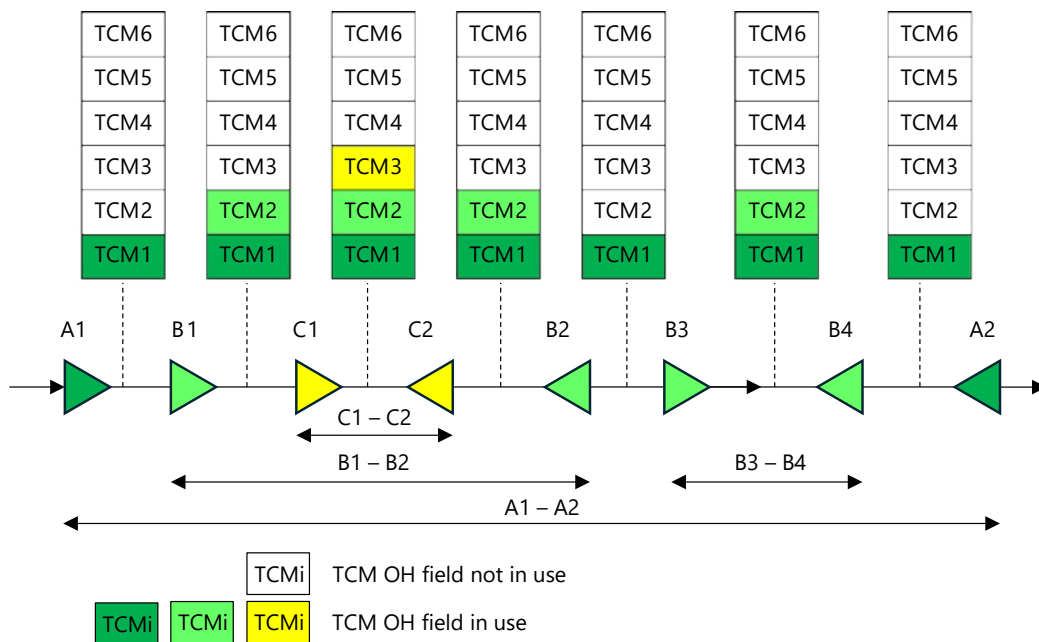


Figure 5 Hierarchical TCM

Receiving a TCM1-BDI error might indicate an error in the payload or overhead. If the payload is received without errors, it indicates that part of the overhead might be corrupted. Of course, if this is in the TCM1 (lowest layer), it is much more critical than a TCM2 error or another higher-layer error.

Note that the OTN standards don't define the setup of TCM layers explicitly, so the effect of an error on each TCM layer is dependent on how each operator decides to define them.

In addition to the ability to fully manipulate alarms and errors, the flexibility to fully edit overhead, as shown in Figure 6, is also important for assessing network quality. This will allow engineers to insert alarms and errors at each layer and verify that each network device is responding correctly. The ability to see all the alarms and errors for each TCM layer allows an engineer to quickly identify many key areas, such as which part of the network is causing the issue, or even the direction.



Figure 6 Edit Window for OTU/ODU/OPU Overhead

An example of errors might be an Incoming Alignment Error (IAE) indicating that an alignment issue has occurred between the transmitting network element and the network equipment receiver port, while a Backward IAE (BIAE) is sent by the network element receiving the IAE to notify the far-end network element about the original IAE. Figure 7 shows an example of the types of alarms and areas that assist an engineer in troubleshooting the network, and the ability to select the relevant TCM layer.



Figure 7 OTU TCM Receiver Alarms and Errors

Standard BER testing

When installing a new link, it is common to run BERT as a standard connectivity test. It's important to complete this test using the same mappings as the network will eventually use. As an example, if an OTU2 (10 Gbps) network is to eventually carry an ODUflex payload, it would be ideal to test the network using the smallest ODUflex frame size that is to be implemented over the network. If this is unknown, the safest solution is to complete the BERT within a 1.25 Gbps ODUflex-mapped configuration, because this is the smallest possible available frame size. This mapping setup is shown in Figure 8.

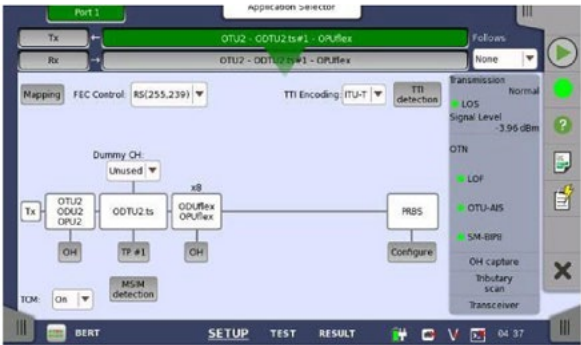


Figure 8 ODUflex Transmitter Setup

Summary

OTN offers significant advantages for telecom operators, and there is a rapidly developing trend for end users (access networks) to become closer to OTN. Considering these trends, operators need to examine the evolution of their methods and equipment to be able to respond to network changes and reduce the time it takes to resolve problems while maintaining the same level of quality of service as before. The Network Master Pro MT1000A makes it easy to analyze OTN problems, thus facilitating problem-solving at the test site.

List of Acronyms

Acronym	Definition
ADM	Add/Drop Multiplexer
AIS	Alarm Indication Signal
BBE	Background Block Error
BDI	Backward Defect Indication
BEI	Backward Error Indication
BER	Bit Error Ratio
BERT	Bit Error Rate Test
BIAE	Backward Incoming Alignment Error
CSF	Client Signal Fail
FEC	Forward Error Correction
FTFL	Fault Type Fault Location
IAE	Incoming Alignment Error
ITU-T	International Telecommunication Union – Telecommunication Standardization

Acronym	Definition
OCh	Optical Channel
ODU	Optical channel Data Unit
OMS	Optical Multiplex Section
OPU	Optical channel Payload Unit
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTU	Optical Transport Network
PDH	Plesiochronous Digital Hierarchy
PM	Path Monitoring
PRBS	Pseudo Random Binary Sequence
SDH	Synchronous Digital Hierarchy
SES	Severely Errored Seconds
SM	Section Monitoring
SONET	Synchronous Optical NETwork
TCM	Tandem Connection Monitoring

Related Products

Network Master Pro	MT1000A
10G Multirate Module	MU100010A1
100G Multirate Module	MU100011A



MT1000A is the all-in-one field tester of B5 size, excellent in operability, combining 10G/100G Ethernet, OTN, SONET/SDH, OTDR, PTP, and CPRI modules, having an automated testing function.

Network Master Pro	MT1040A
100G Multirate Module	MU104011A
400G Multirate Module (QSFP-DD)	MU104014B
400G Multirate Module (OSFP)	MU104015A



The portable B5-size Network Master Pro MT1040A for 400G has customized expandability with easy operation. The MT1040A transport measurement function supports various network interfaces, including 10M to 400G Ethernet, OTN (OTU1 to OTU4), CPRI/OBSAI, etc.

Further Reading

Application Notes on OTN

[OTN – Advance Testing and Dividing the Network](#)

Testing across different network layers and how to troubleshoot them.

References

ITU-T G.709 (Interfaces for the optical transport network)

<http://www.itu.int/rec/T-REC-G.709>