



TROUBLESHOOTING AT THE SPEED OF LIGHT

EMBEDDED OTDR FOR
OPERATIONAL EXCELLENCE
IN PASSIVE OPTICAL NETWORKS

APPLICATION NOTE



ABSTRACT

With our increasing dependence on broadband, service disruptions are not acceptable, and the need for cost-effective fiber monitoring and troubleshooting is escalating. However, detecting connection problems in point-to-multipoint passive optical networks (PONs) is challenging. External Optical Time Domain Reflectometry (OTDR) can localize faults, but it is on-demand, adds to service interruptions and increases costs.

With the first-to-market Embedded OTDR Solution, Alcatel-Lucent brings key capabilities into PON monitoring and troubleshooting tools to create an end-to-end comprehensive network view in a quick, cost-effective and continuous manner.

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INTRODUCTION

Our lives increasingly depend on broadband, and service disruptions are not acceptable to end users. A sudden loss of connection during an exciting football game or an important business videoconference can result in customer dissatisfaction, churn and decreased revenue. Along with the acceleration of fiber deployments and connections of millions of users annually, the need for cost-effective and accurate fiber monitoring and troubleshooting is escalating.

Although fiber networks are very robust and resistant to a number of outside factors, such as humidity and noise, a range of faults can occur:

- Accidental cuts during civil works
- Contact misalignment
- Dirty contacts
- Damaged splitter
- Damaged connector
- Pressured or crushed fiber
- Fiber bends
- Damaged Optical Network Termination (ONT)

A fiber network problem can happen almost anywhere, making it difficult to localize and affecting potentially hundreds of fixed and mobile users.

Today, OTDR monitoring and troubleshooting solutions are based on portable test equipment or remote testing units, manually or automatically connected to fiber links. These solutions require a large amount of additional equipment. Typically, a single external Optical Time Domain Reflectometer (OTDR) is used to supervise multiple PONs and requires a configurable optical switch. This leads to additional investment and operational effort, more power consumption and floor space. Measurements are typically on-demand and might result in service interruptions and separate test wavelength.

Alcatel-Lucent brings unique and innovative Embedded OTDR capabilities into its existing fiber management solution for creating a comprehensive network view and troubleshooting of fiber networks in an easy, fast and cost-effective way. By integrating OTDR functionality into its PON system and Network Analyzer - Fiber, Alcatel-Lucent has the most advanced fiber monitoring tool on the market today. This application note describes the unique Alcatel-Lucent Embedded OTDR Solution and its value to PON operators.

OPERATIONAL EXCELLENCE: THE KEY TO A SUCCESSFUL BUSINESS CASE

One of the biggest advantages of a PON is its OPEX savings potential. The OPEX advantages of fiber can be substantial compared to other access technologies, representing an important component of the business case for fiber-based access networks. Any further OPEX reductions will positively influence the case for fiber networks.

Equally important is the customer experience. High-value, high-broadband services need a reliable and resilient network to guarantee premium quality of experience for all customer segments:

- Residential services: This is the biggest market segment, and operators need to guarantee revenue flow and the smooth introduction of new services in the future. Reliable fiber networks protect revenues by keeping customer satisfaction high and avoiding churn.
- Business services: These contracts usually include service levels that need to be measured, monitored and guaranteed. Not keeping up with guaranteed service levels results in financial penalties or subscription cancellations.
- Mobile users: The phenomenal increase in mobile traffic and number of users increasingly depends on the backhaul capabilities of fiber networks, which need to work flawlessly.

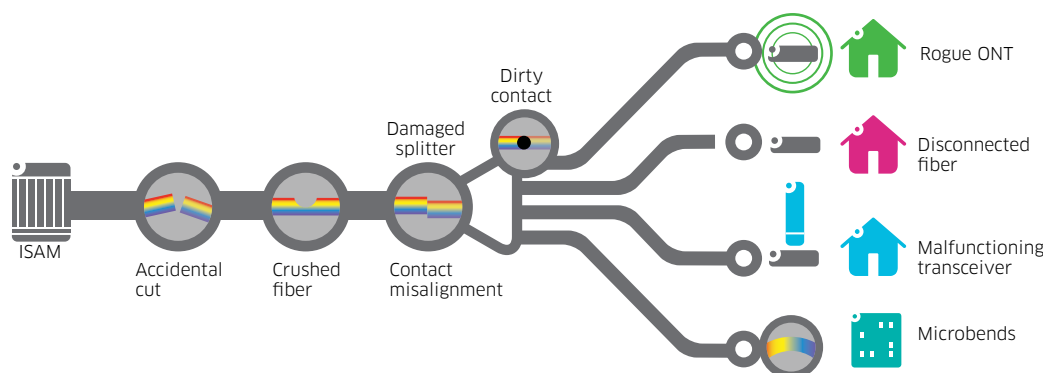
Fiber networks require large investments, the biggest portion of which is in the outside plant. Protection of fiber, the most valuable part of the network, is of the utmost importance for operators' business cases. The implementation of advanced monitoring and fiber network troubleshooting tools reduces OPEX and protects revenues.

THE CHALLENGE OF DETECTING FIBER CONNECTION PROBLEMS

Obtaining an accurate and comprehensive network view is complex because PONs use point-to-multipoint topology. Most PONs have two levels of splitters, which split a single fiber from the Central Office (CO) into up to 64 branches going to the end user. The splitters can be located anywhere. However, most operators place the first splitters close to the CO, with a typical split ratio of 1:2 or 1:4, and the second level of splitters close to end users.

Fiber is buried underground in most fiber networks, making visual inspection difficult (very few countries allow aerial cabling). The challenge of detecting connection problems in point-to-multipoint networks is to find out where the problem has occurred: in which branch and where after the splitter (see Figure 1). The challenge is even more significant considering that a single PON covers a wide area and a large number of users.

Figure 1. Types and locations of fiber connection problems in PONs



The Alcatel-Lucent fiber troubleshooting solution — Motive Network Analyzer - Fiber — is already widely deployed. It offers advanced troubleshooting techniques based on Optical Transceiver Monitoring (OTM). This technology enables the measurement and analysis of various parameters collected from the network to diagnose problems such as pressured fiber, bent fiber or dirty connectors.

However, if there is a total loss of signal and no parameters can be collected to help diagnose the problem, the OTDR plays an important role. The OTDR adds key capabilities to the access node and the Motive Network Analyzer - Fiber to create an end-to-end comprehensive view of the fiber network and to localize faults, even in case of signal loss.

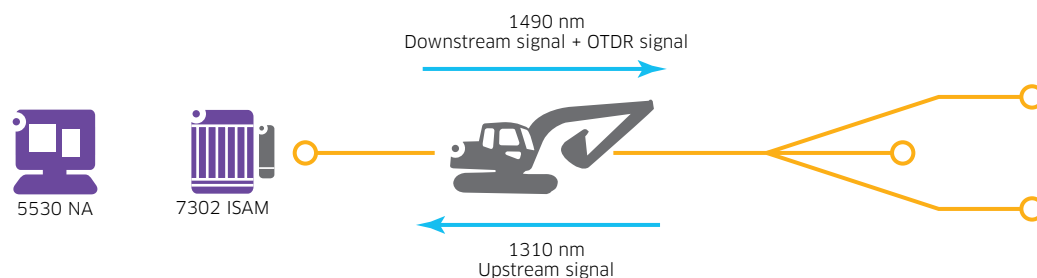
EMBEDDED OTDR: THE RIGHT COST-PERFORMANCE BALANCE

Alcatel-Lucent has played a pioneering role by introducing the first embedded OTDR solution on the market, based on Alcatel-Lucent Bell Labs innovations.

The Alcatel-Lucent Embedded OTDR Solution consists of two key components (see Figure 2):

- Functionality embedded in optical transmission components (Small Form Factor Pluggable transceiver SFPs) in the Alcatel-Lucent ISAM access node, responsible for transmitting a continuous signal in the downstream direction and receiving its reflection
- Advanced software implemented in the Motive Network Analyzer that analyzes network data and its correlations to build a composite picture of the state of the network

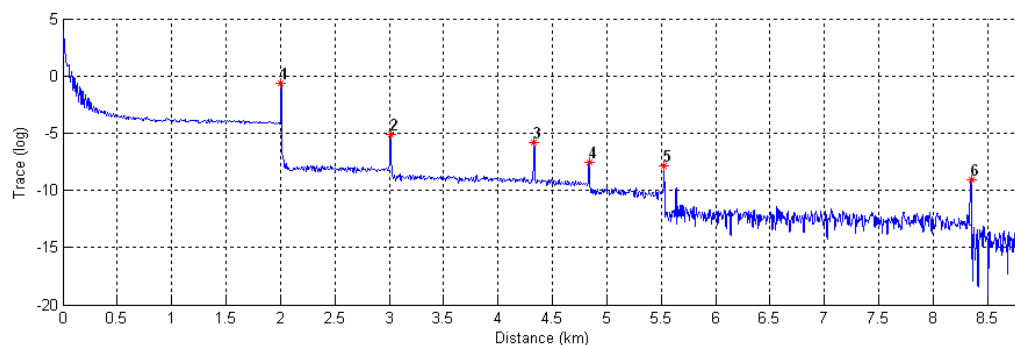
Figure 2. Alcatel-Lucent OTDR Solution functionalities embedded in the ISAM access node optical transmission transceivers and Motive Network Analyzer - Fiber



Because OTDR capabilities are integrated in the actual optical transceiver modules in the access node, the network operator can continuously monitor the physical status of the fiber plant, with no service interruptions and no extra test equipment or unnecessary reallocation of skilled personnel.

No embedded or external OTDR solution is the ultimate solution for all fiber problems. High split ratios and subscriber density result in very small steps between reflected signals, or even signals hidden behind each other, making analysis extremely difficult or impossible, as shown in Figure 3.

Figure 3. Small steps between reflected signals or overlapping signals make analysis extremely difficult



External OTDR brings some improvements in monitoring performance but introduces multiple issues:

- External equipment that adds to CAPEX and OPEX
- Monitoring only on demand instead of continuous
- Time-consuming installation and configuration of OTDR equipment in the monitored location

The Bell Labs innovation center has conducted ground-breaking research in OTDR technology to achieve the right balance between measurement performance, cost and speed, and to improve the overall monitoring and troubleshooting experience with:

- No service interruption
- No extra test equipment
- Continuous monitoring of all lines to ensure an up-to-date reference as the basis for troubleshooting
- Localization of fiber cuts in the common part of the network shared by large numbers of subscribers:
 - ↪ Fiber feeder anywhere within 20 km
 - ↪ 1:2 split anywhere within the first 15 km
 - ↪ 1:4 split anywhere within the first 5 km
 - ↪ High-reflection event detection after 1:8, 1:16 and 1:64 splits

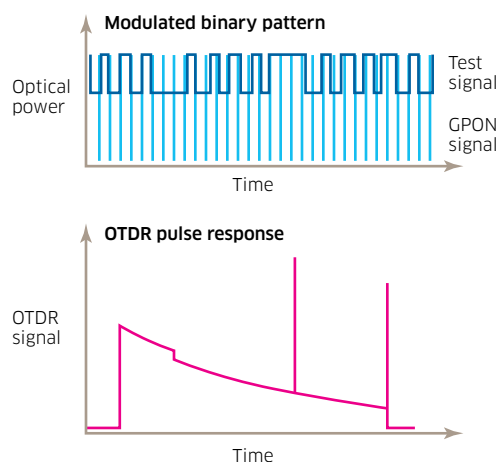
HOW EMBEDDED OTDR WORKS

An OTDR measurement provides a view of the signal attenuation characteristics of the fiber, splices, connectors, splitters, and highly reflective network components. Typical reflective components are SC/PC connectors, splitters and most types of fiber cuts.

A remote OTDR solution typically measures a PON from the CO end. As a result, the measured reflection is ambiguous if it occurs behind a splitter. It is therefore essential to remove ambiguity by integrating this type of measurement with other measurements. In this case, rather than “listening” to the reflections from a single pulse as in conventional OTDR, one can imagine listening to the reflections from a binary pulse pattern that is added on top of the normal PON downstream traffic (see Figure 4).

Knowing the injected pulse pattern, the signals reflected from the fiber link can be transformed to produce the same reflection information that is obtained from conventional pulse-based OTDR. The modulation index of the OTDR signal is sufficiently small to minimize any impact on the data traffic.

Figure 4. Remote and embedded OTDR



EMBEDDED OTDR USE CASES

The comprehensive Alcatel-Lucent Embedded OTDR Solution toolkit can be used for fiber network testing and troubleshooting throughout the complete network life cycle: during rollouts and operations and for customer care.

Embedded OTDR during rollouts

Errors made during installation will likely remain undetected until the end user needs to be activated. With embedded OTDR and the Motive Network Analyzer - Fiber, it is possible to conduct remote validation of the fiber feeder even if the ONT is not active. This ensures that all connections are successfully made. It also provides immediate feedback to technicians that the task has been successfully accomplished so that the end user can be activated smoothly and without delays.

Further on, the results of the quality tests can be fed back to the outside plant (OSP) documentation database and be used as the reference data for future troubleshooting.

Embedded OTDR during operations

Because the Motive Network Analyzer with OTDR capabilities combines complementary techniques, runs continuously in the background, and requires no external test equipment that needs to be installed on demand, the solution brings several benefits:

- Fast and accurate fault localization even behind the splitter
- Enables preventive maintenance — that is, detection of network performance degradation
- Reduces the need for truck rolls if the detected problem can be solved remotely
- Identifies the environment where the problem occurred and increases the speed and cost-effectiveness of truck rolls by sending the right technicians to the right location, equipped with the right tools

Embedded OTDR for customer care

By tightly integrating different tools, such as OTM, OTDR and the alarm system, the Motive Network-Analyzer - Fiber provides a powerful engine for customer care:

- Problems are quickly localized
- First-call resolution is improved by eliminating wrong dispatches
- Issues can be early detected and repaired before the end user is affected

HIGH QUALITY AND LOWER COSTS FOR PON OPERATORS

In modern broadband access networks, everything revolves around cost and quality of service. The Alcatel-Lucent Embedded OTDR Solution addresses both objectives and introduces a range of benefits to PON operators.

Revenue protection

Reliable fiber networks enable the smooth introduction of new services. With embedded OTDR, loops are correctly qualified up front so that new services are deployed with higher success rates and lower risks.

Services are kept on, revenue flows predictably, and churn is reduced by increasing customer satisfaction through real-time feedback on customer complaints.

Proactive problem detection

With continuous network monitoring and early problem detection, operators can take proactive measures before end users are affected. Fiber failures can be avoided, and repair costs can be significantly lower if detected early.

Making a positive impression on end users from the start is the key to long-lasting contracts.

Reduced OPEX

Motive Network Analyzer- Fiber with Embedded OTDR reduces the need for truck rolls, and many faults can be handled by the help desk. When a technician is required, the right expert, equipped with the right tools, can go to the right location. By mapping the network view onto the geographical view, the Motive Network Analyzer - Fiber can determine exactly where the error has occurred — for example, inside a building or utility hole. This valuable information makes repair scheduling and truck rolls more efficient.

The Alcatel-Lucent Embedded OTDR Solution provides a comprehensive view of the network with minimal investment. No external test equipment needs to be purchased and maintained, therefore eliminating additional points of failure.

WHY CHOOSE THE ALCATEL-LUCENT EMBEDDED OTDR SOLUTION?

The revolutionary and unique concept of the solution is to reuse the data transmitter. Fiber monitoring is executed at exactly the same wavelength as the user data, “in-band” as opposed to using a dedicated proxy “out-band” wavelength.

This is important for the following reasons:

- Different wavelengths in an optical signal behave in different ways. For example, a micro-bend problem might not be detected if the measurement is performed on a different wavelength. With the Alcatel-Lucent approach, the same wavelength is used for data and OTDR, which ensures that all measurements are correctly captured.
- A solution with a dedicated OTDR wavelength would require a filter in the ONT to block the OTDR signal, increasing the cost of the ONT.
- A proxy wavelength could require additional hardware in the SFP, again increasing costs and the size of the SFP.
- In-band embedded OTDR is future-ready as PONs evolve toward next generation technologies — for example, TWDM-PON. TWDM-PON is based on the introduction of new wavelengths for data transfer. With in-band embedded OTDR, the problem of finding an available wavelength for the test signal is eliminated.

CONCLUSION

Fiber networks require large investments. Protection of fiber cables, the most valuable part of the network, is of the utmost importance for service providers’ business cases. As fiber access networks grow larger and maintenance activities start to become more frequent, operators need to invest in automated network management and troubleshooting tools that can quickly and predictably outperform manual interventions, minimize the accumulation of degradations, and avoid service and repair.

OTDR technology has been in use for several years, mainly for the monitoring and troubleshooting of transit networks. However, it is based on external test equipment and is not fit for mass-volume residential fiber networks: it is expensive, time-consuming and available only on demand.

Alcatel-Lucent has created a solution that perfectly balances the performance and cost of network monitoring and troubleshooting, protecting both networks and revenues. Embedded OTDR capabilities in the ISAM access node, linked to advanced software algorithms in the Motive Network Analyzer - Fiber, enable a quick, easy, cost-effective and continuous monitoring and troubleshooting experience.

ACRONYMS

CO	Central Office
ISAM	Alcatel-Lucent Intelligent Services Access Manager
NA	Network Analyzer
ONT	Optical Network Termination
OPEX	operational expenditures
OSP	outside plant
OTDR	Optical Time Domain Reflectometry
OTM	Optical Transceiver Monitoring
PON	Passive Optical Network
SFP	Small Form Factor Pluggable
TWDM	Time and Wavelength Division Multiplexing
WDM	Wavelength Division Multiplexing

REFERENCES

1. Motive Network Analyzer - Fiber product page
http://www.alcatel-lucent.com/wps/portal/!ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4w3dnTRL8h2VAQADYR9IA!!?LMSG_CABINET=Solution_Product_Catalog&LMSG_CONTENT_FILE=Products/Product_Detail_001134.xml&LMSG_PARENT=Product_Families/Product_Family_000208.xml
2. Alcatel-Lucent 5530 Network Analyzer brochure
[http://www.google.ca/url?sa=t&rct=j&q=alcatel-lucent%205530%20network%20analyzer&source=web&cd=1&ved=0CDMQFjAA&url=http%3A%2F%2Fwww.alcatel-lucent.com%2Fwps%2FDocumentStreamerServlet%3FLMSG_CABINET%3DDocs_and_Resource_Ctr%26LMSG_CONTENT_FILE%3DBrochures%2FCAR9718080102_bro_\(5530_NA\).pdf&ei=sGlJULjPJcn1iOLkpoGODg&usg=AFQjCNGZgEl5PkiWLkx2STP9SHQe0UMeg](http://www.google.ca/url?sa=t&rct=j&q=alcatel-lucent%205530%20network%20analyzer&source=web&cd=1&ved=0CDMQFjAA&url=http%3A%2F%2Fwww.alcatel-lucent.com%2Fwps%2FDocumentStreamerServlet%3FLMSG_CABINET%3DDocs_and_Resource_Ctr%26LMSG_CONTENT_FILE%3DBrochures%2FCAR9718080102_bro_(5530_NA).pdf&ei=sGlJULjPJcn1iOLkpoGODg&usg=AFQjCNGZgEl5PkiWLkx2STP9SHQe0UMeg)

