

Optical Transport Networks (OTN): Advanced Testing & Dividing the Network

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

Constructing networks for telecommunications carriers demands flexible support for various data traffic, including Ethernet communications and data center interconnects. A technology that addresses these needs is the Optical Transport Network (OTN). OTN provides highly efficient and flexible traffic accommodation capabilities, such that its adoption is expanding primarily among telecommunications carriers and large-scale cloud service providers.

For the effective operation and maintenance of an OTN, dividing the network appropriately by section and utilizing advanced testing and monitoring methods to accurately assess communication quality, such as latency and jitter, is essential. In the future, OTN is expected to further evolve as a foundational technology for next-generation networks, alongside technological advancements that support sustainability (including energy-efficient design) and operational automation.

This document outlines the role of OTN in helping telecommunications operators maintain network quality and flexibility. It covers the latest testing methods, strategies for segment partitioning, and the process for evaluating end-to-end network quality.

OTN Network

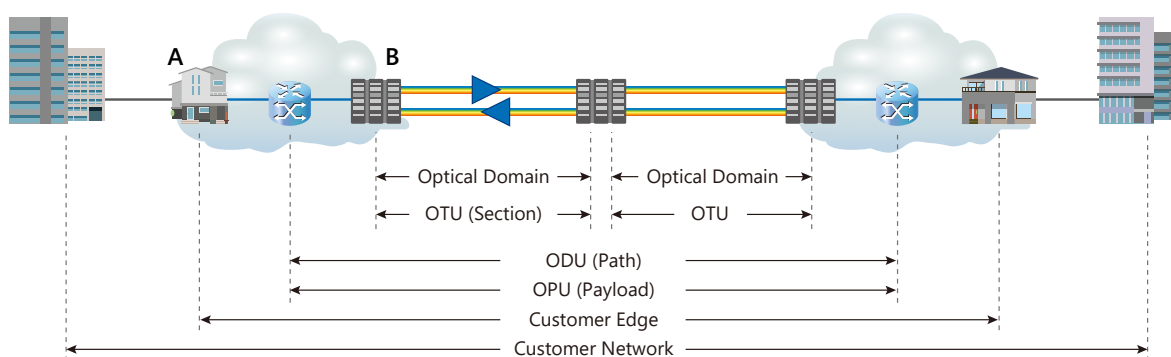


Figure 1 Configuration of End-to-End Network using OTN.

The configuration of an end-to-end network including OTN is illustrated in Figure 1. This network uses OTN frames as its foundation and consists of multiple logical sections. The network is generally divided according to each major physical segment.

- **Customer Network:** Communication segment between end users
- **Customer Edge:** The boundary between the user network and the carrier network
- **OPU/ODU:** Segment where user data is transmitted through the OTN protocol
- **Optical Domain:** Segment where optical signals carry OTU frames, including synchronous signals and forward error correction (FEC) codes

End-user connections are primarily established using Ethernet and virtual local area networks (VLANs). Within the OTN network, these connections achieve efficient routing to the service provider's access points through stacked VLANs or multi-protocol label switching (MPLS).

Verifying OTN Communication Quality

The Importance of Network Testing for Each Segment

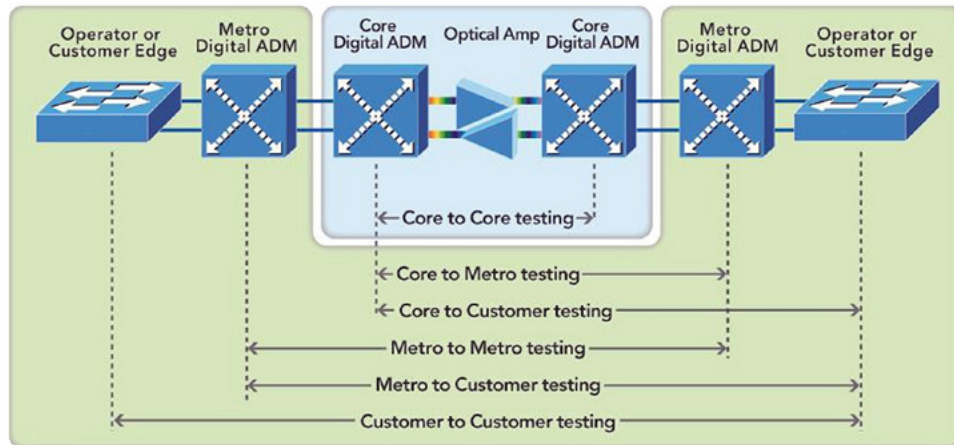


Figure 2 Divided Network.

When conducting network testing, dividing the network appropriately allows for verification not only end-to-end but also between individual sections, across different segments, and between specific endpoints. Logical or physical segmentation of the network enables quick isolation during failures and simplifies pinpointing the cause.

Typical examples of network segmentation include divisions such as:

- Core network to core network
- Metro network to metro network
- End user to end user

Additionally, by segmenting the network into layers — such as backbone, access points, and transit nodes — and conducting monitoring and testing at each layer, it is possible to visualize the overall operational status and quality of the network. This approach enables the maintenance of network health and improves the efficiency of troubleshooting.

End-to-end Network Testing

End-to-end network testing represents the most common approach, conducted by telecommunications operators when activating new networks or providing services. This type of testing aims to ensure end-user network quality and compliance with service level agreements (SLAs) by validating network performance under traffic conditions that closely reflect real-world operations.

During end-to-end testing, traffic similar to that generated in actual user environments is produced to evaluate the communication quality between the network edges, that is, between users. Standardized measurement procedures such as RFC 2544 and ITU-T Y.1564 typically serve as the basis for these tests.

RFC 2544 is a widely recognized benchmarking standard for evaluating the performance of network devices and links. The standard methodically measures criteria such as throughput, latency, frame loss, and burstability, in sequential order. This approach provides a detailed understanding of the maximum network throughput and latency characteristics. However, conducting each test item individually tends to result in longer total test durations. Furthermore, RFC 2544 may not fully address the requirements of today's network environments, where multiple services and traffic streams coexist.

ITU-T Y.1564 was established to efficiently and simultaneously validate multiple Ethernet services before deployment to users. The procedure begins with connectivity testing for each traffic flow (service stream), reflecting real-world network services. Subsequently, a long-duration performance test combines all the streams. Key evaluation criteria include throughput, latency, jitter, frame loss, and burst tolerance. Y.1564 offers an efficient testing method designed for complex, modern service delivery environments.

RFC 2544 remains well-suited for the detailed evaluation of individual network devices or basic performance checks of single services. In contrast, Y.1564 is highly effective for comprehensive performance assurance and simultaneous multi-service testing at the start of service provision. Network operators select the appropriate testing method based on specific objectives and the systems under examination.

Remote Testing

This section outlines specific challenges encountered during remote testing in end-user networks and introduces practical measures to address them.

In actual operations, conducting direct end-to-end connection tests on end-user networks often proves difficult. Troubleshooting during failures faces several constraints, including:

- Difficulties accessing the site due to after-hours restrictions or physical limitations
- Variability in work progress depending on the level of cooperation from the user environment
- Greater complexity of network configurations, which increases the difficulty of identifying fault points

To address these issues, remote end-to-end circuit testing from carrier facilities has become a standard approach. The following technical methods are commonly used in remote testing:

- Constant network monitoring using surveillance devices and dedicated tools
- Connectivity tests and throughput measurements, such as ping and traceroute, from remote terminals
- Automatic failure notification and event log collection

The above enables the early detection of issues, the identification of causes, and the implementation of provisional measures without the need for on-site work. To that end, the organization of operational manuals and incident response flows is essential for efficient operations.

Remote testing presents challenges in obtaining a comprehensive activation report from end-user terminals. However, remote testing delivers significant benefits for monitoring the network status across segments and isolating faults. Combining multiple test patterns, such as those listed below, leads to more accurate fault identification:

- Physical layer: Detecting line disconnections or link-down events
- Data link layer: Verifying connectivity using VLANs and MAC addresses
- Network layer: Analyzing IP routing or path failures
- Application layer: Monitoring service responses and port statuses

In multi-site environments where network access originates from multiple operational locations, performance tests tailored to each site become necessary. The following section outlines typical scenarios and example solutions.

For example, when end-user networks have a higher contracted bandwidth than other offices, conducting connectivity tests from the headquarters office can be challenging due to differences in bandwidth and network topology. In such cases, conducting throughput tests from each regional office to the headquarters may be possible using test protocols such as ITU-T Y.1564 while emulating traffic with multiple streams. This approach enables service providers to quantitatively verify that the guaranteed bandwidth is consistently delivered to each regional office.

Meanwhile, there were previously no clear verification procedures for evaluating whether large-capacity throughput can be provided to the headquarters. The main reason for this stems from the differing requirements: end users need testing at the Ethernet interface, while service providers require testing on Ethernet over OTN interfaces. Accurately assessing the network-wide performance calls for configuring Y.1564 or RFC 2544 tests at one end of the network (e.g., the end-user edge) and collecting the results at the opposite end (e.g., the core edge). For instance, Y.1564 tests are conducted on Ethernet at the end-user side (point A in Figure 1), and on Ethernet over OTN at the service provider side (point B in Figure 1).

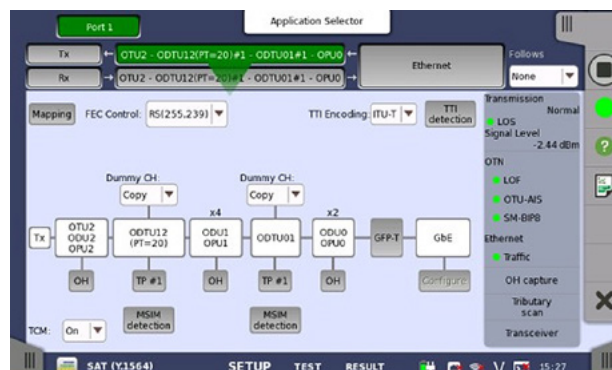


Figure 3 Multi-stage OTN Mapped Path.

Requirements for OTN Test Solutions

Test solutions must accommodate a variety of network configurations, including multi-stage OTN setups (see Figure 3). Figure 3 shows an example of mapping a 10-Gbps (OTU2) signal to 1 GbE. Constructing a test environment capable of handling these complex network signal conversions plays a critical role in quality assurance for carrier-side connections in core networks and enables rapid troubleshooting in the event of a failure.

Protocols delivered on the network's end-user side include not only standard Ethernet, but also VLAN, stacked VLAN, MPLS, MPLS-TP (Transport Profile), and Provider Backbone Bridges – Traffic Engineering (PBB-TE). Applying Y.1564 testing to these protocol stacks allows test traffic to be transmitted across both ends of the core network — specifically, on the OTN transport layer for the carrier and Ethernet for the end user — so that the throughput contracted by the end user can be accurately verified at the headquarters. This method proves effective regardless of whether the test point is in the access or core network, even if transport spans multiple protocol layers. The results obtained through this approach enable carriers to demonstrate the delivery status of the contracted services.



Figure 4 Y.1564 Configuration.

When issues arise, network operators must troubleshoot the network by emulating end-user traffic. In such a situation, tests involving multiple traffic streams are commonly employed, allowing detailed analysis at the network and end-user traffic layers. Such an environment provides engineers with highly valuable information, especially for correlating errors at the OTN layer with those at the Ethernet and end-user traffic layers. This capability enables a comprehensive view of the entire network and facilitates the identification of the root causes, which directly improves incident response and service quality.

Testing solutions should also support the analysis of alarms and errors across all network layers, connection to any network point, and the simultaneous monitoring and management of transport layer protocols such as OTN and MPLS-TP, alongside client protocols including Ethernet, Plesiochronous Digital Hierarchy (PDH), and Fibre Channel. These features greatly enhance the efficiency of network operation, maintenance, and troubleshooting, resulting in reduced downtime for end users.

Error Analysis and Troubleshooting

Figure 5 shows an example of the test results. At 5-s intervals, several Section Monitoring - Bit Interleaved Parity-8 (SM-BIP-8) errors and one uncorrectable FEC error were detected. As shown in Figure 5(b), these errors serve as the direct root cause of Ethernet frame errors. By analyzing such error structures, engineers gain the ability to pinpoint lower-layer sources of network failures and establish a clear starting point for effective troubleshooting.

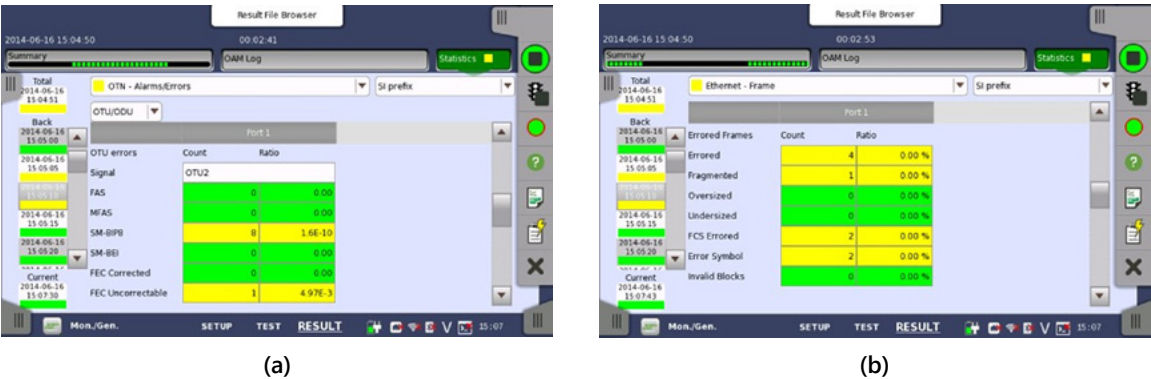


Figure 5 (a) OTN Error/Alarm Results, (b) Ethernet Frame Results.

Understanding these testing methods remains essential for adapting flexibly to a variety of situations based on network configurations and end-user environments. The following are typical application examples:

- Commissioning and troubleshooting of end-user networks when the head office has faster data connections than the branch offices
- Operations to minimize the impact on existing offices during new service launches for the same end-user at other locations
- Response and recovery in the event of any overload or negative impact on existing offices
- Parallel analysis of end-to-end failures within the core network without stopping the end-user network

In these scenarios, telecom operators construct parallel lines from the optical channel data unit/optical channel payload unit (ODU/OPU) point or, if accessible, from the end-user edge, monitoring the operational status along the same path as the end user. This approach enables the continuous verification of the core network health over time. In addition to basic bit error rate testing (BERT), emulating end-user data during testing allows a detailed assessment of the lower OTN layer quality, leading to the early detection of issues related to the end user.

Error Insertion and Detection from Client to OTN

Evaluating the reliability of an OTN system requires verification of fault propagation across multiple layers, from client signals to OTN. To confirm that network equipment correctly detects faults at each layer and propagates alarms both upstream and downstream, deliberate error insertion tests are performed at various levels.

For example, using client signals such as Ethernet, SDH, or FC, inserting faults into the Generic Framing Procedure (GFP) frames within the OTN overhead generates a Client Signal Fail (CSF) alarm, corresponding to a Loss of Signal (LOS) on the client side. This triggers a chain reaction, with the ODU layer generating a Backward Defect Indication (BDI) alarm that carries fault information from lower to higher layers. Figure 7 provides a detailed illustration of this sequence.

By intentionally introducing faults from the client side through to the OTN, and then observing the alarm propagation paths and responses at each layer, engineers can comprehensively evaluate the multi-layer integrated fault detection and notification capabilities of OTN network elements. This approach enables the optimization of network design and operations for faster fault detection while reducing the number of false alarms.



Figure 7 CSF Alarm Caused by Higher.

Summary

This document has outlined the essential role of OTN in maintaining network communication quality and flexibility, the latest testing methodologies and segment division strategies, as well as the end-to-end circuit quality evaluation process. OTN delivers significant advantages to telecommunications operators, which is driving its expanding adoption. Against this backdrop, operators are required to appropriately verify methods and device updates in line with network evolution, ensuring traditional service quality and prompt issue resolution. Notably, leveraging the MT1000A simplifies on-site OTN network fault analysis and enables efficient troubleshooting.

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

For information about the tests necessary to ensure communication quality at the OTN layer, please refer to this application note.

[OTN – What's Important to Test](#)

References

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

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

ITU-T G.7041 (Generic framing procedure)

<http://www.itu.int/rec/T-REC-G.7041>

ITU-T Y.1564 (Ethernet Service Activation Test Methodology)

<http://www.itu.int/rec/T-REC-Y.1564/en>

IETF RFC 2544 (Benchmarking Methodology for Network Interconnect Devices)

<http://datatracker.ietf.org/doc/rfc2544/>