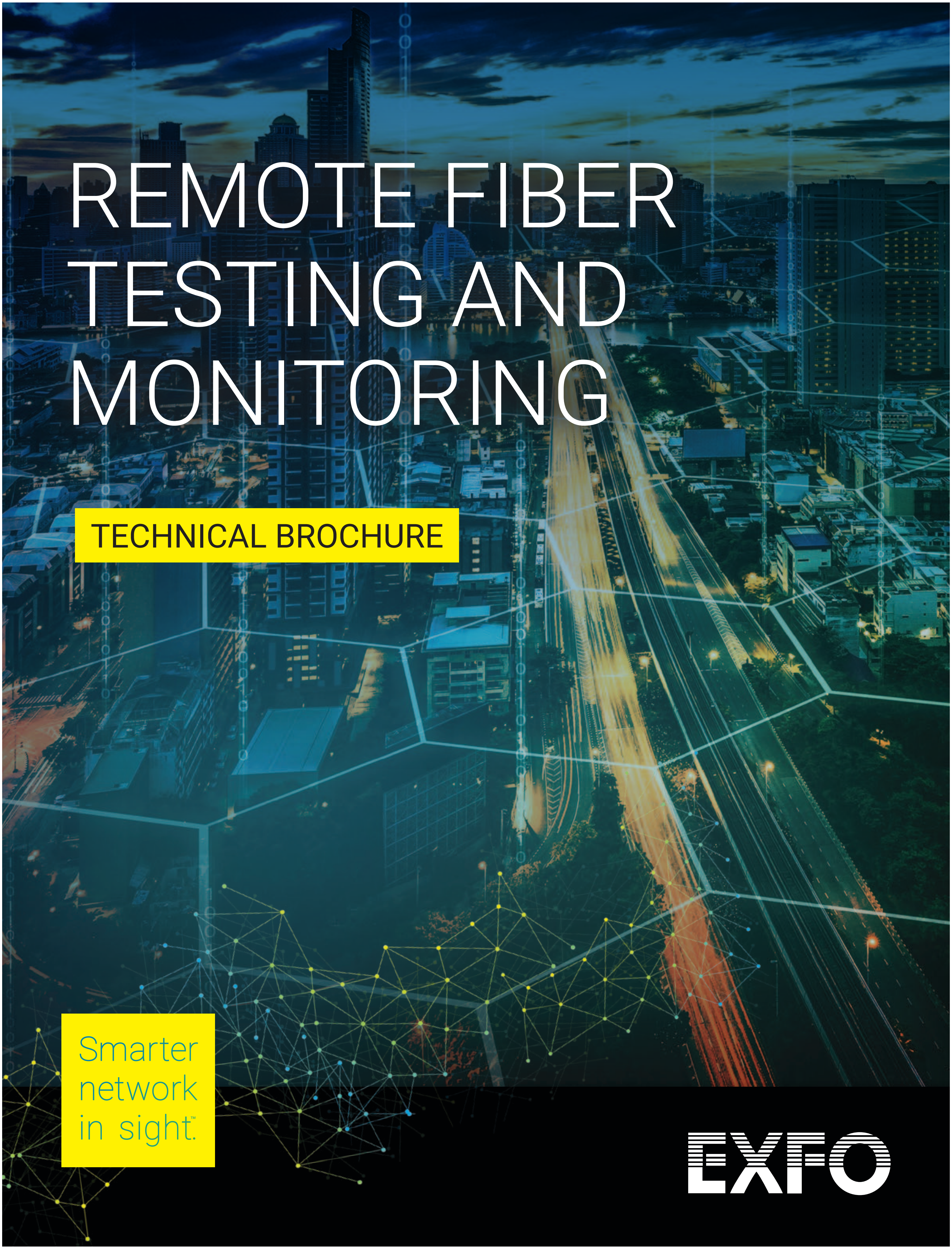

REMOTE FIBER TESTING AND MONITORING

TECHNICAL BROCHURE

Smarter network in sight.™

EXFO

> We're the communications industry's test, monitoring and analytics experts.

About EXFO

EXFO develops smarter test, monitoring and analytics solutions for the global communications industry. We are trusted advisers to fixed and mobile network operators, hyperscalers and leaders in the manufacturing, development and research sector. They count on us to deliver superior visibility and insights into network performance, service reliability and user experience. Building on decades of innovation, EXFO's unique blend of equipment, software and services enable faster, more confident transformations related to 5G, cloud-native and fiber-optic networks.

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Industry's leading OTDR[1]-based solution for remote fiber testing and monitoring

Optical fiber networks are everywhere and are continuously evolving, under heightened stress. EXFO's remote fiber testing and monitoring (RFTM) solution provides increased visibility over critical fiber routes by connecting them to fixed and centralized OTDR-based test equipment—from the initial deployment phase to maintenance and field repairs. With this solution, operators can track changes in fiber infrastructure quality, including slow degradations before they noticeably impact services. As a result, they can both reduce the mean time to repair when a fault occurs and enable preventive maintenance to reduce the incidence of faults. Equipped operators are always aware of the status of their most critical assets and their customer support can demonstrate a level of control.

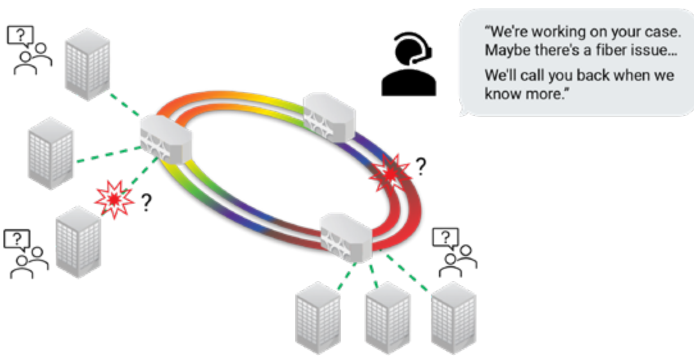


Figure 1: Traditional mode of operation.

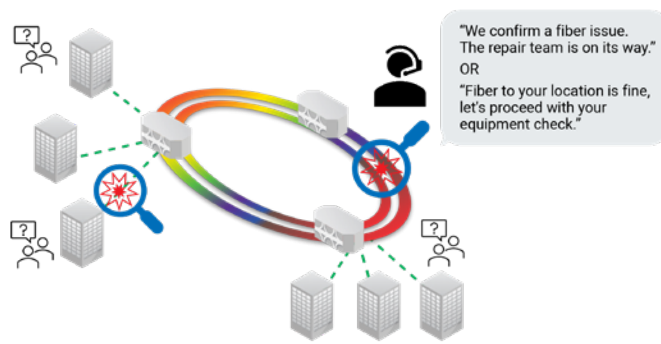


Figure 2: Mode of operation with EXFO's monitoring solution.

Tired of waiting hours to find a field technician with the right equipment for troubleshooting a possible fiber outage?

For most types of fiber deployments, EXFO's remote fiber testing and monitoring solution can eliminate that waiting time by immediately pinpointing the nature of the fault, and providing all relevant parties with the comprehensive information they need to trigger immediate restoration, or discard fiber or cable health as a cause.

Conventional remote fiber test systems are no longer suited for addressing the scale and criticality of fiber networks. A solution that cannot scale or whose performance degrades as the number of fiber links rises is no longer sustainable. Likewise, a solution that only gives you access to a remote OTDR instrument for an expert to troubleshoot will just move your problem, not solve it. EXFO's RFTM solution solves both these issues.

The capability for integration into existing systems (e.g., NMS, OSS) or new workflows is a must today. EXFO's solution goes the extra mile with a truly open and scalable platform for running OTDR tests at any time and from any system. The result? Quick and complete test reports that are easy to interpret and bear value for further investigations throughout the fiber lifecycle.

EXFO's remote fiber testing and monitoring solution provides 24/7 visibility over critical fiber assets and is designed to be used by non-experts so that experts can be dispatched only where and when really needed—saving time and maximizing efficiency.

1 To learn more about OTDR technology: EXFO.com/en/resources/glossary/optical-time-domain-reflectometer-otdr

2 Why EXFO?

EXFO develops smarter test, monitoring and analytics solutions for the global communications industry. We are trusted advisers to fixed and mobile network operators, hyperscalers and leaders in the manufacturing, development, and research sector. Our customers count on us to deliver superior visibility and insights into network performance, service reliability and user experience. Building on decades of innovation, EXFO's unique blend of equipment, software and services enable faster, more confident transformations related to 5G, cloud-native and fiber-optic networks.

Whether you operate a small network (e.g., municipality, private network, small MSO) or a countrywide network, EXFO can help you choose the right type of OTDR-based centralized testing and monitoring to meet your return-on-investment targets:

- Are you looking for the highest performance and density coupled with the fastest testing?
  The RTU-2 powerhouse is designed for you.
- Do you prefer a compact and cost-effective OTDR test head?
  The OTH-7000 is the smallest footprint (½ U rackmount space) optical test head with an embedded OTDR and optical switch with power consumption as low as 10 watts.

EXFO's solutions for remote fiber testing and monitoring deliver functions and capabilities that are yet unmatched:

- Automation of OTDR measurements using patented Link-Aware™ (iOLM) technology providing detailed end-to-end (E2E) fiber characterization without requiring effort nor OTDR expertise.
- Capability to read and use fiber/cable documentation data, managed externally into alarm workflows
- Fully web-based application, including a web-GIS function for fault-on-map capability.
- Denser solution (up to 1024 ports in 3U with RTU-2) using MPO-type connectors on optical switches for large FTTH central offices in high-density urban areas.
- Most compact solution (up to 64 ports in ½U in single box OTH-7000) with front-only connectivity for smaller central offices and cabinet in lower density urban and rural areas.
- Fastest (under 10 seconds), easiest and most accurate E2E PON testing and monitoring using high-reflectance demarcation (HRD) reflectors. Short test times allow each field technician to quickly get results and yield optimal availability for technician crews sharing a centralized OTDR.
- First and only RFTS cloud-native solution based on micro-services with phone-home and event-based communication architecture enabling scalability, higher IT security and cloud operability.

API-based microservices design: All proposed EXFO UIs are built on API sets that are directly exposed to customers, enabling them to create fully integrated and end-to-end workflows. This provides full control over managing the solution via their in-house network management systems. The design ensures seamless integration without the need for an additional layer between the primary database and the customer, guaranteeing consistency and real-time updates regardless of whether changes are made through the EXFO FMS UI or the API.

True mobile application design: Enables efficiency and quick learning curve for field technicians when testing PON or P2P links. It is simpler than web-responsive UI solutions that expose the entire EMS along with confidential information in its URL.

EXFO can also complement the centralized testing solution and boost technician efficiency in the field thanks to a large portfolio of intelligent and connected handheld test instruments[2].

2 For more information on EXFO handheld test instruments: https://www.exfo.com/en/products/field-network-testing

2.1 Link-Aware™ technology (iOLM)

EXFO's industry-acclaimed iOLM is now available for RFTM solutions. iOLM leverages intelligent algorithms that will automatically define and seamlessly execute complex sequences of acquisition, for optimal accuracy. This technology is also key for achieving greater testing speeds through specialized measurement(s) tailored for specific use cases. iOLM comes with full-fledged, detailed end-to-end (E2E) characterization or Optimodes, which are intent-based testing recipes that make the best possible use of the OTDR to obtain optimal speed and performance.

These are just a few of the capabilities and automated processes that can be achieved with iOLM. Our latest solutions for remote fiber testing and monitoring (i.e., RTU-2 and OTH-7000) support iOLM when connected to the fiber management system (FMS) server app.

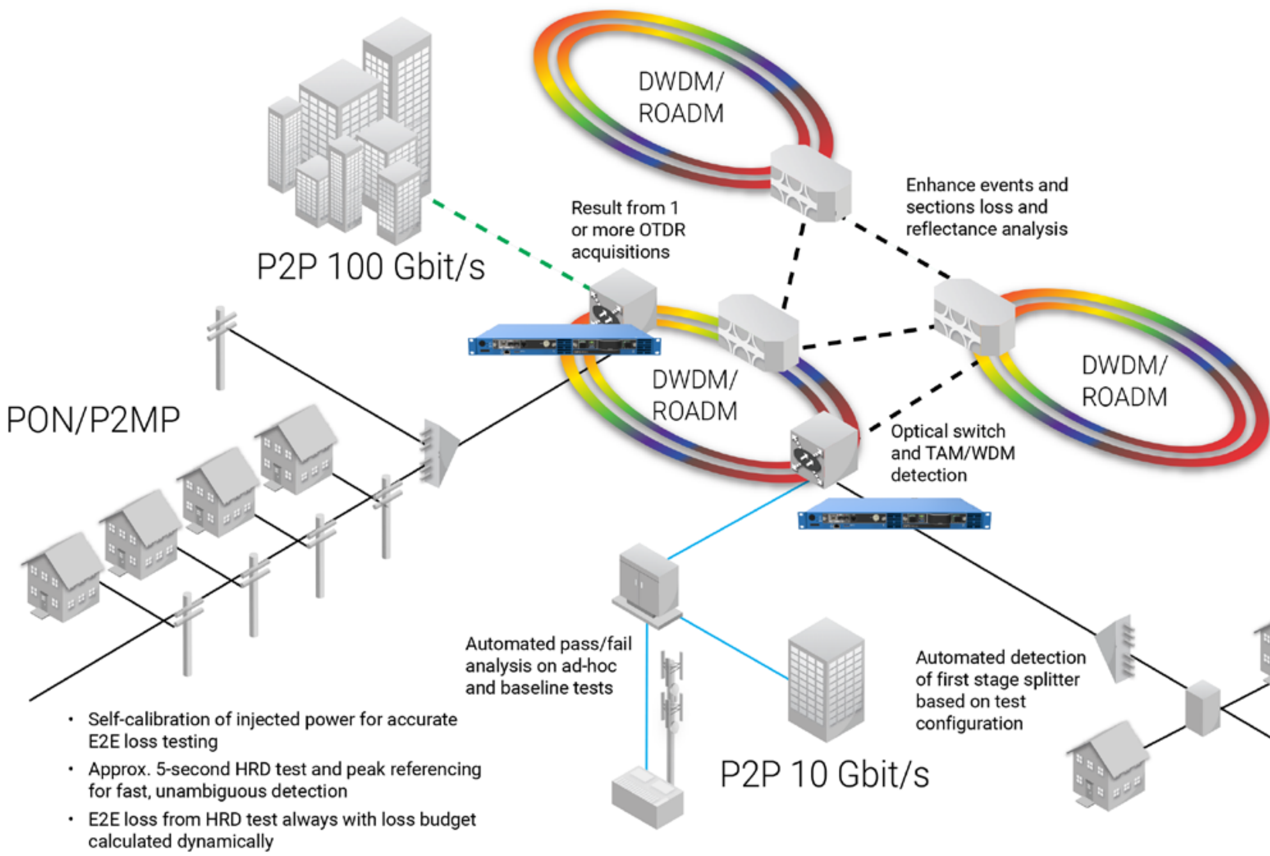


Figure 3: Leveraging iOLM's intelligent automation for optimal measurement on all topologies.

2.1.1 Measurement automation and advanced accuracy

iOLM is an innovative OTDR-based application that uses multipulse acquisitions and advanced algorithms to deliver information on every element in the link. iOLM provides the following advantages:

- Dynamic multipulse acquisition: Adjusts test parameters dynamically for ANY link under test using a mix of short, medium and long pulses. This allows iOLM to scale easily by automating the definition of the best acquisitions for every link; whereas competing solutions on the market still require users to define and finetune acquisition parameters for every link to achieve acceptable accuracy.
- Automation: iOLM enables further automation in testing and monitoring for touchless operations compatible with a machine-to-machine environment.
- Intelligent trace analysis: Based on the multiple acquisitions and with the help of advanced algorithms, iOLM can detect more events with maximum resolution.
- All results in a single view: Results are displayed in an icon-based fiber-link view to quickly assess an event's pass/fail status per standard selected, removing risk of misinterpretation.
- Comprehensive diagnosis: Delivers an analysis of failed events and suggests solutions; guides the technicians in fixing the fault quickly and successfully.

iOLM's patented multi-pulse approach eliminates the accuracy trade-offs inherent to conventional single-pulse OTDR methods. Single-pulse OTDRs often compromise accuracy across the entire link due to the limitations imposed by the Attenuation Dead Zones (ADZ) and Event Dead Zones (EDZ) of longer pulses, which are needed to match the fiber's end-to-end loss. However, EXFO's iOLM technology utilizes an unlimited mix of short and long pulse widths without sacrificing full-span accuracy—a unique feat in the rackmount/remote OTDR sector. This results in enhanced resolution at both the front-end and mid-span while still covering the entire span. The following demonstrates the improved accuracy achieved by EXFO's iOLM multi-pulse acquisition.

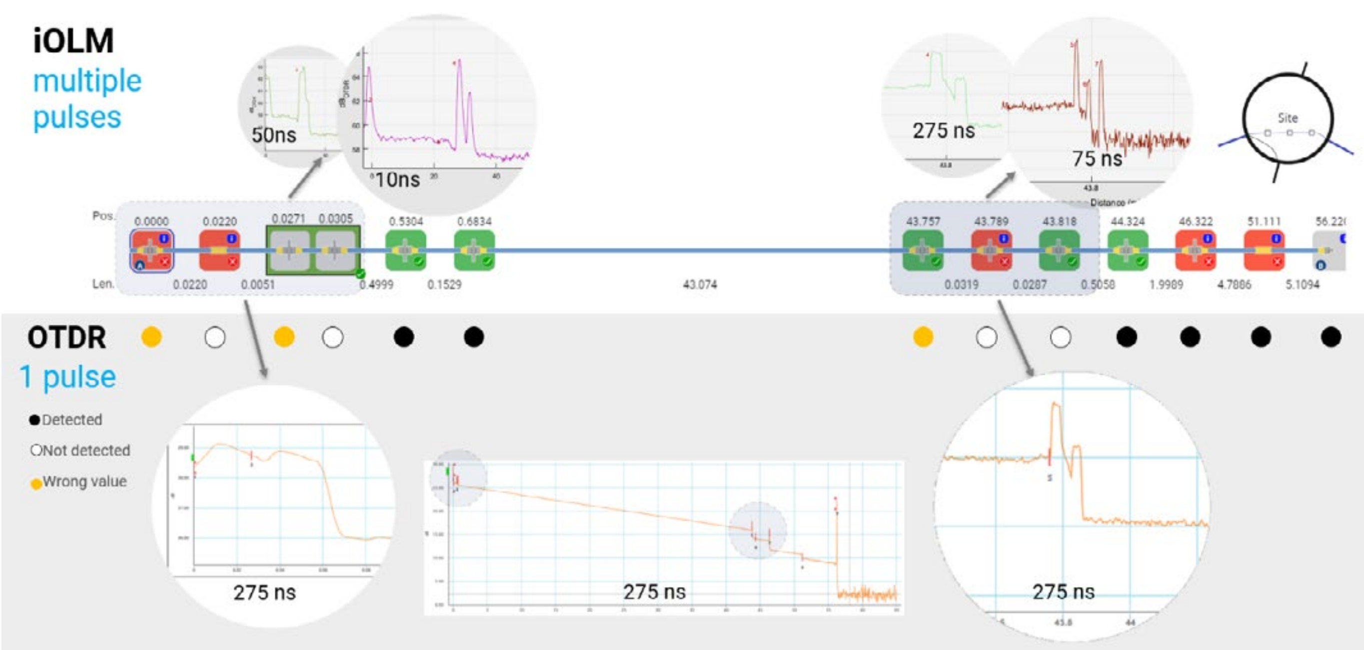


Figure 4: Comparison of an iOLM analysis leveraging multiple pulse widths vs. conventional single pulse OTDR. As seen, shorter pulses identify two closely spaced connectors (based on 10 ns pulse) and measure their combined loss (50 ns), while a longer 275 ns pulse cannot detect all events, blending them into a single, inaccurately measured one.

2.1.2 Optimodes for intent-based testing

iOLM introduces "intent-based" testing recipes called Optimodes. These specialized measurement modes automatically adjust OTDR acquisition parameters based on predefined templates, optimizing performance for specific applications or testing objectives. This maximizes speed, efficiency, and customized testing behavior. Optimodes influence:

- **Acquisition algorithms:** Adjusting pulse settings, test duration, and measurement range.
- **Analysis process:** Customizing actions (e.g., modifying analysis after a splitter) or expected element types (e.g., detecting reflectors like HRDs).
- **Diagnosis list:** Delivering specific or contextual diagnoses tailored to the application or use case.

For example, an Optimode for PON end-to-end loss measurement with HRD focuses resolution precisely where the HRD peak is detected, enabling accurate measurement without wasting time on irrelevant link sections. This delivers optimal resolution (down to 60 cm HRD separation) while completing tests in under 10 seconds, compared to 20+ seconds with competitors. This speed, without compromising accuracy, accelerates network validation, reducing OPEX and enabling faster PON monitoring by covering more PONs with a single test head in less time.

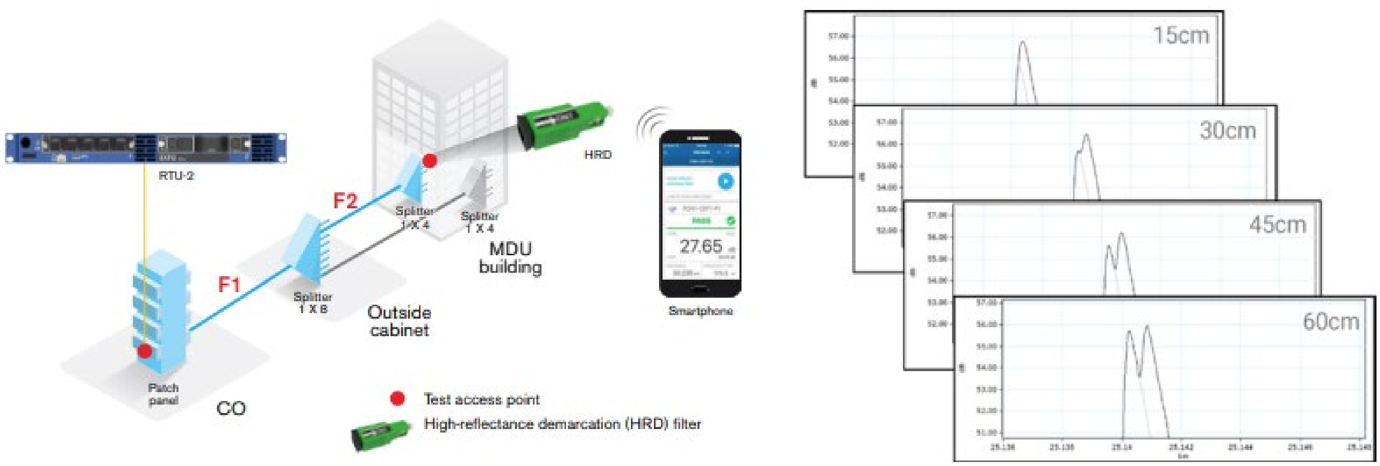


Figure 5: HRD-based link certification in a PON architecture with end-to-end connectivity. High-resolution demarking of PON termination ports capability using HRDs down to 60 cm.

2.1.3 Access to underlying OTDR acquisitions

While the primary view is a linear, iconic display, users can switch at any time from the detailed iOLM view to an OTDR view, revealing each acquisition. This provides expert users with a valuable, granular view of the measurements.

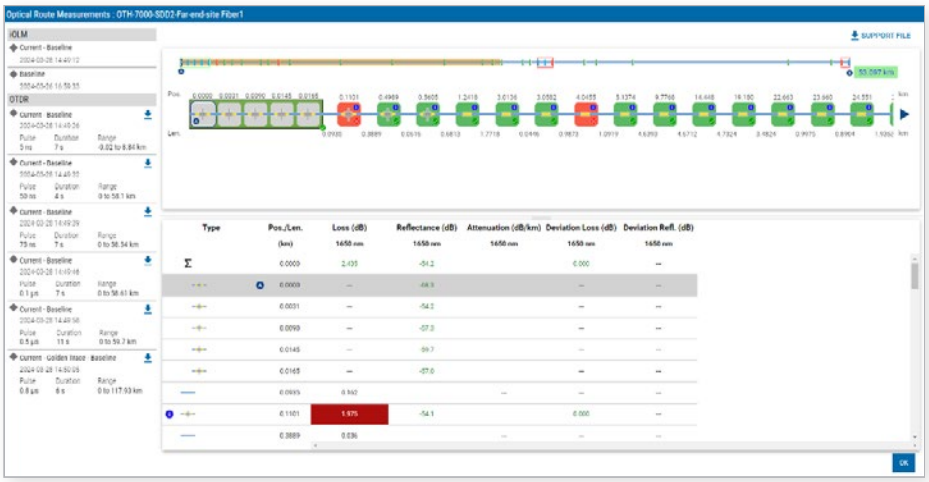


Figure 6: iOLM comprehensive view built from the analysis of multiple OTDR traces.

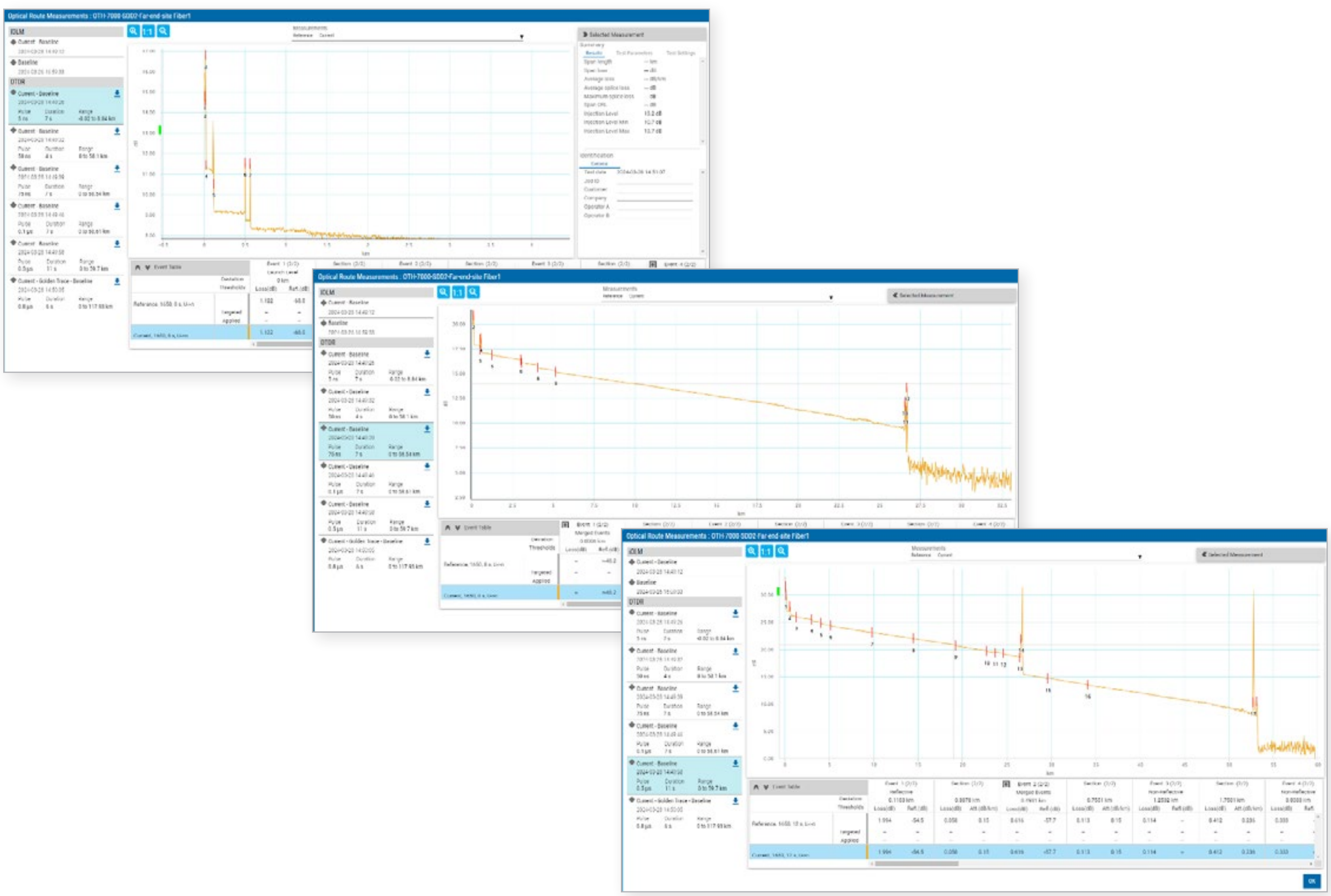


Figure 7: Three samples of OTDR traces leveraged to build comprehensive and most accurate iOLM view.

3 FMS Central management application

EXFO FMS is the management software component of the solution. It is an innovative, open and scalable platform for controlling EXFO's Remote Test Units (RTUs) based on container and microservices technology.

3.1 A cloud-native application

By definition, a cloud-native application is software that orchestrates containers as part of a microservice architecture. This enables the server software to operate on virtually any distributed Linux platform (virtualization layer between OS and containers) and to scale as each container is capable of operating into a cluster (multiple nodes). As telecom operators continue or start to move to public or private clouds, EXFO’s solution for remote fiber testing and monitoring can gradually fit into their cloudification plans—guaranteeing greater flexibility and efficiency.

The first benefit of cloud-native is the ease of exposing services via RESTful APIs, which are available on all of EXFO's remote fiber testing and monitoring microservices (not all exposed, but present by design). These APIs are the same ones used by customers (web, mobile), so this single backend system serves all users, whether they are EXFO, proprietary, or third-party applications. This approach allows seamless integration without the need for an additional layer between the main database and the end customer, ensuring consistency and real-time updates when objects are added or edited through the EXFO FMS UI or API. For example, if one or more terminals are added to an existing route via API, they would be directly available to a field technician using EXFO's mobile app.

Some remote fiber test systems still rely on a desktop/thick client to manage GIS data or require separate physical or VM hosts for each system function or service (e.g., AAA, test functions, GIS, alerting, web server). In contrast, a cloud-native solution uses microservices running as containers on a single Linux host (in most cases) or across multiple nodes, all managed through a single-server application.

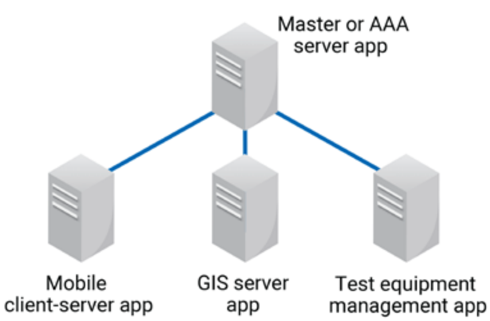


Figure 8: Traditional RFTS management system.

Figure 9: EXFO FMS (single cloud-native server app with 2 nodes, for large systems).

EXFO publishes an API guide and a web-accessible description of all its public APIs. Below is an example of one workflow supported by one of the microservices/endpoints:

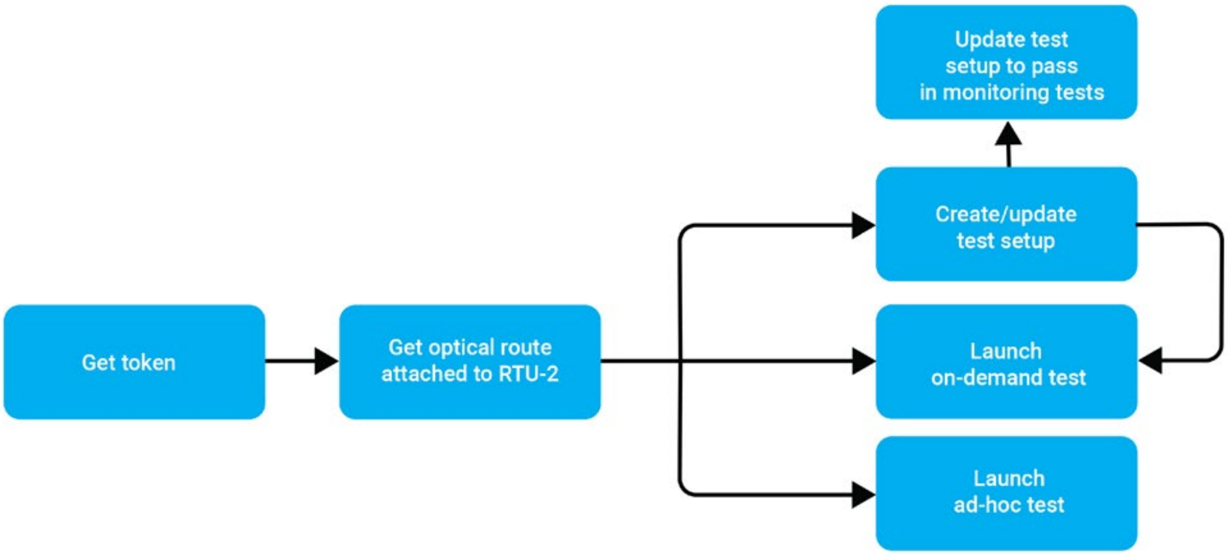


Figure 10: Use case – How to set up and run an iOLM test on P2P optical route (P2P type of route in FMS).

3.2 Flexible deployment options to meet your IT requirements

EXFO's Remote Fiber Testing and Monitoring provides flexible deployment options, from serverless setups to centralized management via FMS. This document focuses on scenarios using Test Heads managed through FMS centralized management. For details on serverless solutions, refer to "EXFO's Serverless Remote OTDR Solution Overview."

	Test Agent 2.0	Connected Test Agent (API)	FMS-in-a-Box	FMS-as-a-Service	Customer managed FMS hosting
Highlights	Test head UI accessible locally or remotely (no FMS)	Test heads configured as client API hardware (no FMS)	FMS deployed on pre-installed dedicated server	FMS deployment in the EXFO managed cloud	FMS deployed on-premises or in a customer-managed cloud
Applications supported	P2P ad-hoc test and deviation analysis	P2P ad-hoc test and deviation analysis	P2P test and monitoring	P2P test and monitoring: PON build, connect and assure	P2P test and monitoring: PON build, connect and assure
Key selection driver	• Need OTDR capability for reactive maintenance (no monitoring/prevention) • No connectivity on RTU site (can operate as a closed system) • Low complexity	• Need OTDR capability for direct integration with customer OSS (API) • Complete end-to-end control • Scalability	• No connectivity on RTU site (can operate as a closed system) • Complete end-to-end control with no IT maintenance • Autonomous operation • Simpler deployment than on-premises	• No IT skills required • Free up internal IT resources • Faster deployment • Scalability • FMS integration with existing OSS	• Complete end-to-end control • Can work in air-gapped environments • Scalability • FMS integration with existing OSS
IT install skills required	Low (IP address config)	Low (IP address config)	Mid (Linux CLI)	Low	High
Test-acquisition mode	OTDR + iOLM	OTDR + iOLM	iOLM (+ ad hoc OTDR)	iOLM (+ ad hoc OTDR)	iOLM (+ ad hoc OTDR)
Mobile app support	NO	NO	NO	YES	YES
Local switch support	YES	YES	YES	YES	YES
Remote switch support	NO	NO	NO	YES	YES
Multiple test units centralized management	NO (access one at a time)	YES - Customer responsibility from their centralized solution	NO (One per server)	YES (up to 1,000 in FMS)	YES (up to 1,000 in FMS)
Software - commercial model	No software fee	No software fee. API starter pack (for integration)	Perpetual license included	Annual subscription	Perpetual license

3.2.1 Customer-managed FMS hosting

In this traditional approach, the customer is responsible for providing the IT infrastructure (on-premises server or customer-managed cloud) on which the FMS is deployed. See section "3.3.1 FMS software and minimum requirements" for details regarding IT requirements.

3.2.1.1 Advantages of customer-managed FMS hosting

- **Full end-to-end control:** Retain complete control over your systems, ensuring your specific operational needs are met.
- **Air-gapped operation:** Capable of functioning in air-gapped environments, enhancing security and isolation.
- **Scalability:** Easily adapts to growing demands, allowing system to expand smoothly.
- **Seamless OSS integration:** Compatible with existing OSS systems, enabling smooth and efficient integration into current infrastructure, leveraging FMS's extensive API set.

3.2.2 FMS-as-a-Service

EXFO can host the FMS central management software on a cloud instance, eliminating the need to rely on your internal IT resources and bandwidth. In this setup, responsibilities are divided as follows:

EXFO	Customer
• Orders cloud instance from cloud provider (1 dedicated instance per customer) • Deploys FMS with full feature set (FMS, GIS, mobile app) on cloud instance • Connects first test head to FMS and creates Admin user • Trains customer team • Monitors availability of cloud instance and performs FMS upgrades	• Acquires and physically installs test hardware (e.g., remote test units, optical switches, passive components) • Ensures outbound connectivity is available at remote test unit locations • Subscribes to renewable annual plan (based on number of remote test units) • Operates the FMS: creates users, topologies and tests, manages alerts and results

3.2.2.1 Key advantages of FMS-as-a-Service

- **No IT expertise needed:** Eliminate the need for specialized IT skills, simplifying management and operation.
- **Optimize internal resources:** Free up your internal infrastructure resources and IT team, reducing operational costs.
- **Accelerate deployment:** Ensure rapid system readiness, avoiding internal bottlenecks.
- **Scale easily:** Adapt to growing demands, allowing your system to expand smoothly.
- **Seamless integration:** Enable smooth and efficient integration with existing OSS systems, leveraging FMS's extensive API set.

3.2.3 FMS-in-a-Box

FMS-in-a-box is a COTS server with a pre-configured FMS installed. It is stacked on an RTU-2 or OTH-7000 (1 for 1) and provides a customized FMS for P2P fiber monitoring applications.

Figure 11: An OTH-7000 with an FMS-in-a-Box server.

Available in 1x SSD (no RAID) or 2x SSD of same size with RAID type of drive redundancy for higher availability in case of disk failure. Both configurations with large HDD for database back-ups in order to be able to restore system in case of data corruption or other bad manipulation to the active databases.

3.2.3.1 Why choose FMS-in-a-box over a centralized approach?

- **No need for connectivity at the RTU site:** Operates efficiently as a standalone system, making connectivity optional.
- **Comprehensive control:** Maintain full end-to-end management without the hassle of ongoing IT maintenance.
- **Autonomous operation:** Run independently, ensuring reliable performance with minimal intervention.
- **Simplified deployment:** Deploy more easily than traditional on-premises solutions, streamlining the setup process.

3.2.3.2 Advantages of FMS-in-a-Box over traditional RFTS standalone solutions

- **Superior computing performance:** Support advanced features such as long-term trending dashboards, a built-in full GIS system for comprehensive geopath route creation and management (see Automated and simplified OTDR fault geomapping (GIS) for further details), and robust data backup and recovery capabilities.
- **Sustained software evolution:** Ensure ongoing maintenance and feature enhancements aligned with EXFO's centralized FMS software, providing long-term reliability.
- **Effortless OTDR replacement:** Easily replace failed OTDRs and reconnect seamlessly to existing data, minimizing downtime.

FMS-in-a-box is compatible with RTU-2, OTH-7000 and RTUe-9120. It can be operated in connected or non-connected scenarios.

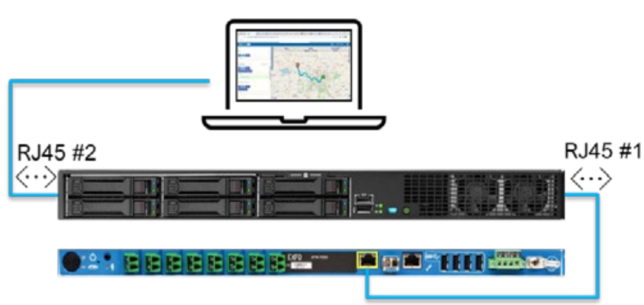


Figure 12: Non-connected scenario - Direct connection on test unit.

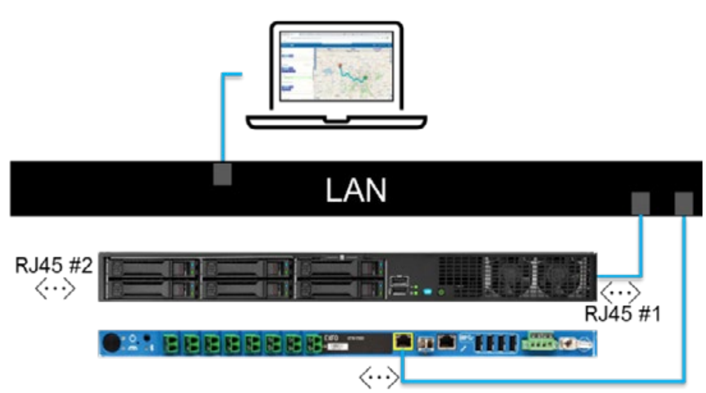


Figure 13: Connected scenario - Remote access and LAN connection.

3.3 Key functions and features of FMS

The Fiber Management System (FMS) functions as the Element Management System (EMS) for all test units configured as clients within a client-server architecture. Communication between the FMS and test units occurs through event-based interactions, with FMS managing the subscribers for each queue opened by the test units. This approach ensures scalability and efficient load distribution. During large-scale or targeted firmware updates, the test units securely access the necessary files on the server using HTTPS (port 443), acting as fully authorized clients. The figure below illustrates the simplified system architecture.

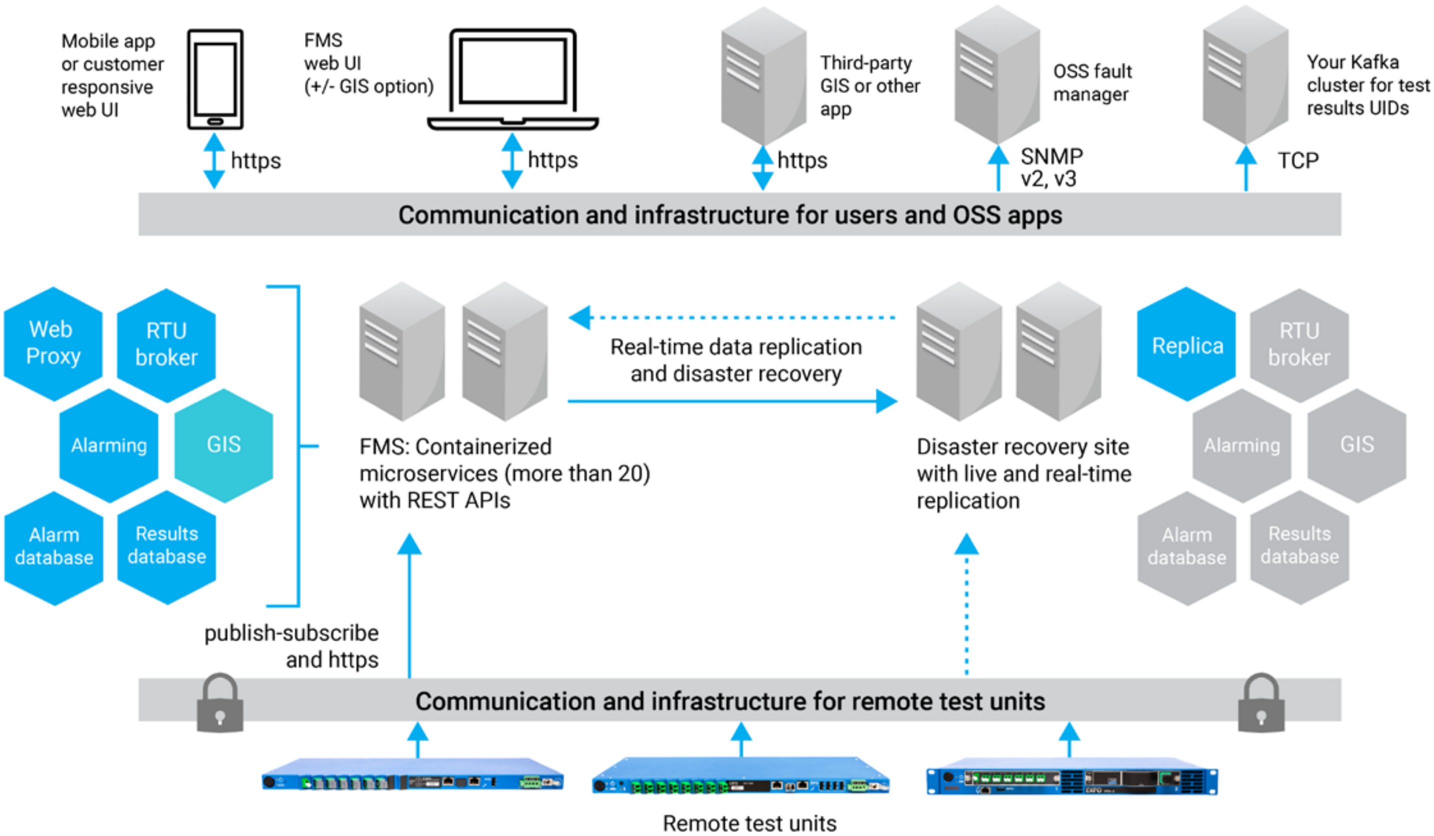


Figure 14: FMS architecture.

The *FMS* provides numerous functions across the following areas:

- Central user and client management i.e., authentication, authorization and auditing (AAA) with connectivity to various identify providers.
- User access scope definition: restrict access and visibility to designated regions or sub-regions only.
- Routing to the right RTU of all ad hoc and on-demand test requests; unique entry point for UIs and OSS, external app.
- Result viewing (OTDR traces, tables, iOLM icon-based views, etc.).
- Test equipment registration mechanism.
- Test equipment listing and status along with extractable report.
- Test equipment firmware updates; massively up to 100 units per day or selectively a few units at a time.
- Tasks to automate batch of actions performed in sequence (e.g., baseline creation on N routes, ad hoc test or test-on-demand on N routes, link N routes to RTU).
- Build and connect centralized test configuration management including pass/fail criteria.

– Operational views to aggregate Build and Connect data.
– Monitoring centralized test configuration management, including monitoring thresholds.
– Operational views to aggregate Monitoring data.
– Physical-Optical correlation tool to improve fault location and demarcation.
– Alarm creation and lifecycle management based on configurable rules with reporting.
– Notifications via email to domains.
– Status view over network topology by region/domain/diagram.
– Equipment and server health supervision with integrated dashboards.
– Real-time fiber health metrics from an open-source time series interface into dashboards (see Figure 15).
– Fault mapping into an optional GIS fully integrated with the base web UI.
– Back-ups, real-time database and files replication with disaster recovery capability.
– SNMP notifications mapped to alarms.

Figure 15: Platforms (RTU) metrics are captured in real time, providing comprehensive health checks to all test units.

3.3.1 Supported intelligent Optical Link Mapper (iOLM) tests

Driven by iOLM, EXFO's remote fiber testing and monitoring extends beyond basic OTDR troubleshooting triggered via remote console. Below is a summary of OTDR-based tests supported for point-to-point (P2P) and point-to-multipoint (P2MP) networks, such as passive optical networks (PONs). All tests and configuration changes can be accessed via a RESTful endpoint: [Base URL: /api/topology]. Ad hoc OTDR testing with customizable parameters is available for all routes through the FMS (EMS) web UI and the API, delivering results in standard .sor format.

By default, all tests are stored centrally for reporting and further processing. Each test is also logged in an open-source time-series database and can feed time-series dashboard tools.

There are three test priority levels on each iOLM unit. If a higher-priority test is triggered during an ongoing lower-priority test, the lower-priority test is postponed to allow the higher-priority one to run immediately. If a high-priority test is already running and a test with the same priority is launched, a busy message will appear. Queueing is supported for multiple second-priority tests on different routes/ports, running on a first-in, first-out basis. Once all tests are finished, a "test complete" message will appear[3].

P2P FIBERS – iOLM TESTS SUPPORTED IN TABLE BELOW

Test types	Test description
RTU provisioning (mobile app) P1	• Pass/Fail (P/F) analysis on limited range • Switch detection • Quick test
Test as you build (ad hoc) (mobile app) P1	• P/F analysis on all link elements • Switch detection • Link loss, ORL, length • Detailed test[4]
Baseline test prior to launch monitoring P2	• P/F analysis on all link elements • Switch detection • WDM (TAM) detection • Detailed test[4]
Troubleshoot on-demand (TOD), automated fault detection P2	• Automatically compares each section and event loss part of the baseline to detect and report an actual change • Detailed test[4]
Proactive monitoring, 24/7 testing P3	• Round robin and continuous testing of a preselected number of routes/ports • Alarm is created if a deviation meets a series of configurable alert rules

(mobile phone icon) = Also available from mobile app

3 Detailed tests leverage iOLM capabilities for optimal link evaluation, measuring link loss, ORL, and length and identifying and assessing individual events, before providing helpful diagnosis with recommended corrective actions.

P2MP (PONS) – iOLM TESTS SUPPORTED

Test types	Test description
RTU provisioning P1	• P/F analysis on limited range • Switch detection • Quick test
Test as you build (ad hoc) P1	F1/Spine test: • P/F analysis • Switch detection • Link loss, ORL, length • Detailed test Remote F2 test (via F1 lead fiber): • P/F analysis on remote fiber after F1 + cord leads • F2 fiber link loss, ORL, length • Detailed test through calibrated lead fiber F2/F3 E2E test with HRD reflector for continuity, loss, distance from splitter: • P/F for E2E loss against calculated loss budget (dynamic limit) • Fast 5-second test
Baseline test prior to launch monitoring P2	• P/F analysis on all F1/spine link elements • Switch detection • WDM (TAM) detection • Detailed test—any small change can be detected during troubleshooting or monitoring
Troubleshoot on-demand (TOD), automated fault detection P2	On demand test for: • Verifying F1, F2, F3 fibers (as seen from OLT side) • Detailed test; automatically compares each section and event loss part of the baseline to detect and report any change • Generating alarms if any change exceeds customizable threshold Additional capability with HRD reflectors installed on the PON: • Faster on-demand test (approx. 10 seconds) to verify all end points in a single test • Discriminate individual status/health of each PON legs
Proactive monitoring, 24/7 testing P3	Round robin and continuous testing of a preselected number of routes/ports with HRD installed on the PON for: • Faster scan test (approx. 10 seconds) to verify all end points in a single test • Discriminate individual status/health of each PON legs • Generating alarms if any E2E link loss exceeds customizable threshold • Further on-demand troubleshooting to narrow down root cause analysis

= Also available from mobile app

3.3.2 Mobile Application

EXFO RFTM Mobile application enables a single technician with a mobile phone to run a specialized or purposely built OTDR test in the form of an iOLM Optimode. From the mobile application, the field technician can first launch a fiber identification test to ensure that it is the right fiber. This function works by injecting a tone into a given route, for a predetermined time to avoid blocking other users. The tone can then be picked up by the technician in the field with a handheld instrument[4]. Thereafter, four Optimode tests are available to verify the fiber under test. Standard ad hoc iOLM test: the complete fiber link from the OTDR port to the endpoint(s) is the fiber under test (FUT). Remote iOLM test: the FUT is a specific section of the link further out from the OTDR. In this scenario, iOLM leverages an existing fiber infrastructure as an extended launch fiber that will then be connected on a remote fiber span. This launch fiber is calibrated to be excluded from measurement analysis and pass/fail, but still considered to optimize the test parameters according to its length and loss. The same launch fiber can be re-used multiple times to connect to N remote FUTs and characterize them.

Figure 16: Tone activation for fiber identification.

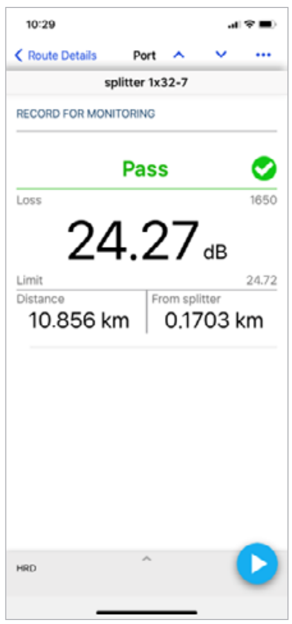


Figure 17: HRD test result on a live PON.

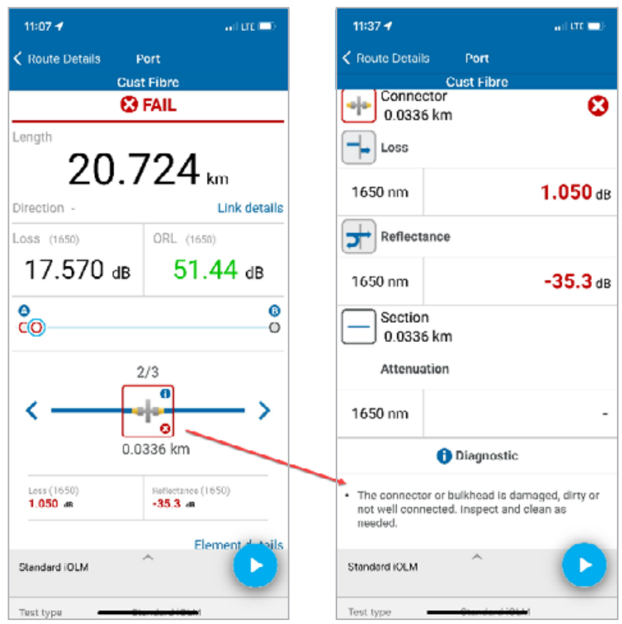


Figure 18: Standard ad hoc iOLM result, with diagnostic and guidance for field technician.

4 A live fiber detector (LFD) can be used to identify the tone within a fiber jumper without disconnecting any fiber, or tone can be picked out of an open fiber connector with an optical power detector device (e.g., an optical fiber multimeter or an optical power meter).

As this application is iOLM-based, it is compatible with the RTU-2 and the OTH-7000 for both P2P and P2MP (PON) fiber topologies. Available for download on Apple and Google app stores, it connects easily and securely to your FMS application.

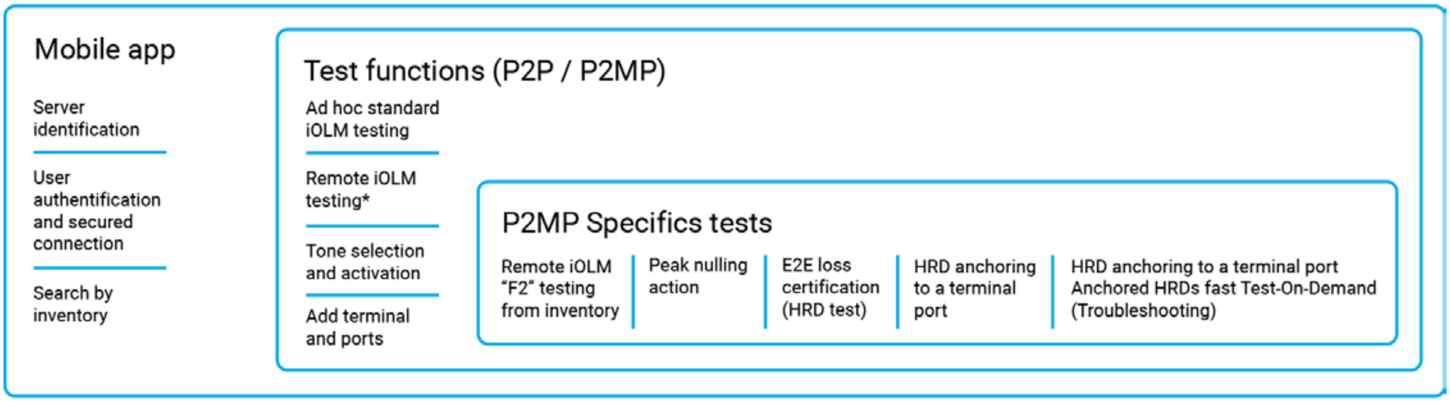


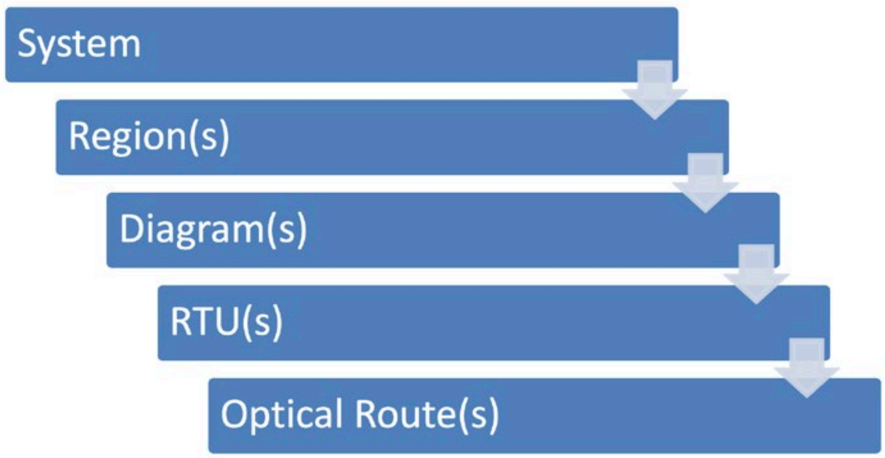
Figure 19: Summary of mobile app functions

EXFO RFTM Mobile application is a true mobile application, fit-for-purpose, centered on field technician reality. A native mobile application, it offers significantly greater security compared to mobile web responsive interfaces (See details on security in 3.3.9 Cybersecurity attributes).

3.3.3 Operational views

The topology can be explored through two operational views: the **Build & Connect** view (for fiber deployment) or the **Monitoring** view (for fiber network monitoring).

Navigation is presented in tree mode, offering drill-down capability according to the following hierarchy:



3.3.3.1 Build & Connect operational views

Measurement data collected during build validation is integrated into operational views, offering visibility into both build progress and installation quality from a regional overview, with the ability to drill down to specific terminals. These views are enriched by contextual KPIs allowing stakeholders to track deployment progress against the planned inventory, ensuring that the project stays on course. Installation quality can be verified, recorded, and assessed, providing a clear picture of how well the build meets standards.

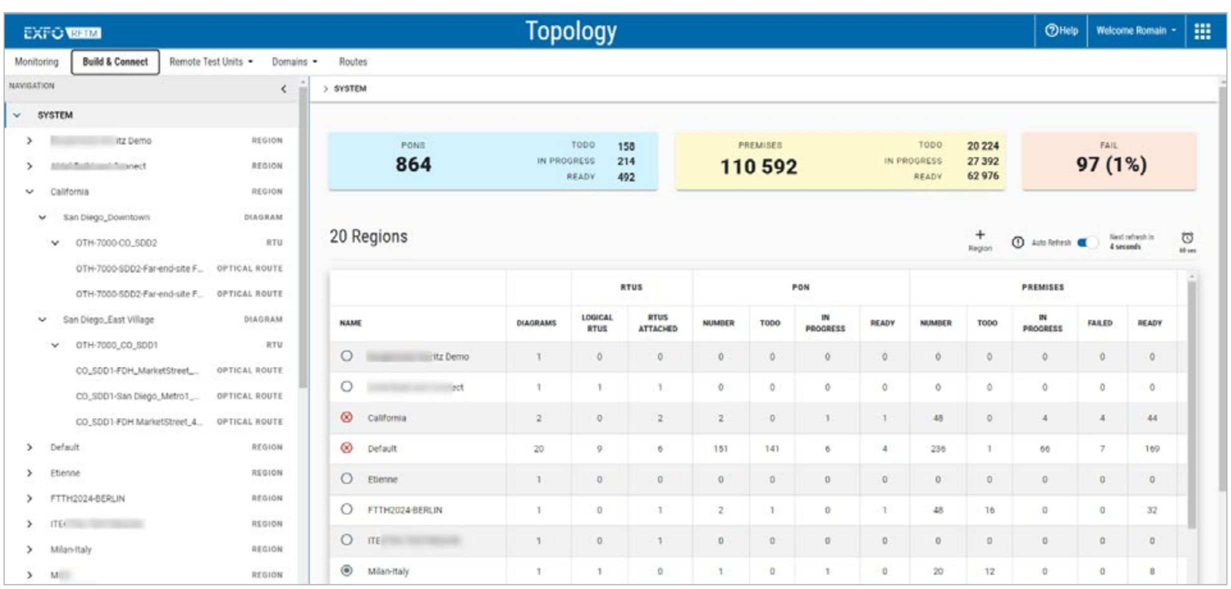


Figure 20: Build & Connect Operational view (top of hierarchy)

The centralized test data enables the identification of trends at multiple levels, offering actionable insights that can guide decision-making. Detailed insights are also available at a micro level, such as at the drop terminal and port levels, allowing for the monitoring of service readiness in specific neighborhoods.

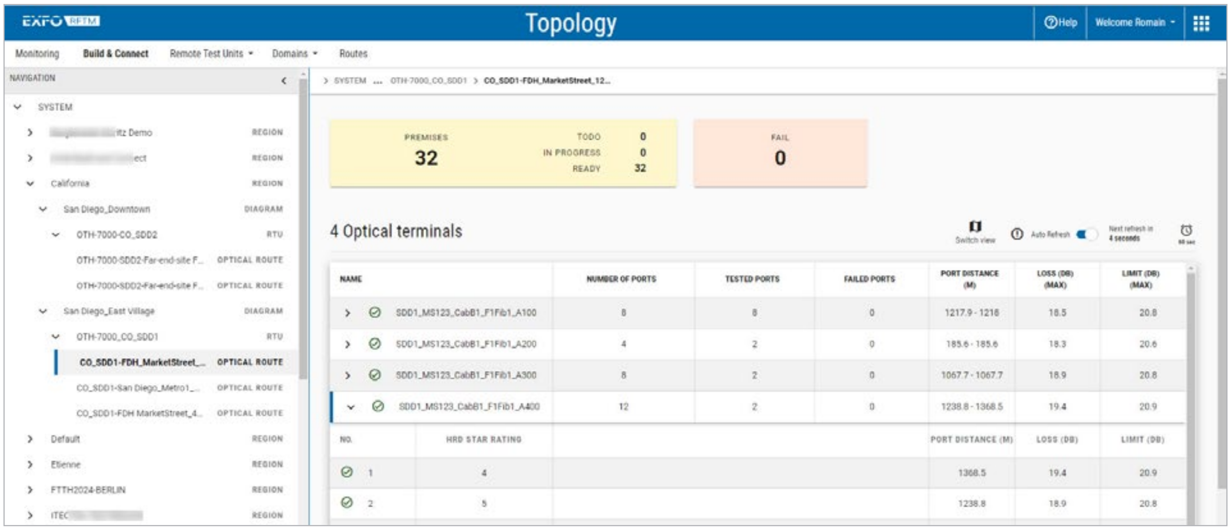


Figure 21: Build & Connect operational view (at the level of the optical terminal and ports)

Additionally, a direct access to aggregated data through secured SQL is available as add-on options. It enables to share this aggregated data with third-party systems, facilitating broader integration and analysis across different platforms.

3.3.3.2 Monitoring operational views

Monitoring operational views provide near real-time insights into the status of the fiber network, starting from a regional overview and allowing detailed drill-down navigation to specific optical routes. These views are enhanced with contextual KPIs, offering a 360-degree perspective on network health, monitoring coverage, and alarms related to fiber integrity or Remote Test Unit statuses. The data is aggregated from the microservices architecture, ensuring accurate and up-to-date information.

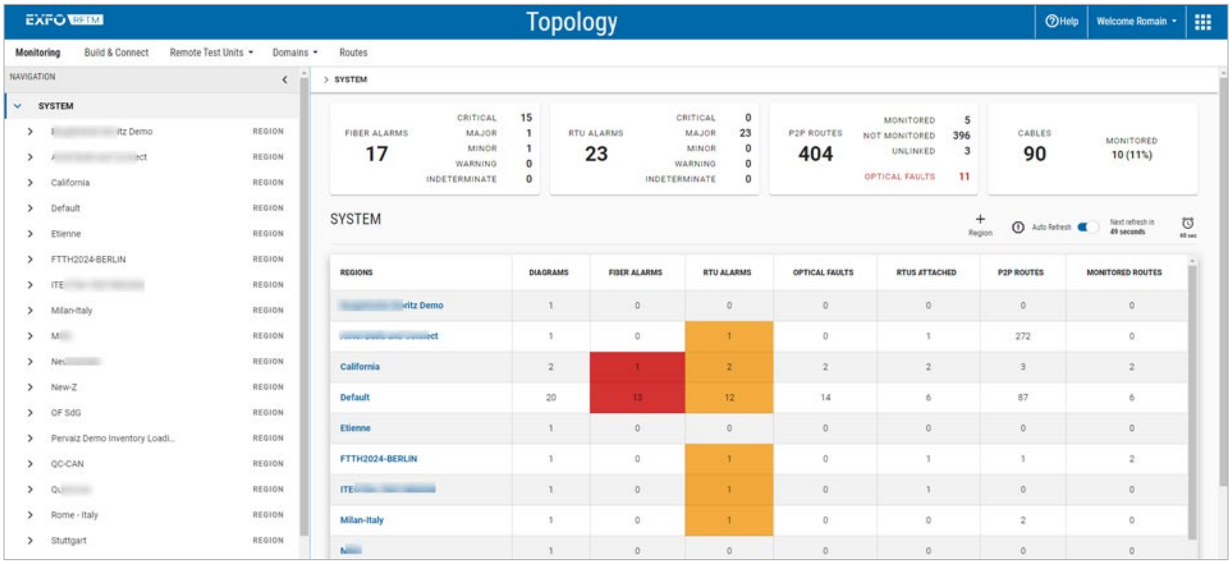


Figure 22: Monitoring operational view (Top of hierarchy)

3.3.4 Tasks

Tasks enable users to automate and batch multiple actions, improving efficiency and reducing manual effort. Available bulk operations include:

Optical test	Route maintenance
• Launch AdHoc • Launch Tests on Demand • Create New Baseline • Update Baseline	• Link to RTU port (link logical RTU to physical RTU and its ports - when a physical RTU is repurposed) • Unlink from RTU • Change Monitoring status (enable/disable)

Results from bulk operations are presented in a Tasks dashboard.

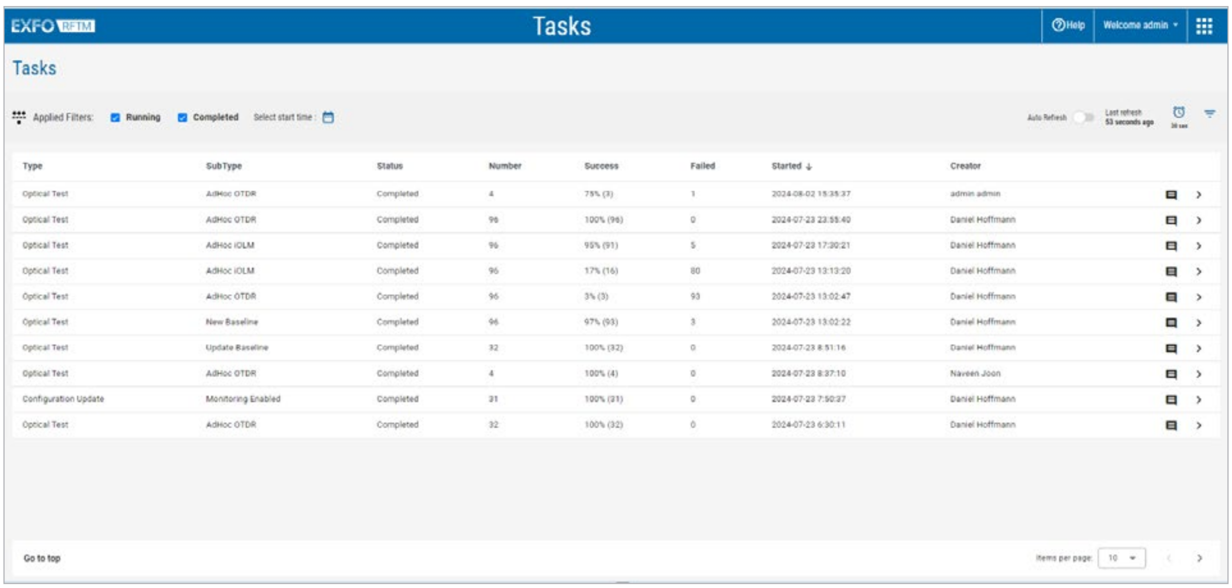


Figure 23: Tasks dashboard - List of tasks with their individual statuses.

Key features of the Tasks dashboard include:

- Auto-refresh and real-time status updates.
- Summarized test results and access to individual outcomes.
- Batch download of results and .zip file extraction.
- Progress tracking and detailed failure reports.
- Dedicated reporting for each task.

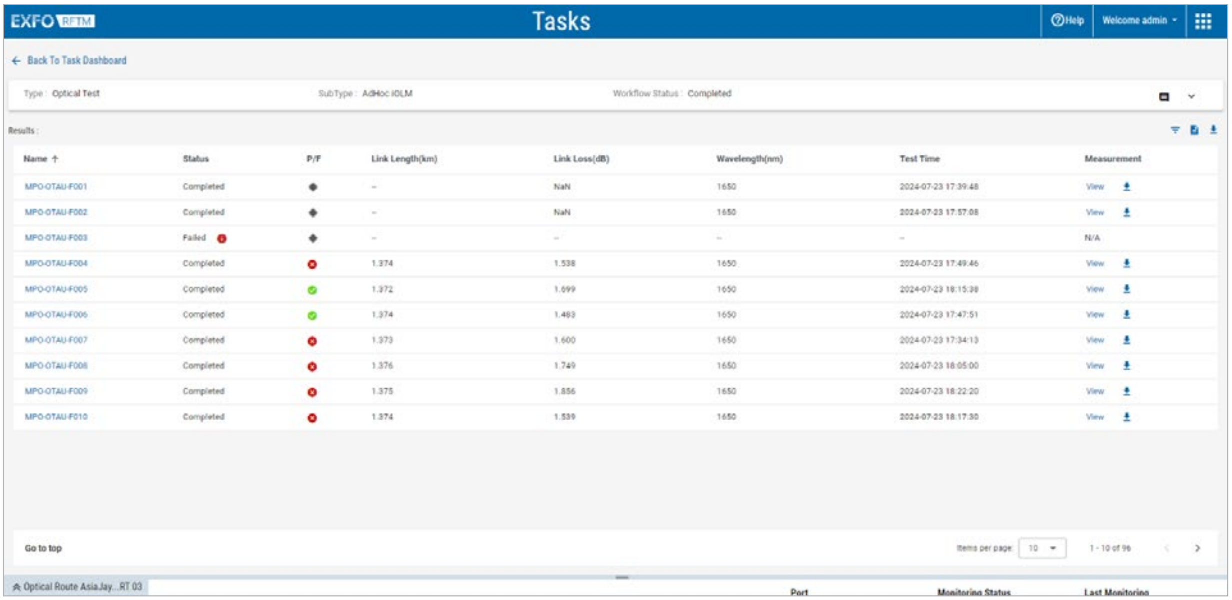


Figure 24: Detailed view of a specific task status (list of individual actions with their results and link to related files available for download).

3.3.5 User access limitation

User access can be restricted to specific portions of the network (diagrams), ensuring that users only see data relative to optical routes and terminals relevant to their role. This targeted approach not only enhances focus by minimizing distractions but also helps preserve the confidentiality of sensitive information by limiting access to specific and aggregated data those with the appropriate authorization. It also prevents any edition on diagram out of a user scope.

If a user is granted access to only certain diagram(s), this is reflected in both the FMS WebUI and the EXFO RFTM Mobile application.

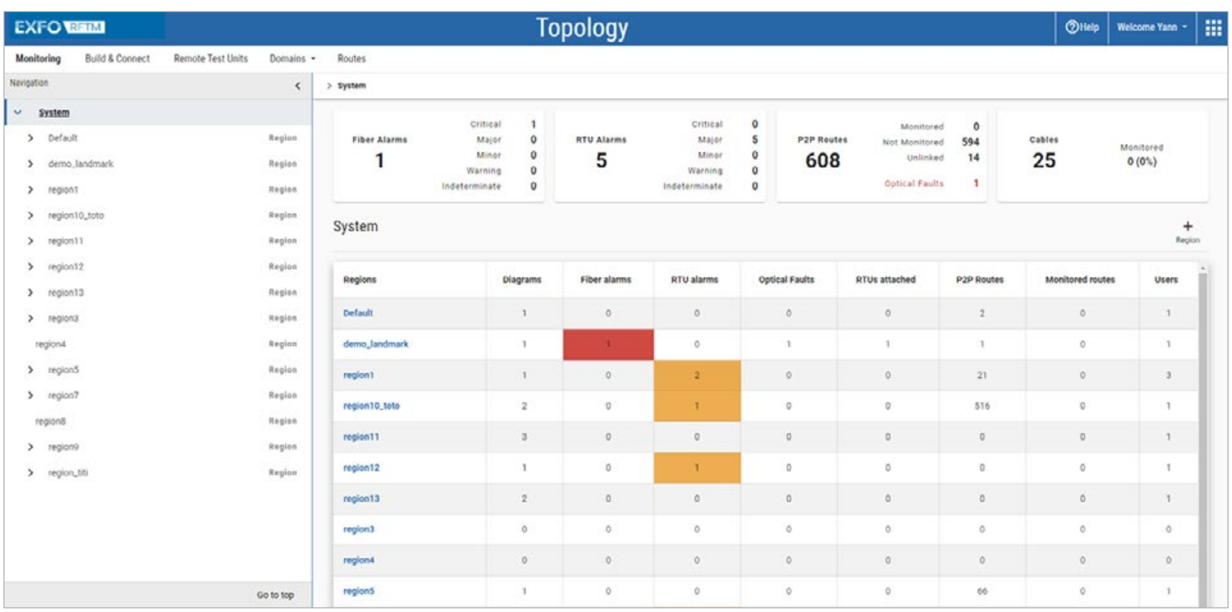


Figure 25: Example of view for user with full access to complete system.

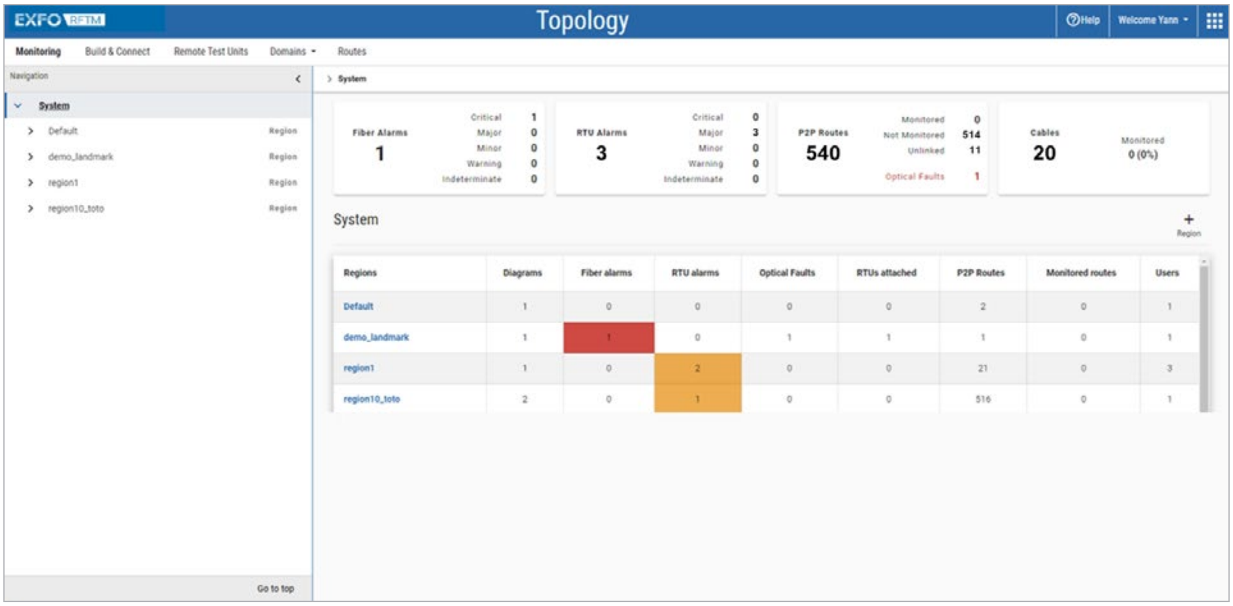


Figure 26: Example of view for a user with limited access (restricted to specific diagrams).

3.3.6 RTU separation: logical vs. physical

Separating the logical Remote Test Unit (RTU) from the physical RTU in an Element Management System (EMS) like EXFO FMS provides a valuable layer of abstraction for efficient Remote Fiber Test & Monitoring (RFTM) management.

This approach offers several benefits:

1. **Pre-configuration flexibility:** Optical routes and network equipment can be set up in advance on the logical RTU, allowing seamless and faster readiness when the physical RTU is available.
2. **Streamlined (re)-deployment:** Once a physical RTU is associated with its logical RTU at a site, it is ready for testing immediately. This association also allows for efficient reuse of physical RTUs across multiple sites as each RTU can be subsequently associated to various logical RTUs. If a physical RTU returns to a previous site(tested by this specific RTU or another), it can reconnect instantly to all existing routes and associated data. For use cases like Fiber QA during construction, decoupling enables an efficient "build and lift" approach.
3. **Minimized downtime:** If a physical RTU fails or is relocated, its logical counterpart ensures that all configurations and historical data remain intact. This enables rapid recovery or reassignment to a new physical RTU with minimal downtime.
4. **Automation and integration:** The abstraction enables upstream inventory creation in NMS/GIS to centralize the inventory management systems and supports automation processes for remote fiber testing, reducing manual intervention.

In essence, separating the logical RTU from the physical RTU not only increases operational flexibility and efficiency but also optimizes resource utilization and system resiliency in fiber network testing.

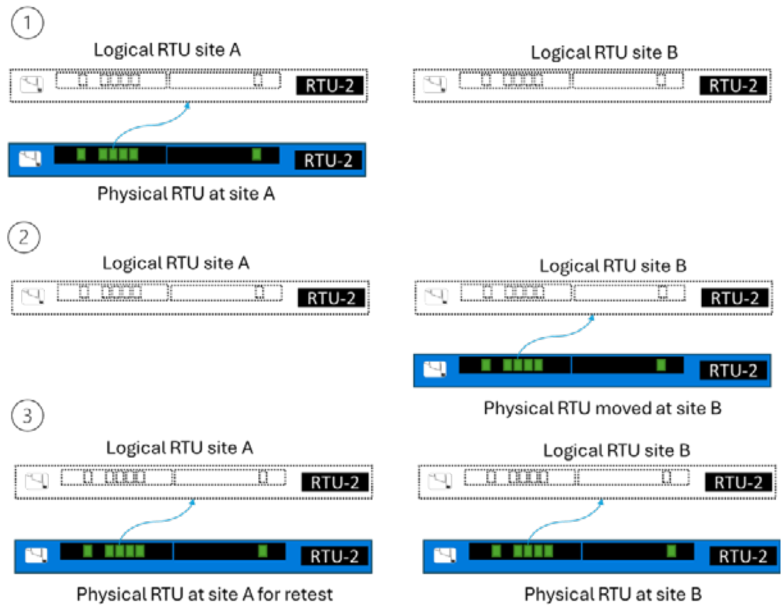


Figure 27: Flexibility to associate physical RTUs to Logical RTUs for efficient "build and lift" scenarios.

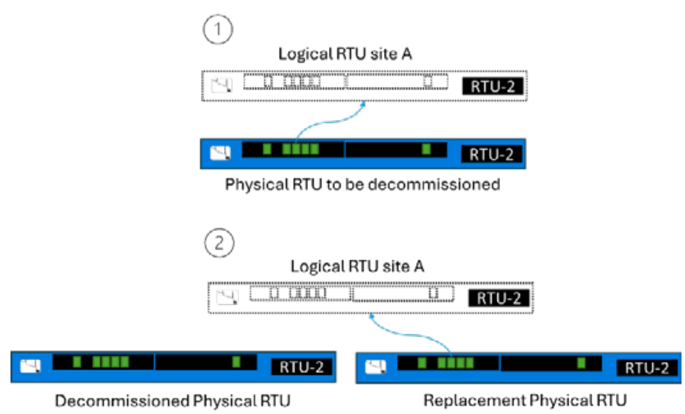


Figure 28: Minimizing downtime when replacing a physical RTU.

3.3.7 Optical-to-Physical distances correlation

Determining the exact location of a fault based on optical measurements can be challenging. While knowing the OTDR distance to a fault is valuable, the optical trace showing a fault at 35 km from the test access point rarely corresponds precisely to the geographic location along the cable path. This discrepancy can be significant, sometimes spanning hundreds of meters or even kilometers, and can severely slow down repair processes, increasing the time required to pinpoint the exact fault location in the field. Exact fault location is often critical in determining repair responsibilities, and lack of visibility into the precise demarcation can lead to delays and unnecessary conflict between stakeholders.

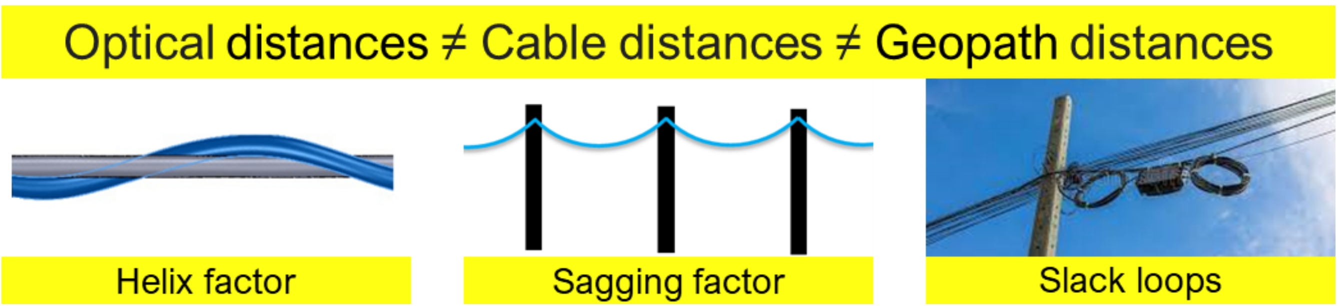
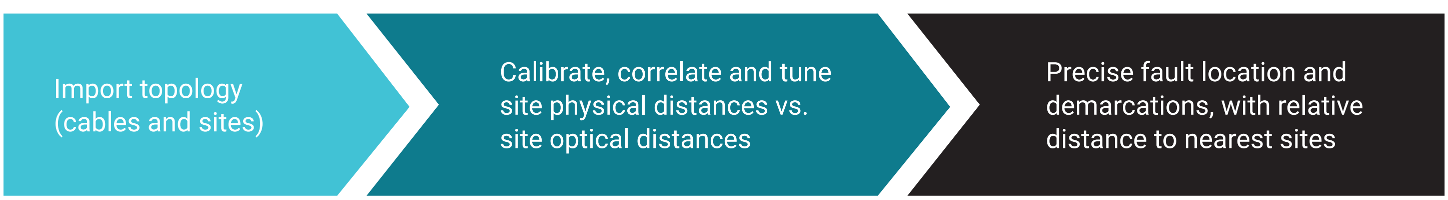


Figure 29: Factors generating discrepancies between optical distances and geographical distances / location

This gap between optical and geographic distances arises from factors such as the helix factor, cable sag, and slack loops, which are unevenly distributed along the fiber optic cable. These variations make it difficult to accurately match an optical distance to a specific map location, even when global scaling (adjusting the total optical length to match the total physical length) is applied. In fact, these variation factors differ from segment to segment, and while helix and sag factors are distributed throughout the link, slack loops are not. As a result, the global scaling method alone leaves significant offsets when attempting to accurately geolocate an event.

To bridge this gap, EXFO's physical-optical correlation process starts by importing your cable network’s topology and site locations. This enables an initial global scaling adjustment, followed by fine-tuned alignment between optical events and physical locations. This alignment can then be applied to all fibers within the cable, ensuring more accurate fault location correlation.

- **Helix factor:** Fiber cables are often installed with a slight twist or helix to reduce stress and prevent damage during installation. This twisting adds to the optical length vs cable length.
- **Sagging factor:** Overhead cables tend to sag between poles or supports. This sagging increases the actual length of the fiber compared to the straight-line physical distance.
- **Slack loops:** To allow for future repairs or adjustments, extra fiber is often coiled at various points, which adds additional length to the optical path compared to the physical distance.



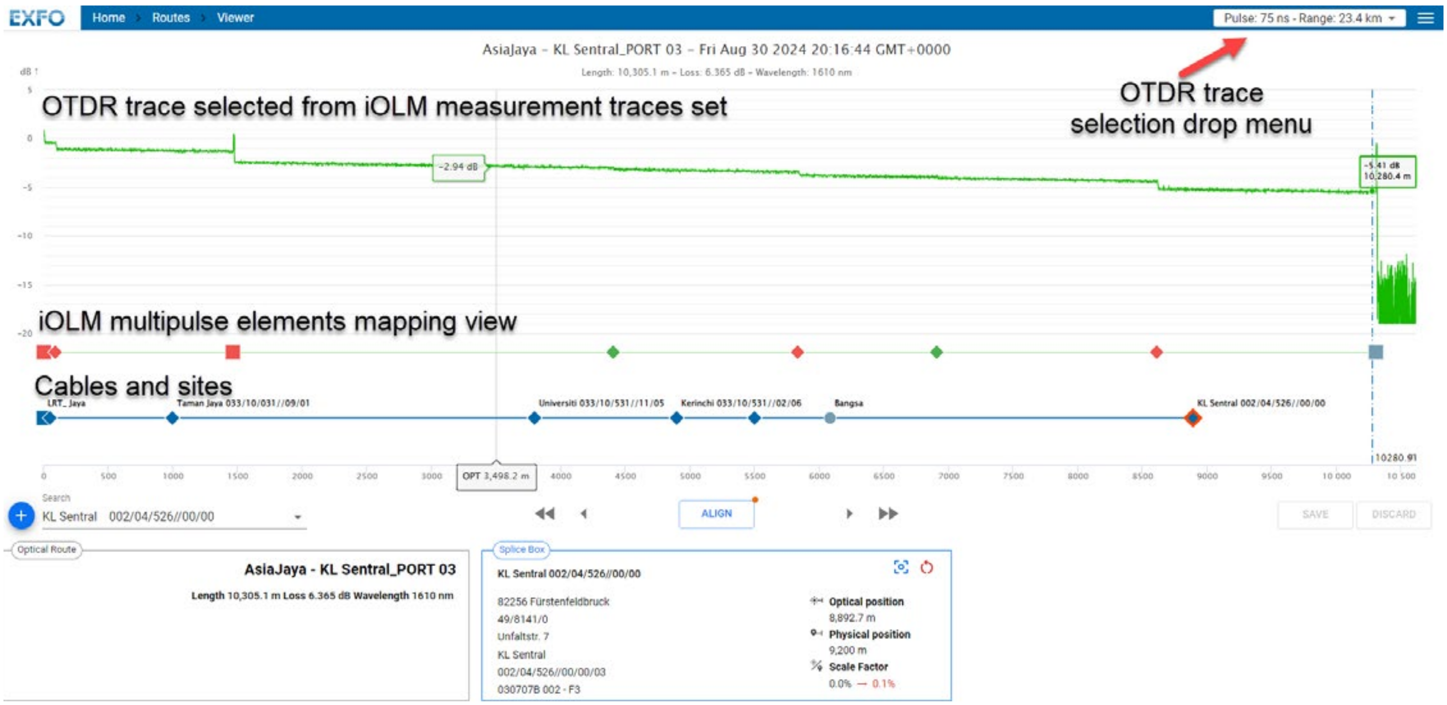


Figure 30: Unified view with OTDR traces, events as detected by iOLM, and topology (cables and sites) before correlation.

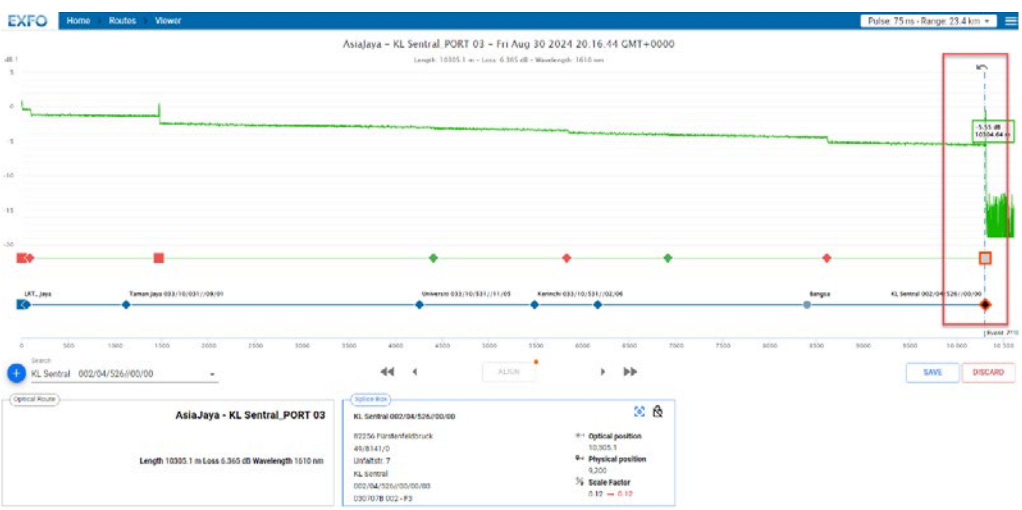


Figure 31: Unified view with OTDR traces, events as detected by iOLM, and topology (cables and sites) after global scaling.

Figure 32: Site alignment.

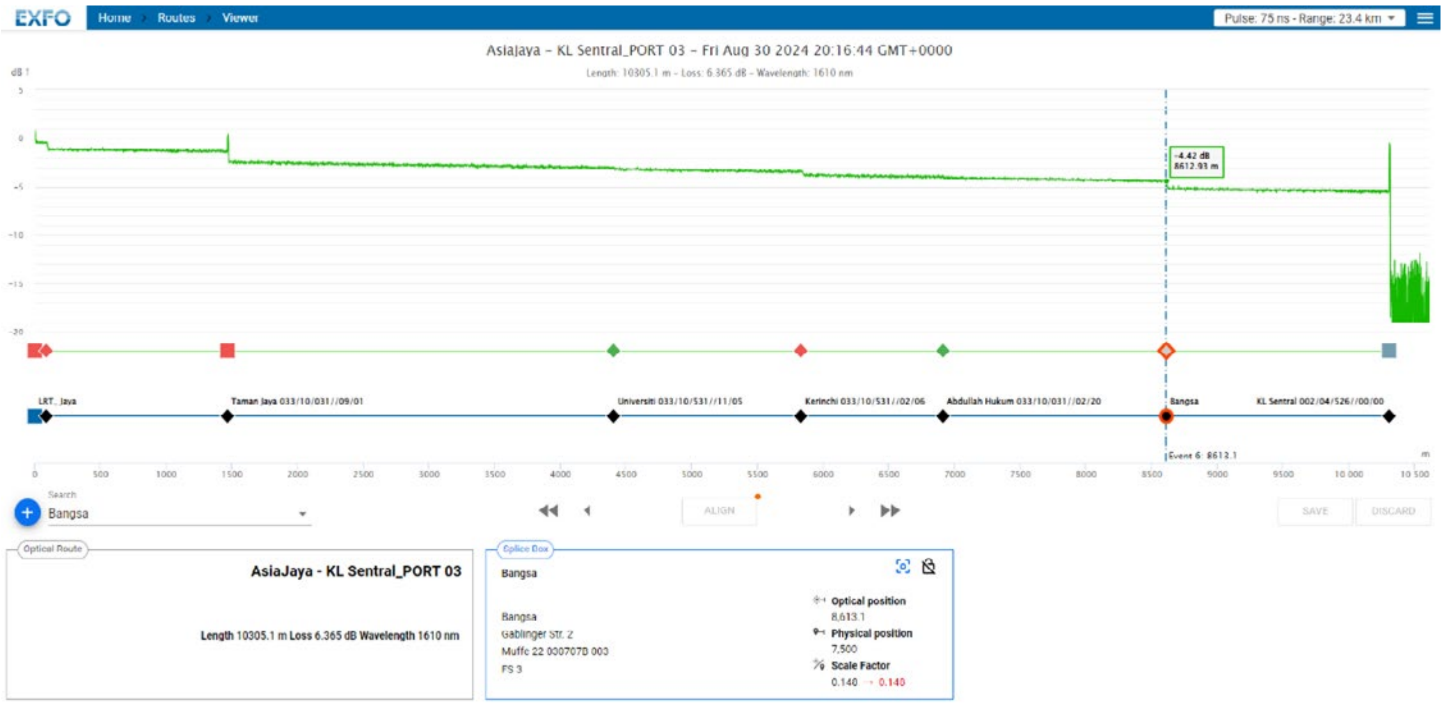


Figure 33: Unified view with OTDR traces, events as detected by iOLM, and topology (cables and sites) after complete correlation.

Once this alignment is properly recorded in the inventory, any fault events detected during monitoring or other testing can be accurately and easily located-even without a GIS. For example, if a fault is identified as being 50 meters after a cabinet or a specific splice enclosure, you can quickly pinpoint the exact location of the problem and send the right team to fix it, rather than searching for it or wasting time assigning repair responsibility.

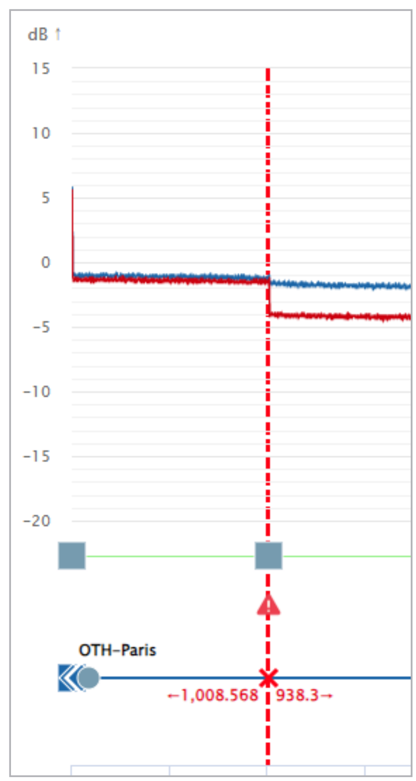


Figure 34: Fault identified with relative position from and to next sites.

3.3.8 Automated and simplified OTDR fault geomapping (GIS)

The GIS feature is a software option (FMS-GIS option) that provides additional container images, which when installed, enable further functions and features:

- Draw cable routes and interconnecting sites directly over the background map from any device on a web browser (no dedicated workstation application required) by any authorized user (Figure 35).
- Import optic cable routes in batch from georeferenced datasets (.kml and .kmz) and edit them locally as needed from a web browser.
- Use background maps either from online or offline services.
- View fiber fault locations at the street level.
- Email notification with mapping information.
- Support diagrams to scale from monitoring few critical sites to countrywide topologies. A diagram regroups a customer-defined batch of monitored optical routes together (e.g., a specific region) to allow users to focus only on routes relevant to their needs and navigate from one to another. Optical routes of diagrams can be automatically organized into schematic topological views: Radial view, Organic view, Orthogonal view (Figure 36).

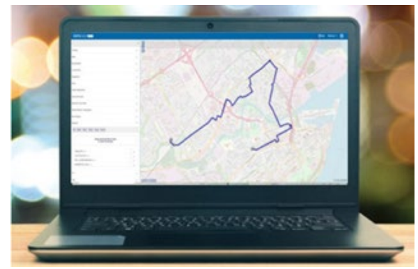


Figure 35: Import, draw and edit routes from any workstation through web browser.

Within seconds, FMS-GIS automatically converts optical length fault measurement into a physical location on a network map. The web-based application integrates background maps (from internal or public clouds), which makes the drawing and setup of new fiber routes easier and smarter. The feature is compatible with all EXFO remote test units, including the FG-750, RTU-2, and OTH-7000.

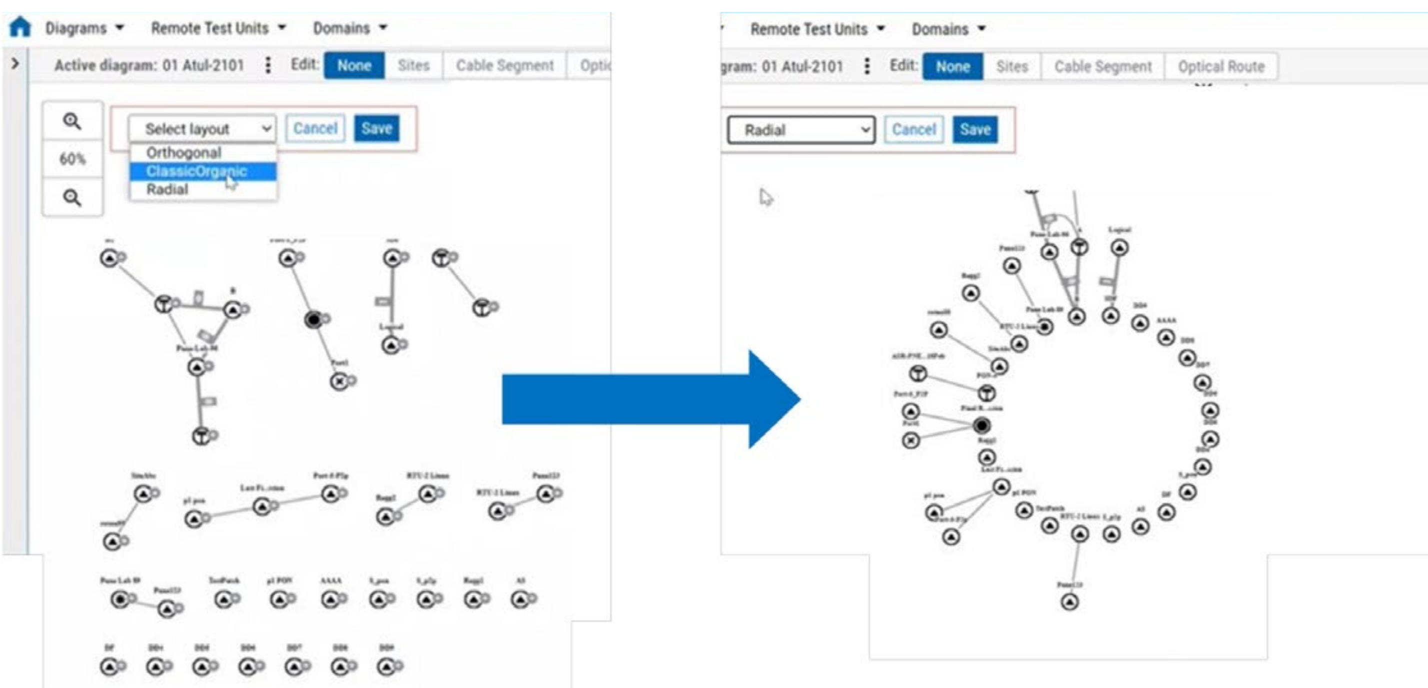


Figure 36: Organizing elements of a diagram in radial view within a single action.

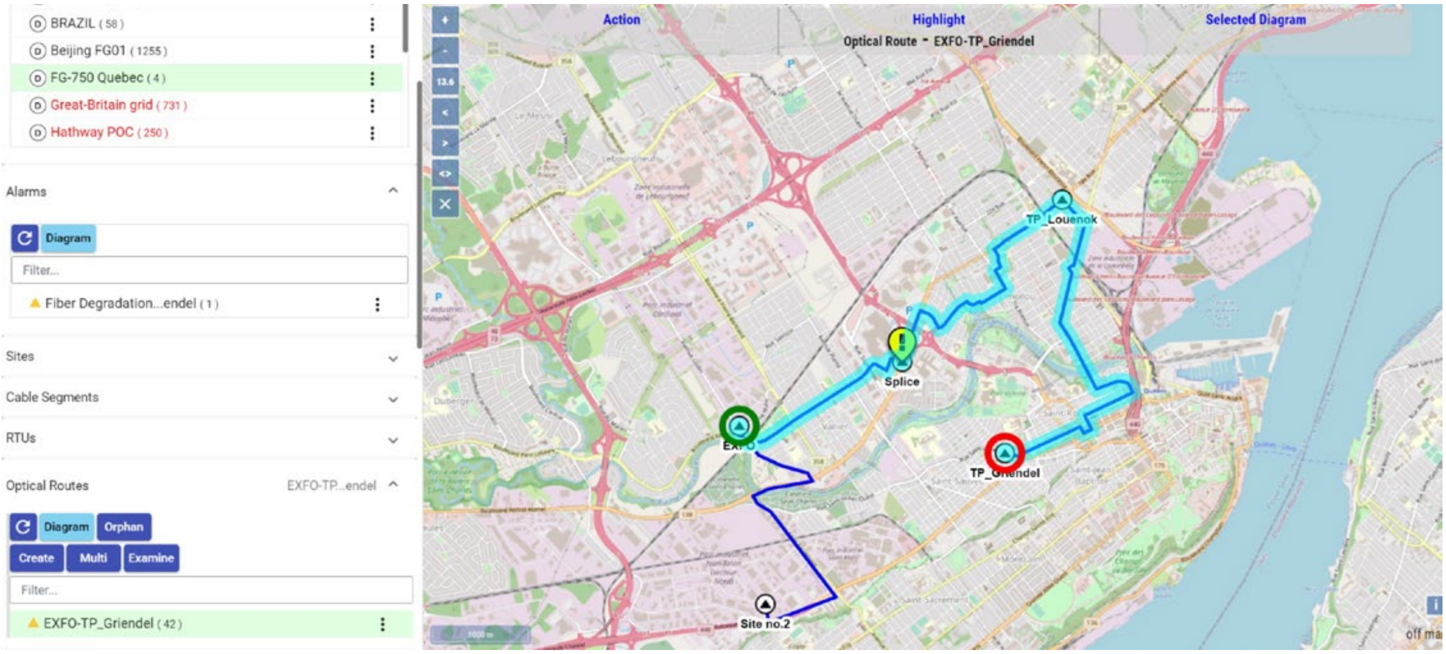


Figure 37: FMS-GIS view showing optical path (highlighted in blue) with start point (green circle) and end point (red circle) as well as fault alarm (exclamation mark).

FMS-GIS view displays fiber faults using an intuitive color scheme based on alarm severity: minor (yellow), major (orange) and critical (red).

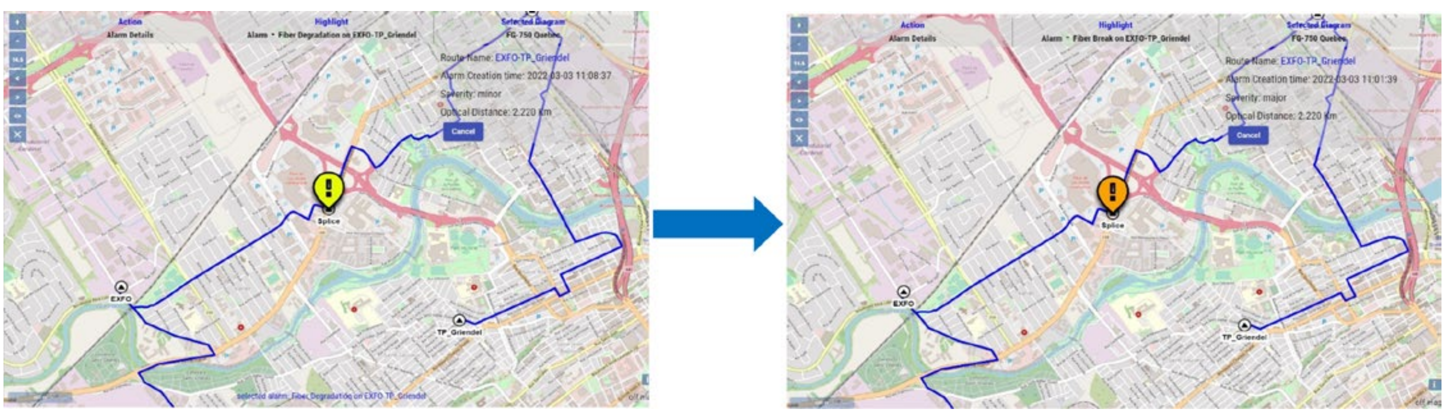


Figure 38: Icons change color to show changes in status (minor alarm on left and major alarm on right).

3.3.8.1 Entry and maintenance of optical fiber GIS documentation

Within FMS-GIS, the user can easily draw cable route segments and position connectivity infrastructure (e.g., cross connect site, splice enclosures) on the map. Users can then correlate optical event information from an OTDR result with the geographical position of all these locations. For enhanced fault mapping accuracy, users can document slack loops to further improve the physical to optical correlation and obtain better fault accuracy on lines that have long looping.

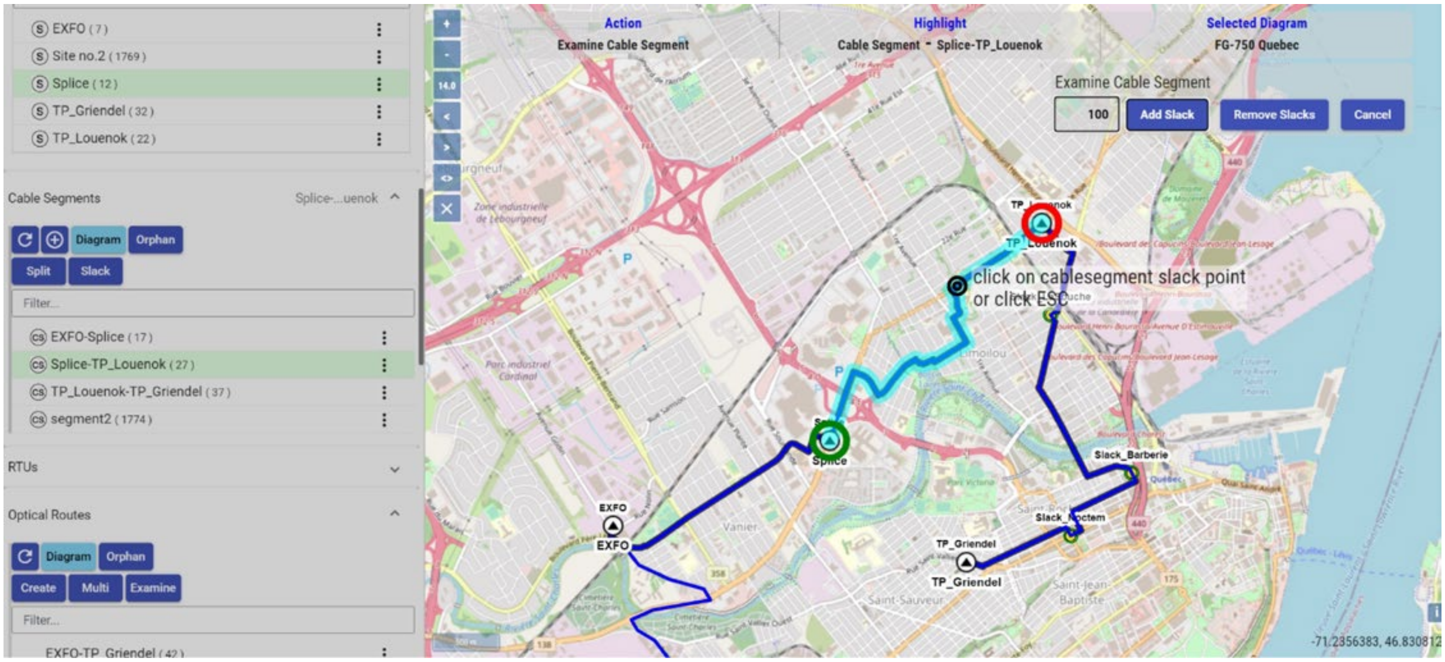


Figure 39: Setting optical distance to a physical site or location.

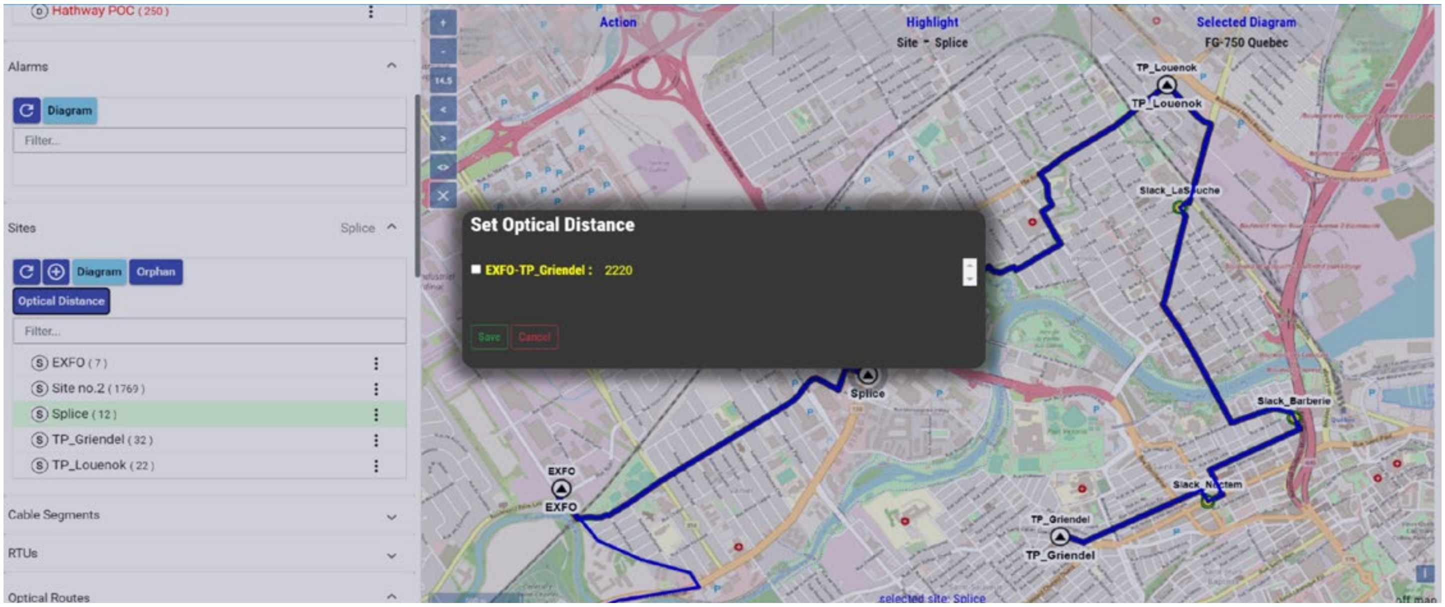


Figure 40: Adding slacks capability.

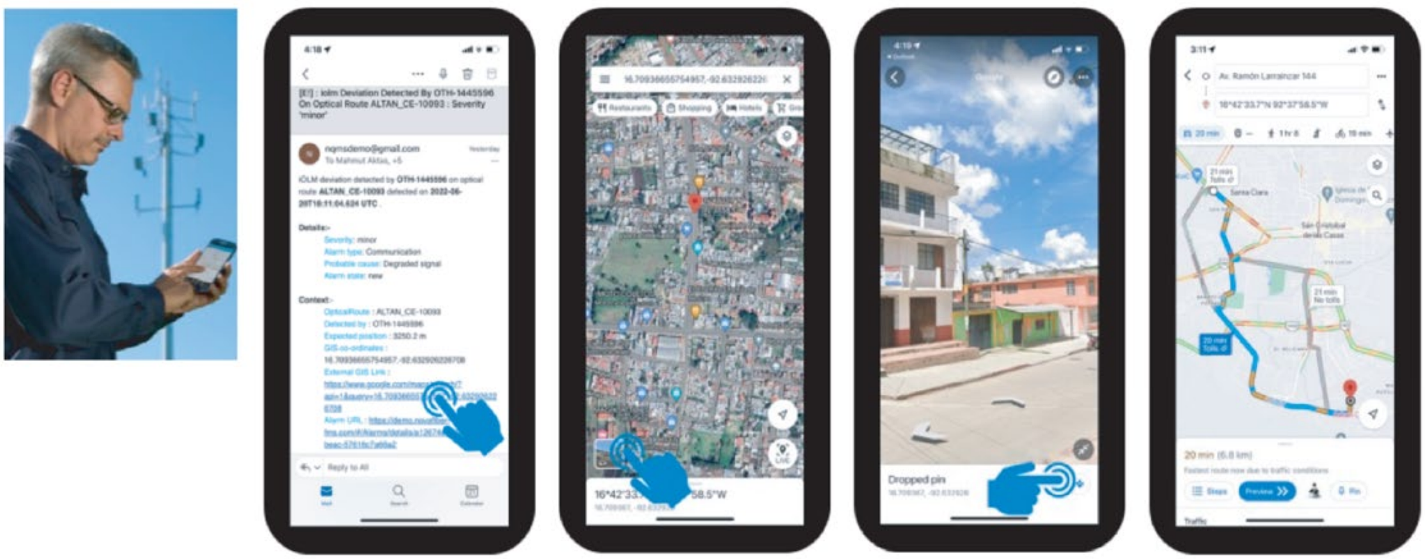
3.3.8.2 KML import

By uploading KML or KMZ files, FMS-GIS can automatically import object types such as lines and points. Those objects can then be turned into cable spans and sites in a few clicks. FMS-GIS includes editing tools as part of the KML import such as:

– Adding nodes
– Collapsing multiple nodes
– Splitting cables

3.3.8.3 Email notification with fault coordinates and callback URLs

The FMS triggers alarms whenever a fault occurs. Along with the GIS add-on, the notification includes GPS coordinates of the fault, as well as a Google Map link to open the location in your browser or from a smartphone:



Email notification with a Google Maps™ links to the point of failure

Visualization of the point of failure within Google Maps™ mobile app

Street view of the point of failure within Google Maps™ mobile app

Drive to fault directions within Google Maps™ mobile app

Figure 41: From email notifications to drive-to-fault directions.

The email also contains a URL to access alarm details from the FMS web UI. Alarm details include important information such as:

– Fault coordinates
– OTDR trace(s)—reference and current
– OTDR table of events

3.3.8.4 Online and offline maps

FMS-GIS uses open-source maps, such as Open Street Maps (OSM), as background maps. Additionally, some offline maps are available to be used along with FMS-GIS when internet connectivity is a security issue, or if not available. In those cases, FMS-GIS can still use offline maps as background (contact your EXFO representative for more details).

3.3.8.5 Supported scenarios for fault-on-map function

The FMS can natively provide the web-based GIS function including cable path edition and automation in mapping OTDR or iOLM faults. Some operators prefer to maintain a single source and update their fiber-optic network documentation only in one place; this is why EXFO has developed various integration schemes depending on customer requirements and budget, from event-based posting to a server that can consume and process the various alarms issued to a more complete client-server integration (RESTful based) where few services are typically needed and exposed to FMS software so that various integrated workflows are enabled:

- Physical to logical linkage, i.e., obtain from your inventory a list of the paths or routes UIDs to which the remote test unit will be physically connected.
- Automatic OTDR length tracing from your own GIS, i.e., upon new alarm being opened with above UID, query the external GIS service for geo-tracing of the fault in response.
- FMS to create alerts (email, SNMP notifications) with the information provided by the external GIS so that similar information can be available whether the GIS is external or not.
- Additional workflows are possible such as enabling testing from your inventory/GIS software (contact your EXFO representative for more details).

EXFO supports integration with various third-party fiber network inventory systems and has successfully deployed multiple integration projects over the last decade.

3.3.9 Cybersecurity attributes

EXFO's solution goes beyond the basic and mandatory IT security measures to protect your data and your IT infrastructure. Built on cloud-native technologies, it meets the cybersecurity level required to operate in a cloud, where all clients must establish trusted (with support of certificates) and encrypted communication channels with the server(s) they are connecting to. All remote test equipment used with this solution are such clients. They always initiate the communication and request authorization to connect based on their validated identity. A phone-home architecture enables remote test units as clients to use an outbound secured connection only, which is fundamental in blocking unwanted attempts of inbound connection. Our solution supports the following key protection measures:

- Within the cloud-native FMS server application, all communication between containers is encrypted.
- Token-based authentication prior to consume FMS Web APIs.
- All secrets are stored in a safe vault.
- Complete IAM/AAA functions including two-factor authentication, password policies, audit logs, session time-outs.
- Supports external authentication by means of LDAP and Kerberos.
- Customizable security banner on log-on screens.
- Radius server connection add-on/option (customization required).
- IPV6 support.
- Client certificate on RTU-2 and OTH-7000 (optional) is part of the registration process.
- Massive change of remote test units' local administrator credentials from FMS.
- Real-time streaming of audit logs from RTU to FMS.

3.3.9.1 Enhanced security with native mobile applications

RFTM Mobile Application is a true native mobile application. Native mobile applications offer significant security advantages over web-responsive interfaces. There are several reasons why a native mobile application provides stronger security.

– **Compliance with marketplace security standards**

  Mobile applications published on marketplaces such as the App Store or Google Play must adhere to the strict security standards imposed by these platforms. This ensures better implementation of security practices, a benefit not offered by mobile web responsive UIs. This external validation improves overall security and instills greater confidence in the app.

– **Isolation from the Web Browser**

  A dedicated mobile app is inherently isolated from the web browser, providing enhanced protection against certain attacks such as Cross-Site Request Forgery (CSRF). As a standalone entity, the mobile app benefits from specific layers of security that web applications cannot always implement as effectively.

– **Targeted and customized security policies**

  Native mobile apps enable the implementation of specific corporate security policies, independent of browser security rules. This allows for more granular control and better alignment with organizational needs. For example, a customer could:

  - Block Internet access on employee work devices while still allowing use of the mobile app.
  - Restrict VPN usage to the mobile application only (or exclude the web browser) for added security.

– **Protection against XSS attacks**

  Native mobile apps are inherently protected from cross-site scripting (XSS) attacks that exploit web browser-specific vulnerabilities.

Therefore, native mobile applications provide additional security benefits through process isolation, the ability to enforce targeted security policies, and adherence to market best practices. Native mobile applications are a more robust choice for environments that require a high level of protection and data control.

3.3.10 FMS software and minimum requirements

EXFO's FMS can be installed on virtual machines (VMs) or bare metal Linux hosts. Linux operating systems supported are as follows:

- Ubuntu 18.04, 20.04, 22.04
- RedHat Enterprise 7.x, 8.x
- CentOS 7.x
- Oracle Enterprise Linux (OEL) 7.x, 8x
- Rocky Linux 9.x

Minimum FMS operating requirements for a small number of connected remote test units:

- 4-core CPU, with SSE4.2 support. SSE4.2 is supported on Intel Core i7 (Nehalem), Intel Atom (Silvermont core), AMD Bulldozer, AMD Jaguar or later processors
- RAM: 24 GB
- Disk space: 500 GB

The solution architecture allows for horizontal scaling by adding more nodes to cope with additional units and users, thus ensuring that performance will not be impacted as the system expands. Typically, a single node (with adequate resources) will be able to cope with a few hundred remote test units, while 500 or more will typically require dual-node cluster.

Additional resources may have to be planned for proper sizing (contact your EXFO representative for more details):

- SSD-type storage media for larger systems
- Daily backup-related storage space
- Extra server for data replication (replica server)
- Storage for daily back-ups from replica server
- NFS for multi-node cluster storage, ideally external to the application cluster

4 Test and Measurement Hardware

4.1 Remote test units

Remote test units are OTDR-based test heads. Combined with local or remote switches, they scale up for testing from a few ports to thousands. OTH-7000 and RTU-2 units (shown below) run EXFO's patented Link-Aware™ technology and are thus referred to as iOLM test units. They both support link validation from the mobile application in P2P and PON configurations.

		OTH-7000-AWAT	New OTH-7000-UBRD	RTU-2-735C-SM7R	RTU-2-750C-SM3
KEY FEATURES	Dynamic Range & Wavelength	42 dB 1650 nm	41 dB 1650 nm	41 dB 1650 nm	45 dB 1310/1550/1625 nm
	Reflectometry: characterizes, evaluates or audits fiber quality	x	x	x	x
	In-service testing	x	x	x	
	Tone generation identifies the fiber	x (including in service)	x (including in service)	x (including in service)	x
	HRD testing certifies the link end-to-end for PON architectures		x	x	
FIBER NETWORK TYPES	P2P dark fiber	Optimal	Suitable	Suitable	Optimal for trilambda characterization and longhaul monitoring
	P2P live fiber	Optimal	Suitable	Suitable	
	P2P live fiber with L band traffic or supervisory		Optimal	Suitable	
	PON dark & live - mid to low density (sub 512 PON per test head)		Optimal	Suitable	
	PON dark & live - high-density (over 512 PON per test head)			Optimal	

4.1.1 OTH-7000 optical test head

The OTH-7000 is the smallest footprint (½ U rackmount space) optical test head with an embedded OTDR and optical switch. It features fanless operation, low-power consumption (10W) and all-in-front access. The OTH-7000 is remotely controlled via EXFO's central fiber management system (FMS) for fiber certification and monitoring through patented OTDR/iOLM technology or can be directly integrated into systems as a client API OTDR.

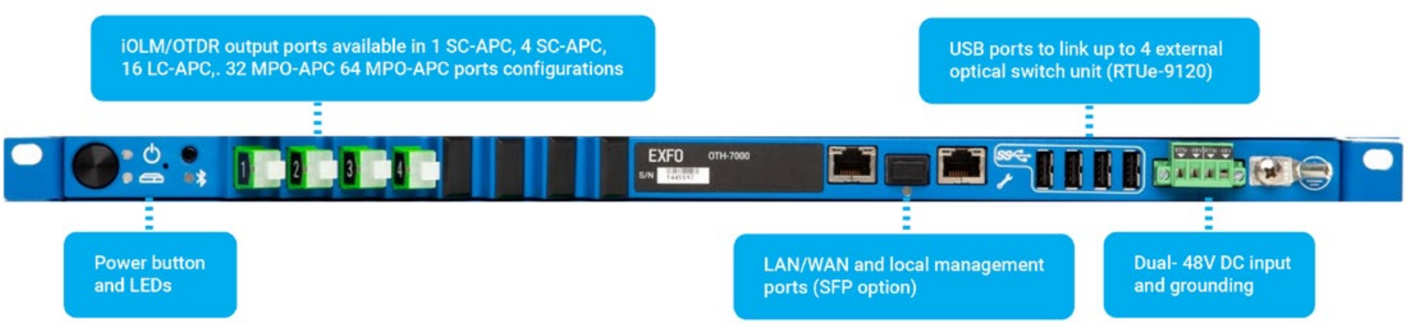


Figure 42: OTH-7000

In addition to dark fiber testing, in-service testing and monitoring of P2P and PONs is possible thanks to a filtered OTDR port at 1650 nm coupled with a compact test access module coupler (up to 64 ports per ½ U rackmount space). PON end-to-end fiber attenuation at 1650 nm is measured with a traceable test method using a high-reflectance demarcation filter.

Figure 43: MPO-24 port configuration with 16 fibers for 32 and 64 ports models.

The OTH-7000 is available with a choice of 1, 4, 16, 32 or 64 ports. Optical link management can be scaled up to 512 ports with compact external optical switches (local or remote, up to 256 ports per ½ U rackmount space). With its MEMS-based design optical switch, the OTH-7000 delivers durable performance in a compact package. Fast switching time and a 1-billion cycle lifetime expectancy make it ideal for the demanding needs of production testing, monitoring applications or PON certification.

Thanks to its narrower laser and filtering, the UBRD model is also optimal on P2P live networks when the upper L-band is used by traffic or supervisory.

4.1.2 RTU-2 remote test unit

The RTU-2 is a 1U-rack-size remote test unit. For flexibility and scalability, it is modular (two module slots) and compatible with EXFO's FTBx modules used in portable and manufacturing test applications. The unit provides fast on-board analysis and large local storage. The unit can also support up to four RTUe-9120s switches, scaling the number of test ports up to 1024. An optional junction panel is available so that all connections are available at the front of the unit (see Figure 44 with the ½U shelf underneath the RTU-2 unit).

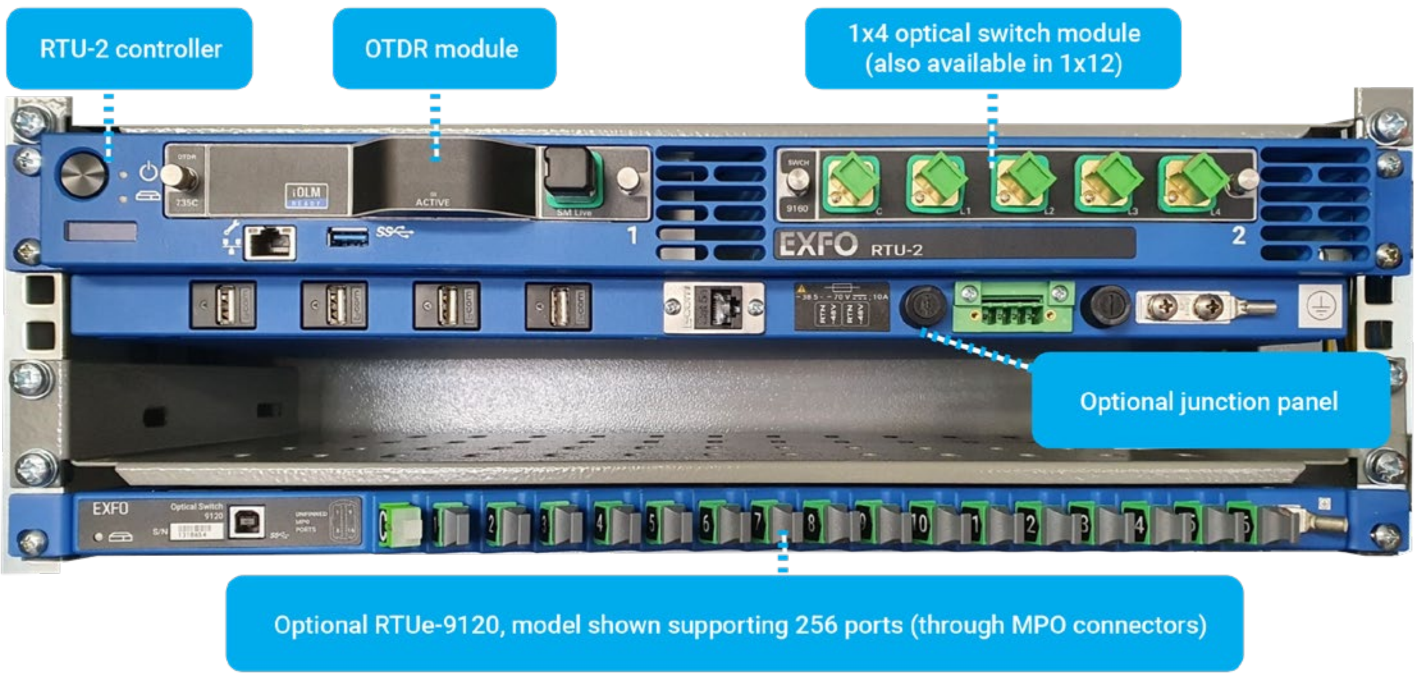


Figure 44: RTU-2 with OTDR module, first stage 1x4 switch and optional junction panel and second stage switch to support 256 ports.

The RTU-2 leverages EXFO's FTBx-700C/D high-resolution OTDRs modules.

The FTBx-735C is designed for metro/PON network testing and splitter characterization. This unit can conduct E2E testing in dark and live PONs using HRD filter testing. It can then monitor reflective ends that only reflect strongly at 1650 nm, the out-of-band wavelength used for the test. The RTU-2 can run an end-to-end test on a PON with a loss of up to 30 dB in under 5 seconds (test head time utilization); typically, this means a wait time of only 10 seconds for the field technician launching the test from the mobile app. The unit can also be connected to P2P links (either backhaul or access type) to provide both build and connect testing, as well as 24/7 monitoring.

The FTBx-750C-SM3 is a three-wavelength OTDR designed for dark fiber characterization and monitoring, offering a dynamic range of 45 dB, making it ideal for both short- and long-haul links.

4.1.3 RTUe-9120 optical switch

Based on reliable and cost-effective MEMS technology, the RTUe-9120 units are external optical switches for connecting an OTH-7000 or an RTU-2 to large quantity of fibers terminating in the same hub. It is low power consumption (typically 1 watt per unit) and very dense (up to 1x256 in ½ U). It uses MPO connectors to interface with the fiber route to be tested/monitored. Models are available in 1x32, 1x64, 1x128 and 1x256 fitting most OLT port configurations, both being based on multiples of 16. Each MPO connector (see Figure 45) based on standard MPO 24-fiber ferrule, exits 16 ports (2x8 on the middle rows) and is therefore compatible with most MPO cleaning and inspection tools[5].

Figure 45: MPO-24 port configuration with 16 fibers

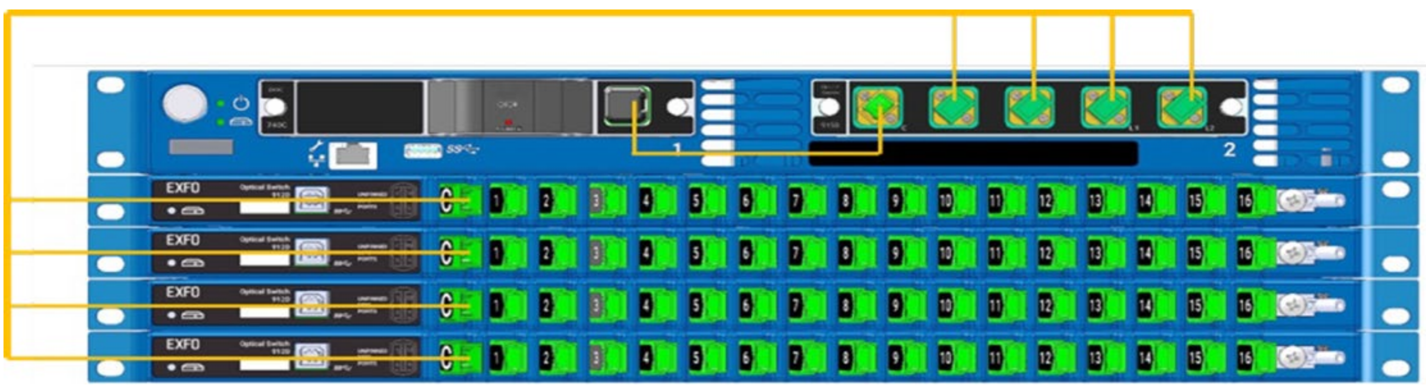
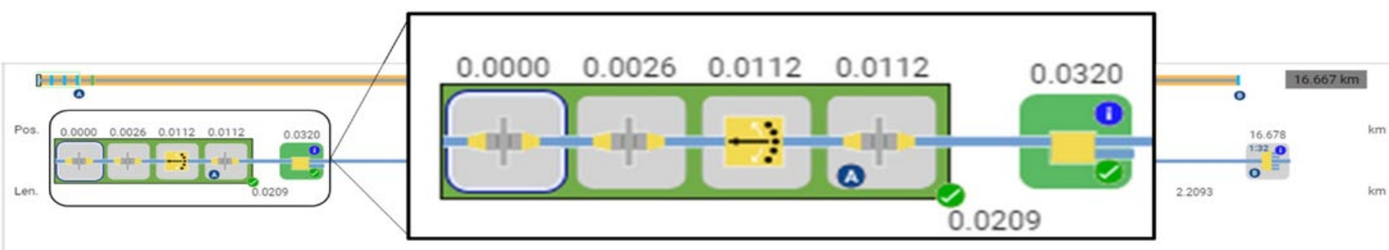


Figure 46: Four MPO-based RTUe-9120 units, each with 256 test ports in ½U size, deliver 1024 ports in 2U. A 1x4 optical switch connects to a 1x256 external switch, with typical excess loss of 3 dB due to optical level switching. Power and control come directly from the RTU-2 or OTH-7000 chassis, requiring no additional DC circuits.



Type		Pos./Len. (km)	Loss (dB) 1650 nm	Reflectance (dB) 1650 nm	Attenuation (dB/km) 1650 nm	Deviation Loss (dB) 1650 nm	Deviation Refl. (dB) 1650 nm
Σ		0.0000	3.214	-58.4		0.000	---
		0.0000	---	---		---	---
		0.0026	---	-58.4		---	---
		0.0112	---	---		---	---
	A	0.0112	---	---		---	---

Figure 47: Thanks to iOLM's patented multipulse technology, even on a 17-km PON with high loss, last stage optical switch port on the front end is properly detected, allowing to set link start accordingly (A) at the output of the last connector, part of the injection.

5 Learn more about EXFO's fully automated FIP-500 inspection scope: EXFO.com/en/FIP-500

4.1.4 OTAU-9150 remote optical switch

When multiple lateral links must be checked one by one (while limiting the number of upstream fibers to be used to reach end points), remote switching is required. EXFO's remote fiber testing and monitoring supports those scenarios, leveraging remote optical test access units (R-OTAUs), which are standalone MEMS-based 1xN optical switches. They are installed remotely from the main remote OTDR test unit and communicate with the main OTDR or the FMS either through any available LAN/WAN connection at the edge or remote site or through optical transceiver modules. Distributing OTDR signal to various racks in same or different floors is one example of this type of double-star optical switching.

Models are available in various port count and connector types.

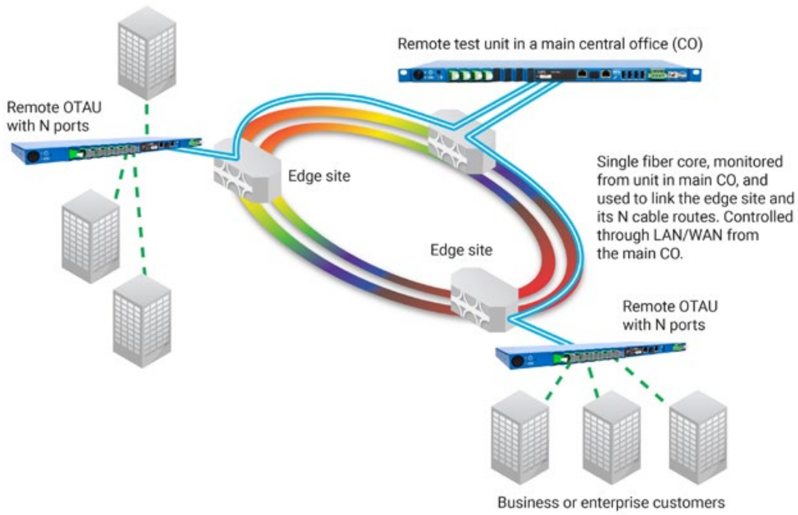


Figure 48: Use case for remote switching. A single remote test unit is used to reach multiple edge sites—each through a single fiber. At the edge site, the remote switch enables testing and monitoring of multiple links.

Compatible with RTU-2 and OTH-7000, the OTAU-9150 is the industry's most compact remote switch—offering up to 1x144 in ½U. The OTAU-9150 can be controlled over Ethernet port or SFP port and it requires less than 1 watt. It can also be operated as a local switch with the test head.

Figure 49: OTAU-9150

Operational up to 65°C (149°F), OTAU-9150 can be operated in street cabinets under harsh environmental conditions. With the RTU-2 or OTH-7000-UBRD, the OTAU-9150 is ideally suited for remote OLT-based PONs, while its combination with the OTH-7000-AWAT is designed to centrally test multiple batches of P2P links at various edge sites.

The OTAU-9150 can be configured with LC-APC ports (1x4 or 1x16), or MPO-24 with 24 fibers per connector (1x48, 1x96 or 1x144) or MPO-24 with 16 fibers per connectors (1x64) (see Figure 50). OTAU-9150 can also come in a version combining switching and WDM (for live networks) in a dense ½U single box requesting less fiber management.

Figure 50: MPO-24 connectors with 24 fibers (left) or 16 fibers (right).

4.2 Passive components for testing on live fibers

When testing on a live fiber link, the OTDR signals needs to be injected with live traffic and then extracted on its way back. For that, the OTDR uses an out-of-band wavelength which is multiplexed with the traffic wavelength(s). The multiplexing, as seen in Figure 51, is handled by a test access module kit (TAMK), offered in ½U or 1U full-wide rack units. Typical out-of-band wavelength(s) used for OTDR in this implementation are 1610 nm, 1625 nm or 1650 nm (depending on applications). EXFO's remote fiber testing and monitoring offers a wide variety of configurations from single path WDM with SC/FC connectors to 128 WDMs in a 1U rack space. The 1U TAMKs use a mix of LC connectors and MPO 24f ferrules where 16 or 24 ports can be quickly connected to EXFO's RTUe-9120 and OTAU-9150 optical switch units and to line (Tx/Rx or OLT) as illustrated in Figure 52.

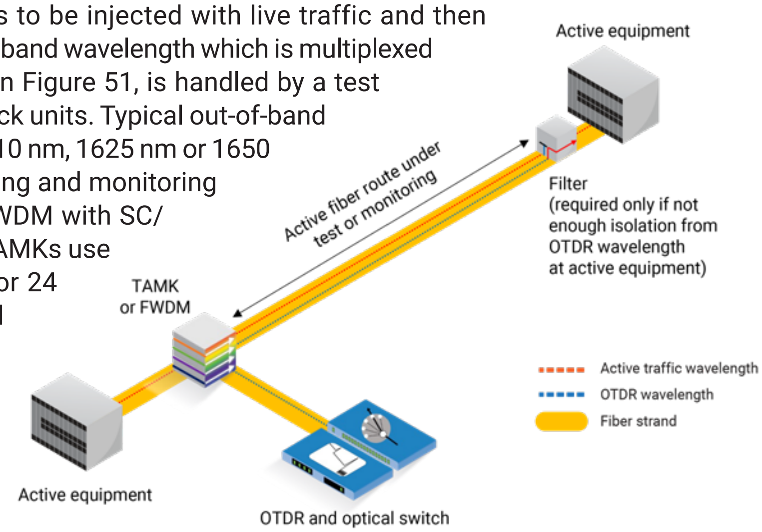


Figure 51: Use of a test access module kit and a blocking filter on a P2P schematic example

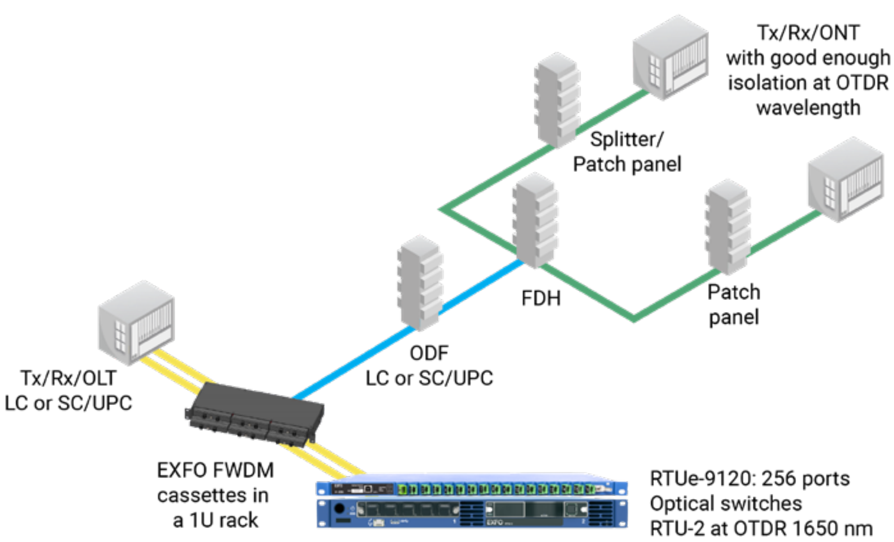


Figure 52: P2MP (PON) example.

Optical transport equipment from network equipment manufacturers (NEMs) now often integrate an OTDR port; although great in theory, these ports have to let the entire OTDR emitting power pass through and must present high-enough directivity, low reflectance (APC recommended) and enough isolation so that the return loss from the fiber and connectors hit by a strong OTDR signal are filtered out by the WDMs before they could reach a receiver. In comparison, EXFO WDMs typically provide:

- Low loss for traffic and OTDR—less than 0.8 dB for the device itself.
- Isolation larger than 30 dB on the line port at the OTDR wavelength.
- Directivity above 50 dB.
- Various cut-off wavelengths between traffic and OTDR to ensure specifications are optimized for the application.

4.2.1 Test access module kit (TAMK)

A TAMK is ½U or 1U full-size rack, in typical configurations of 12, 24, 32, 48, 64, 96 and 128 WDMs. Low-density units are ideal for use with FG-750 or OTH-7000 equipped with more than 12 ports while denser units such as 48, 64 and above are preferred for use with RTU-2 or OTH-7000 combined with RTUe-9120s. Different types are available upon request with volume pricing available.

Figure 53: TAMK-WDM-GA-64-MPO16-104: 1/2U, 64 WDMs all in front

Low-density units are ideal for use with FG-750 equipped with more than 12 ports while denser units such as 48, 64 and above are preferred for use with RTU-2/RTUe-9120s. Different types are available upon request with volume pricing available.

4.2.1.1 Models

- TAMK-WDM-GA-64-MPO16-104: 1/2U, 64 WDMs all in front. LC-APC ports for common, MPO-24/16f (4) ports for line and 1.5m pigtails MPO-24/16f (4) terminated for OTDR. Aso available in 48 WDM (TAMK-NS3244) and 32 WDM (TAMK-NS3293) versions.
- TAMK-WDM-GA-24-XX: 1U, 24 WDMs SC-APC for line and common (front) with 3-m pigtails (different connectors) for the OTDR (rear).
- TAMK-WDM-GA-48-MPOC-104: 1U, 48 WDMs LC-APC for line and common (front) with MPO -24/16f (3) for OTDR (rear).
- TAMK-NS3089: 1U, 128 WDMs LC-APC common ports (front) with MPO -24/16f (8) for OTDR and MPO -24/16f (8) for line (rear).

4.2.2 FWDM: single fiber

LGX compatible modules and rack-mounting kits are also available and are ideal for the 2- and 4-fiber configurations that need to be connected to testing and monitoring equipment. In these models, the front SC or FC connectors are removable from the front, giving access to the ferrule for ease of inspection and safe cleaning.

Figure 54: FWDM

4.2.2.1 Models

- FWDM-234: regular 1310-1550 nm with 1625 nm for the OTDR.
- FWDM-NS2065: 1310-1550 nm with 1650 nm for the OTDR.

4.2.3 FWDM: Bypass assembly – single path

To enable the OTDR signal to bypass or jump over an active equipment (e.g., a traffic re-gen) or an optical add-drop multiplexer (OADM) site, EXFO offers a similar FWDM configuration but with the monitor ports of two WDMs spliced together so that it bypasses a transmission gear, an amplification equipment, or an OADM with minimal loss added to the link.

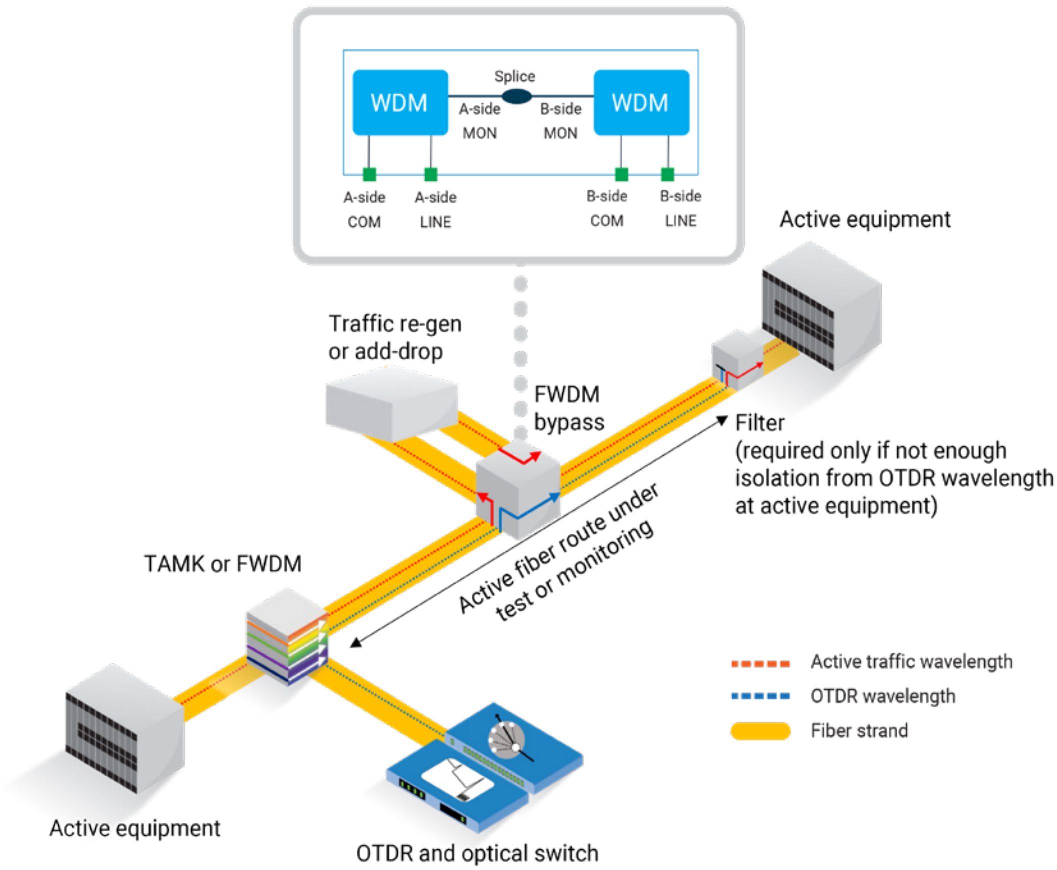


Figure 55: Schematic example using an FWDM bypass to monitor a fiber route including traffic regen or add/drop module.

4.2.3.1 Model

– FWDM-NS1734: Dual-channel FWDM for bypass site.

4.2.4 Low-density FWDM cassettes

Ideal companion for OTH-7000, for EAST-WEST TX/RX live fiber monitoring

– FWDM-NS3191 -1/2 U cassette, all ports in front. 4 WDMs for the monitoring of up to 4 live fibers. 2x duplex LC/UPC connector for 'Line' ports, 2x duplex LC/UPC connector for 'Common' ports, 2x duplex LC/UPC connector for 'Monitor' ports.

– RMK-NS3115: 1/2U holder module hosting up to 3x FWDM cassettes.

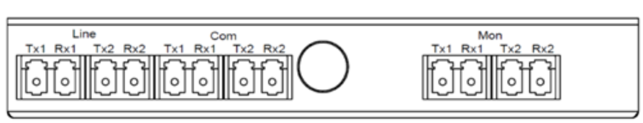


Figure 56: low density FWDM cassette

4.2.5 High-density FWDM cassettes

MPO 24f APC ferrules are used to terminate more fiber ports into high-density fiber racks. These cassettes can replace single-fiber connector patch panels already used to link up OLTs to ODFs, while offering an OTDR test access without a larger footprint.

Figure 57: MPO-based high-density FWDMs cassettes.

4.2.5.1 Models:

- FWDM-NS2919: 48 WDMs, all in front MPOs, maximum 288 WDMs per 1U in scaling steps of 48x.
- FWDM-NS2944: 16 WDMs, front/rear MPOs, maximum 96 WDMs per 1U in scaling steps of 16x.
- Rack-NS2919: 1U size, 6-slot chassis for holding up to six (6) high-density FWDMs.

4.2.6 Other passive components

- Rejection filters for P2P fibers in jumpers or bulkhead adapters.
- WDM in small and ruggedized package with various jumper lengths and connector types.
- HRD devices to be used as 1650-nm reflectors for FTTH/PON testing and monitoring applications (HRD devices are available in various formats and pricing depending on volume).
- Bulkhead adapter for insertion onto an existing infrastructure such as at the ONT port or an inside an existing jack.
- Pigtails for splicing into a jack or at any of the terminals.
- Multiport terminal (MPT) termination depending on manufacturer (contact your EXFO representative for more details).

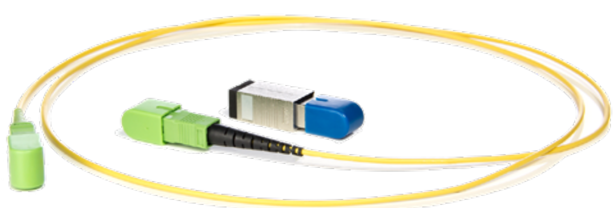


Figure 58: Example of HRD in a test jumper and in a bulkhead adapter.

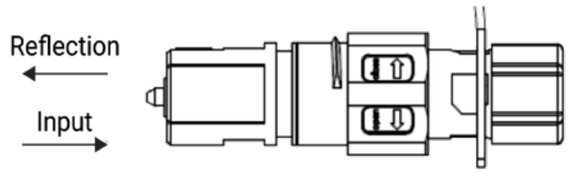


Figure 59: single turn quick-connect terminated HRD for Corning's OptiTap® MPTs.

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