The Importance of Fiber Monitoring

Applications and Solutions

Introduction

Fibers are a Valuable Resource

Optical fibers have revolutionized and transformed the telecommunications industry over several decades. Service Providers across the world depend on optical fiber to transmit high bandwidth data reliably over greater distances with lower loss. These key attributes make fiber the predominant and preferred choice for multiple communication applications ranging from telecom backbone infrastructure, broadband distribution, mobile X-haul, Ethernet systems, and general data networking.

Government initiatives are forcing providers to invest heavily in fiber-based networks to address the digital divide and to make working from home (WFM) both possible and efficient. Increasing the average revenue per user (ARPU) remains a key business objective but with competition increasing, network reliability is absolutely essential for customer retention.

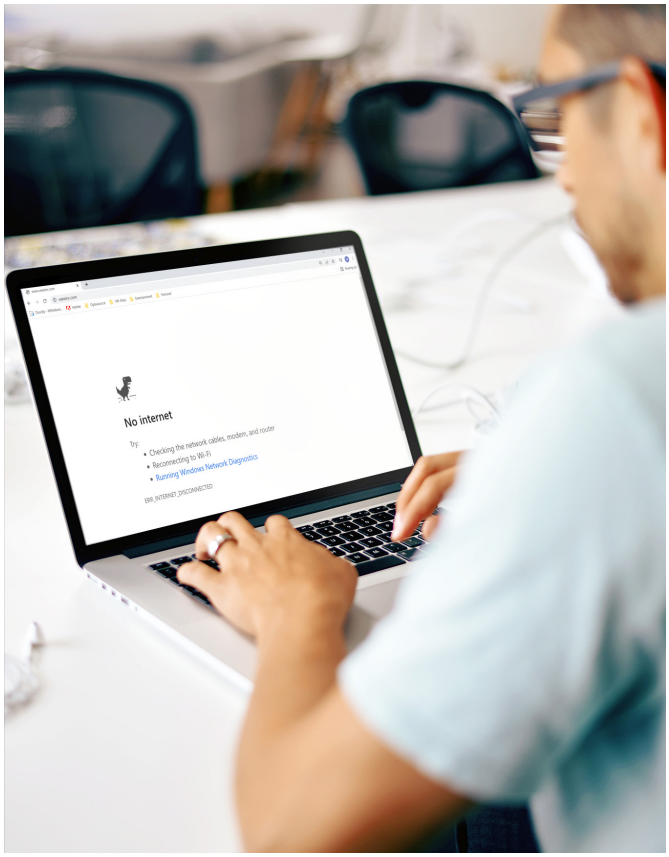
Contents

Fiber Cuts are Costly

Service Providers constantly strive to provide fast and reliable internet service to their customers; however, a fiber break can drastically impact their ability to deliver on that promise. Fiber cuts quickly disable critical internet connections and rerouting or restoring service isn't always fast, simple, or seamless. Service outages to fiber distribution hubs and other key data aggregation points can be very problematic as they impact a high volume of customers.

Fiber cuts or disruptions can take hours, days or even weeks to locate and repair. Irrespective of how they occur, resulting network outages are extremely costly to telecom companies. In some instances, local laws may require operators to compensate customers when outages occur, but in the corporate world, financial penalties are usually levied based on Service Level Agreements (SLA). Most SLA's boast network uptime figures of between 99.8% up to 99.99% which on the surface appear quite impressive, with neither 0.2% nor 0.01% downtime suggesting any significant negative consequence. However even small percentages add up over time and this can be extremely costly to operators. Considering the three common industry network uptime metrics below, downtime can be determined as follows:

- 99.8% availability – 17.52 hours/year downtime
- 99.9% availability – 8.76 hours/year downtime
- 99.99% availability – 52.56 minutes/year downtime



Based on leading industry surveys conducted in 2021, the cost of network downtime for an average size organization ranges anywhere between $137 to $17,244 per minute, amounting to as much as $906,345 per year based on a 99.99% SLA availability metric, a significant figure in any company's budget. Businesses providing online or data center services will generally experience higher network downtime costs compared to others, but almost all companies will struggle to quantify the exact cost due to loss of revenue, productivity, or other intangible costs related to damaged reputation. In addition, recovery expenses related to the cost of employees working overtime, the cost of repairing equipment or fiber infrastructure, and data recovery costs all contribute to the total cost of network downtime.

Furthermore, when fiber cuts occur, skilled technicians equipped with specialized fiber-splicing and testing equipment are required to repair broken cables or connections. Although damage usually involves some expensive repair, the indirect costs due to network outage is usually much greater. Factoring a budget for "downtime" and "non-productivity" is a serious issue for many companies including business continuity planning.

The cost of network downtime is quite frankly enough reason to cause some companies to go out of business. To mitigate the negative consequences of network downtime due to fiber cuts, companies are implementing automated fiber monitoring solutions to achieve faster and improved RTO (Recovery Time Objectives), RPO (Recovery Point Objectives) including MTTR (Mean Time to Restore/Repair). MTTR is defined as how quickly a service provider responds, repairs, and restores a reported problem.

Fiber Cables are Vulnerable

What Can Damage your Cable?

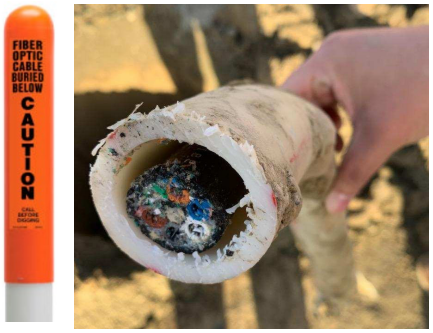
Private fiber networks and internet backbones are designed to be reliable, but they are not indestructible. The majority of underground and overhead cables are unguarded and unprotected exposing them to numerous threats as they traverse urban environments or travel long distances across remote/rural parts of the country.

Wildlife, adverse weather conditions, sabotage, and construction work are some of the most common reasons for fiber cuts and network outages. Vehicle accidents also damage fiber infrastructure - drivers with little or no spatial awareness and people driving under the influence are usually responsible for automotive related fiber cuts.

Wildlife Activity

Rodents chewing on indoor and outdoor fiber optic cables cause extensive damage resulting in service outages impacting thousands of customers annually. Gophers, moles, rats, and mice are usually to blame for damage in buried cabling, underground ducts, splice vaults, manholes, and building basements while squirrels are the biggest culprits of damaged aerial infrastructure.

Damage is typically destruction of a few fibers within a cable disrupting service or compromising the cable's jacket creating an ingress path for water resulting in corrosion of strength members. Birds are also responsible for fiber cable damage on mobile towers and utility poles.



Construction Work

Fiber cuts due to construction activity is usually unintentional but unfortunately occurs quite frequently. Municipal workers using excavators or backhoes to install or repair public utilities are not always vigilant of cable markers, or they operate in areas where underground cable routes are undocumented.

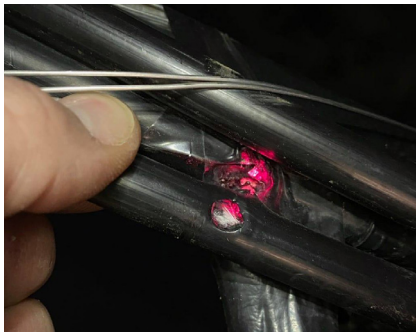
Homeowners often damage or sever cables with a shovel while installing fences around their property, while farmers using post-hole augers and tractors are often responsible for damaging rural cables running through or around their farms.

Weather and Natural Disasters

Mother Nature's environmental and natural forces are truly formidable and unstoppable. Extreme cold, strong winds, heavy flooding, abnormal snow fall, hailstorms and even earthquakes easily damage fiber optic cables with major consequences.

In colder climates, ice forming in splice enclosures not sealed properly/correctly during installation, quickly degrade, and disrupt optical connections with crushing force. Wildfires arising from natural causes such as lightning, accidental events such as out-of-control campfires or intentional acts of arson can cause irreparable damage to aerial fiber cables.

Climate change also poses a major threat in coastal areas as sea levels rise and storms intensify.



Sabotage and Vandalism

Most governments consider fiber cables an integral part of a nation's critical infrastructure however their operation, management, and protection are ultimately the responsibility of the respective service provider. Despite efforts to conceal cables underground or installing video surveillance at key locations, vandalism on telecom infrastructure is on the increase, and damage can be significant depending on cable and equipment type.

Gunshots to aerial fiber routes can be accidental due to irresponsible hunting activity or intentional due to deliberate target practice - inevitably the damage is severe and expensive to repair. Damage due to bullet penetration is difficult to identify from the ground, prolonging network downtime.

*Photos courtesy of Felix Martinez, John Hoffman, Jacob Bell, and Thomas Dilliplane Jr.

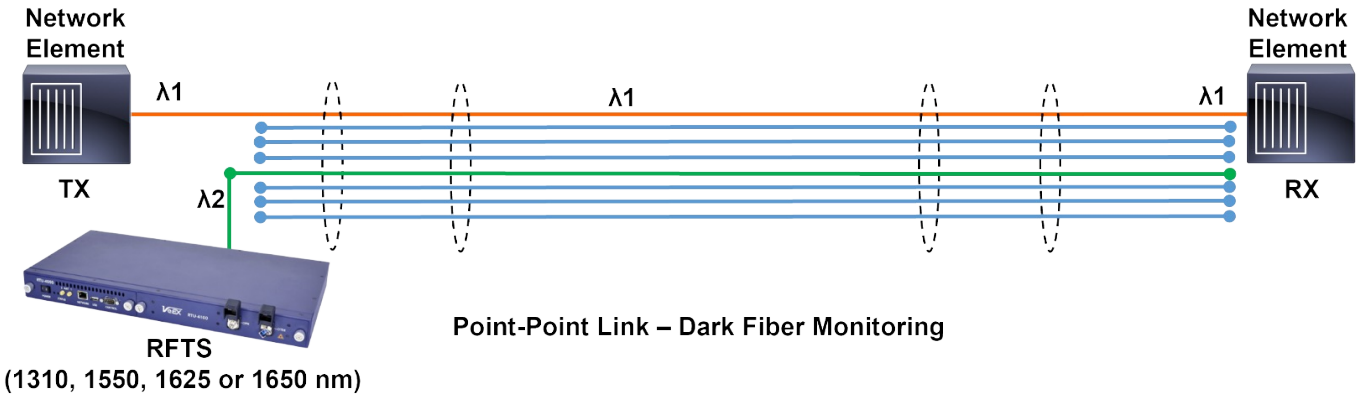
Fiber Monitoring Solutions

Telecom service providers cannot prevent fiber cuts from occurring due to natural or human activity, but they can take steps to minimize network downtime when aerial or underground fiber cables are compromised. Reactive troubleshooting using portable field test equipment carries with it too many “risks than rewards” in today’s competitive telecom landscape - this reactive practice exposes an operator to an unpredictable amount of time to identify and pinpoint problems before fiber repairs can commence.

Fiber Monitoring is a proven, pro-active, risk-reduction and asset protection approach of pinpointing fiber degradation and breaks that threaten strategic infrastructure providing service to thousands of customers. With the ongoing deployment of high-speed Ethernet, DWDM and 5G services, it’s crucial for service providers to leverage fiber monitoring technology to protect their investment. Higher data rates and increase in channels result in more data being carried across a single fiber. Any service outage has significantly greater impact to lost revenue and reduced customer satisfaction.

Dark Fiber Monitoring

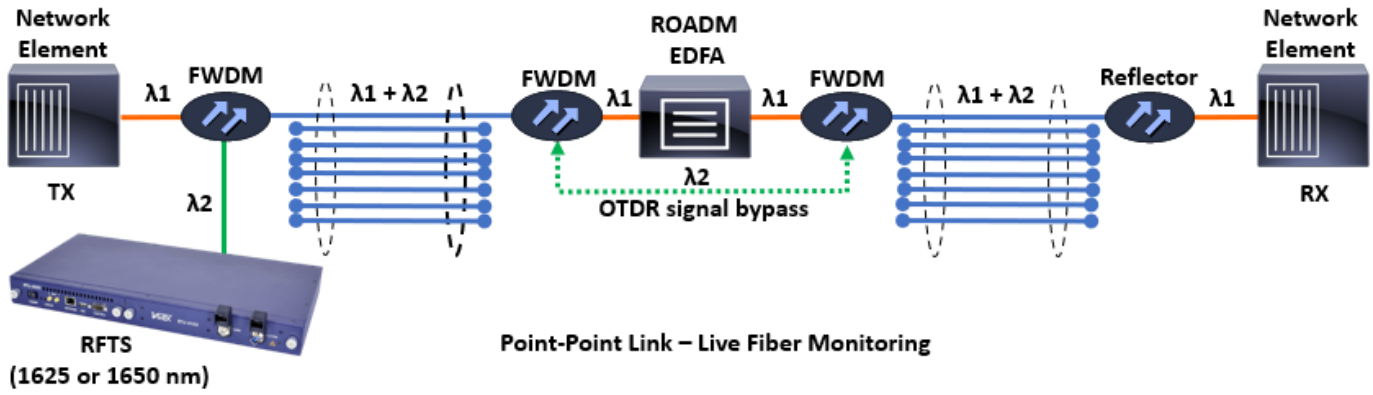
Typically, one spare fiber in a cable not assigned to carrying traffic is selected for monitoring purposes. The fiber under test is connected directly to an OTDR test head located in a central test location – since the fiber is dedicated for monitoring purposes only, either in-band or out-of-band wavelengths can be used for testing. If that particular fiber is damaged in any way, the provider assumes the entire cable has suffered some sort of catastrophic failure. Although monitoring a single dark fiber is an economical and efficient approach to monitor a fiber link, it does present some risks. Partial damage to a cable occurs quite regularly due to wildlife and other human activity, so the individual fiber being monitored might not always be a true indicator of when a cable has been compromised.



Point-Point Link – Dark Fiber Monitoring

Live Fiber Monitoring

Due to a general shortage or “fiber-exhaust” in operator cables, spare fibers for monitoring purposes are quite scarce. Live fiber monitoring uses specific ITU-T standardized test wavelengths which don’t disrupt or interfere with traffic on the fiber being monitored. “In-service-test” is a non-intrusive methodology which has gained popularity since it provides a dynamic evaluation of link continuity and performance, plus the monitored fiber can be associated with a particular customer or tied to additional system alarms. In simple terms, a filtered wave-division multiplexer (FWDM) combines the OTDR’s test signal with the traffic signal onto the fiber to be monitored. The FWDM also filters and directs the OTDR backscatter for processing preventing the test signal reaching and affecting the far end wide band network receiver.



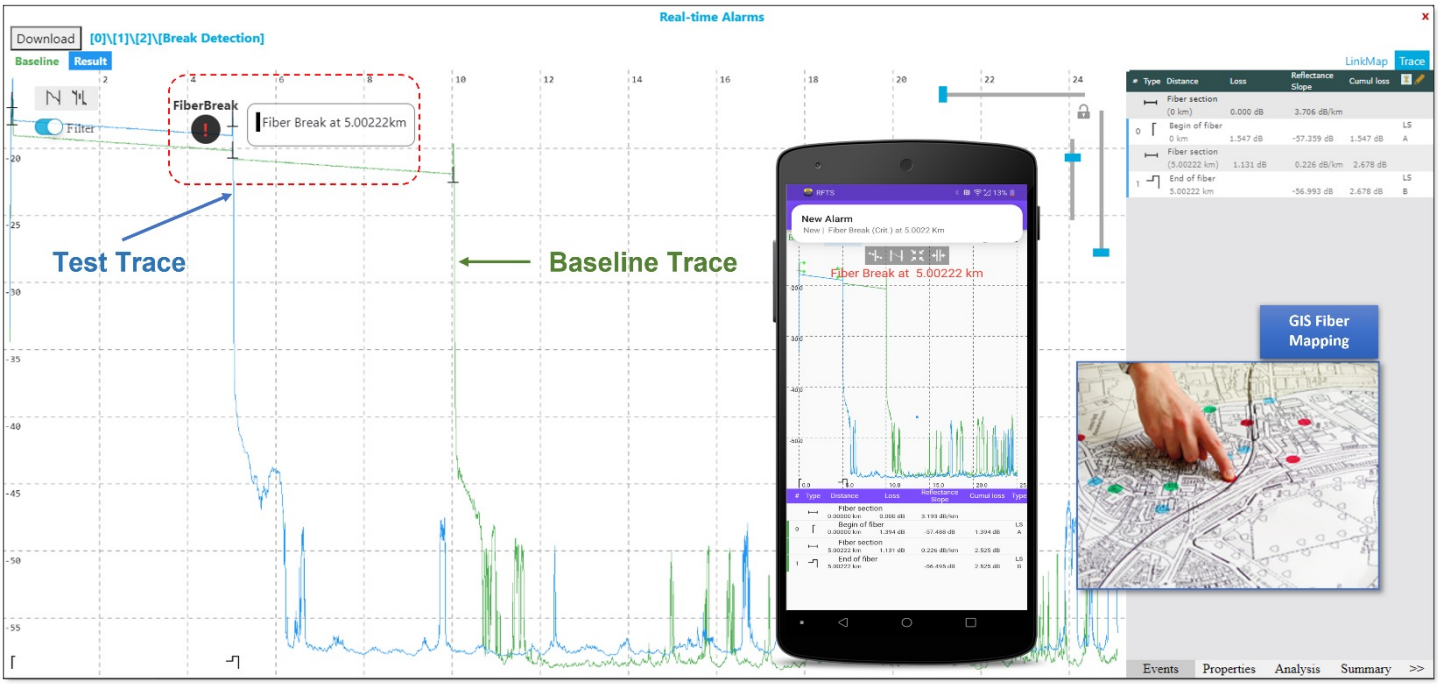
Point-Point Link – Live Fiber Monitoring

How Fiber Monitoring Works

Principle of Operation

A Remote Fiber Test System (RFTS) allows service providers to monitor and troubleshoot a fiber optic network from a centralized location. An RFTS employs optical-time-domain-reflectometer (OTDR) technology to identify breaks (reactive) or other less critical event changes (proactive) on a fiber link including their precise location. Also referred to as a Remote Test Unit (RTU), this rack mount OTDR is programmed to routinely monitor fibers for anomalies or degradation that can impair optical signals, with the help of an optical switch.

Each measured trace is compared to a reference trace of the fiber or known good baseline during normal condition – any deviation from preset thresholds is flagged as an exception and the operator is notified by text, email, and SNMP messages. The detected fault's location is correlated on a map using a Geographical Information System (GIS) pinpointing the precise location, speeding up the dispatch and repair.



Benefits of Fiber Monitoring

The advantages of fiber monitoring cannot be overstated. VeEX's fiber monitoring system simplifies fiber operations leveraging more value from the network. Benefits of the RFTS system include:

- Dark and Live fiber monitoring applications
- Point-to-Point and PON network types
- FTTH/P network construction
- 24x7 Monitoring and Testing improving network reliability
- Localize points of failure with immediate fault notification
- Automatic or on-demand testing/troubleshooting
- Pro-active troubleshooting improves MTTR reducing network downtime
- Monitor point-to-point fibers up to 200km (45dB RTU)
- Multiple fibers can be tested using an optical switch matrix
- Predictive analysis of fiber degradation preventing service disruption
- Local or remote access to system for on-demand testing
- Passive reflectors demarcate fiber drops for FTTH construction
- Integration with industry leading GIS to display fiber routes on a map
- Standalone operation, or OSS and 3rd party API system integration

MTTR | Mean Time to Repair

Network Applications

Flexible and Scalable

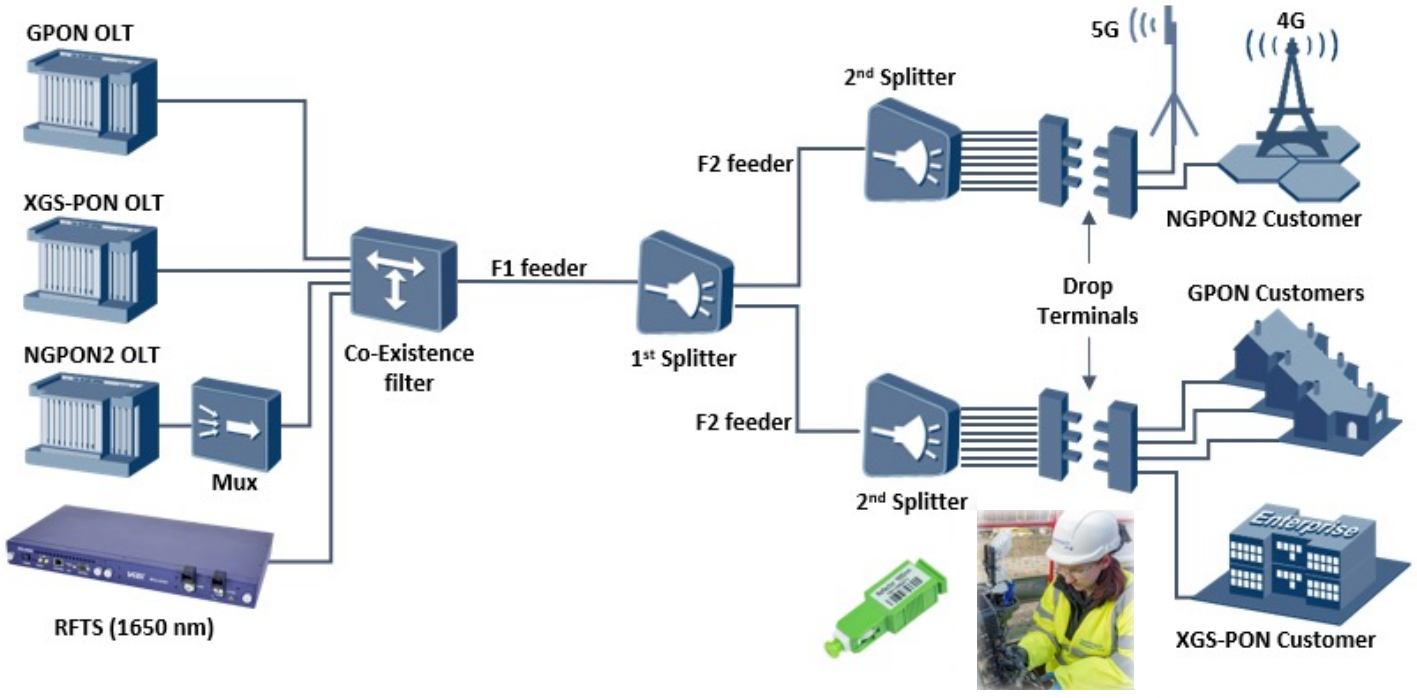
VeEX's remote fiber test system (RFTS) is designed and optimized to test and monitor point-to-point fibers used in metro and long-distance core applications, as well as point-to-multipoint fibers employed in PON access networks.

PON Networks

Passive Optical Networks (PON) have evolved considerably to support residential FTTH and non-residential FTTP applications over the past few years. With the advent of 5G, next-generation PON variants such as XG(S)-PON, 10G EPON, and 25G EPON have emerged to transport wireless fronthaul and backhaul traffic over PON optical distribution networks (ODN) previously dedicated to FTTH/P services. Re-purposing the PON infrastructure leverages existing fiber assets, lowers operational costs, achieving faster ROI.

Construction - The pressure to deploy FTTH/P as quickly and cost-effectively as possible has never been greater, however service providers still need to ensure high quality and reliable installations without disrupting existing customers. A shortage of skilled fiber technicians and field test equipment makes the task even more challenging - operators are quickly turning to fiber monitoring systems for efficient PON construction.

When a PON network is being built or when new customers are being added to an operational system, an RFTS mounted in a centralized location is a very efficient way to validate and commission new customers. The field technician simply inserts a passive optical reflector at the new service location and initiates a test using a mobile device App. Within seconds, fiber connectivity, length, and loss are all performed at the fiber drop or service point - the RFTS records all test data securely on a server, completely removing the post-documentation burden from the technician.

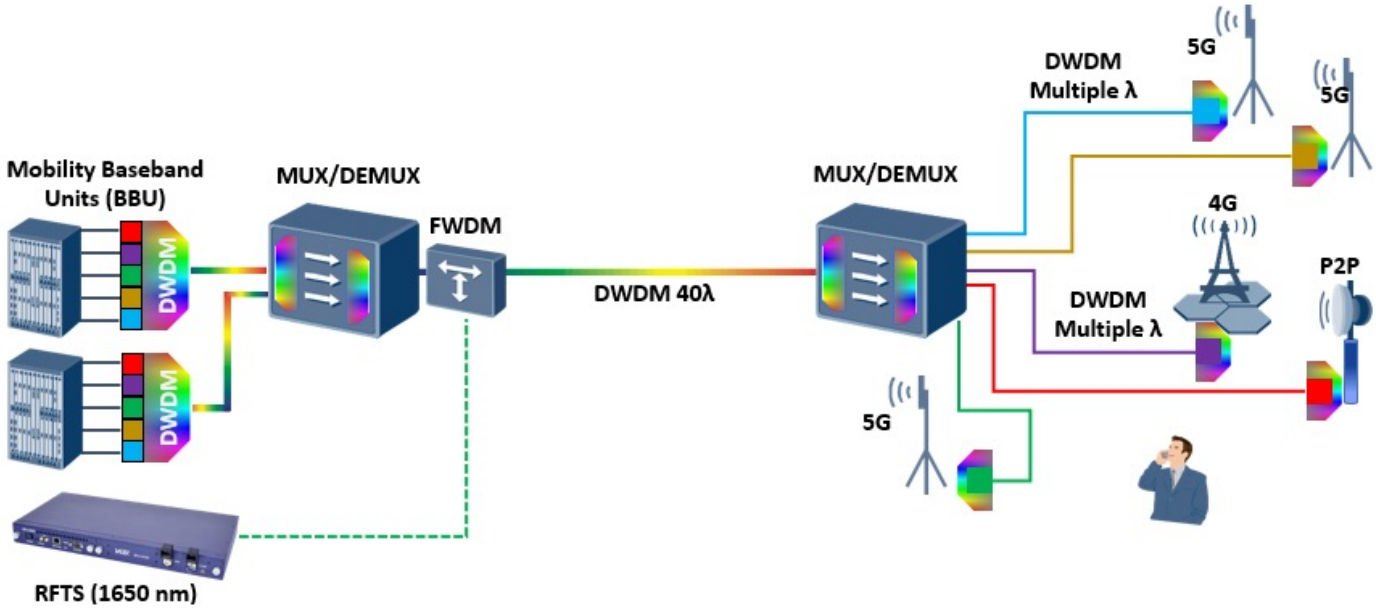


Monitoring - Once a PON is operational, there are several compelling reasons for service providers to monitor their valuable fiber asset using advanced monitoring technology. The ability to assess and obtain real-time information on a particular fiber's integrity, latency, and attenuation characteristics, enables providers to offer higher-revenue advanced services.

An RFTS located at a central location is configured to routinely test fibers in the ODN. Pro-active monitoring checks for excessive losses, high attenuation, abnormal reflectance, and other anomalies along the fiber link including any malicious activity. Passive optical reflectors can be used as demarcation devices to identify specific customers, different network segments or service handoff points.

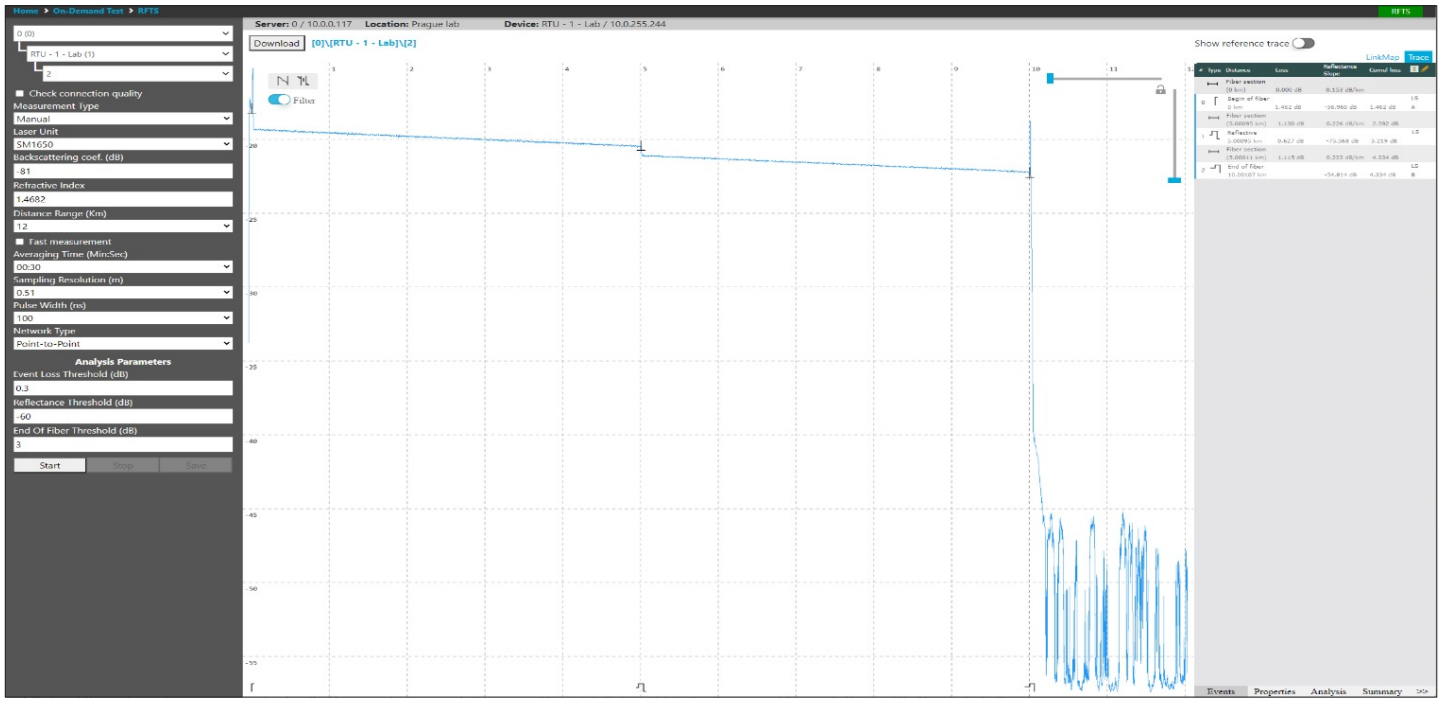
Point-to-Point Networks

Point-to-point fibers are used extensively in long haul, high-speed core/metro, and access networks, including 5G mobile, distributed access architectures (DAA), and datacenter interconnect applications. To mitigate fiber-exhaust and cope with the increased bandwidth requirements, service providers are maximizing their fiber capacity using coarse wavelength-division multiplexing (CWDM) and dense wavelength-division multiplexing (DWDM). Due to the sheer volume of high value traffic these fibers carry, service providers are obligated to provide the best quality of service (QoS) possible, which includes almost zero downtime. If any fiber cut or disruption does occur, mean-time-to-repair must be kept to an absolute minimum – this can only be achieved with fiber monitoring.



In-service, out-of-band testing using a 1650nm RTU/OTDR has become the most adopted and preferred solution for long haul including CWDM and DWDM based networks. Traditionally, because of cost, 1625nm was used for testing grey fiber 1310/1550nm legacy networks; however, 1625nm is not recommended for use with CWDM networks or other networks that may utilize 1610nm wavelength for traffic or communication. The same applies to DWDM since some channels could extend into the L-band (1565-1625nm). Testing at 1650nm has the added advantage of identifying unwanted bending of the cable or individual fibers, since the wavelength propagates in the outer diameter of the fiber core exposing any micro and/or macro-bending issues.

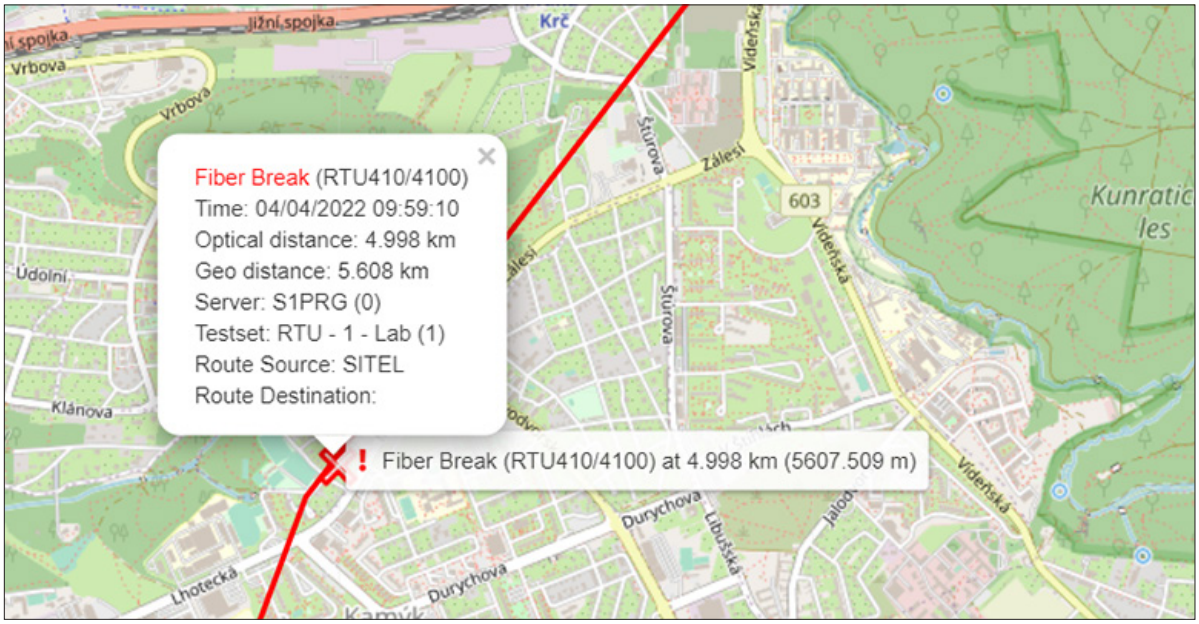
To inject the OTDR signal to the fiber being monitored, a frequency wavelength-division multiplexer (FWDM) is inserted at the central test location to couple test and traffic signals together. Optical switches can be added to support high fiber count cables which can also be equipped with multi-fiber push on (MPO) connectors.



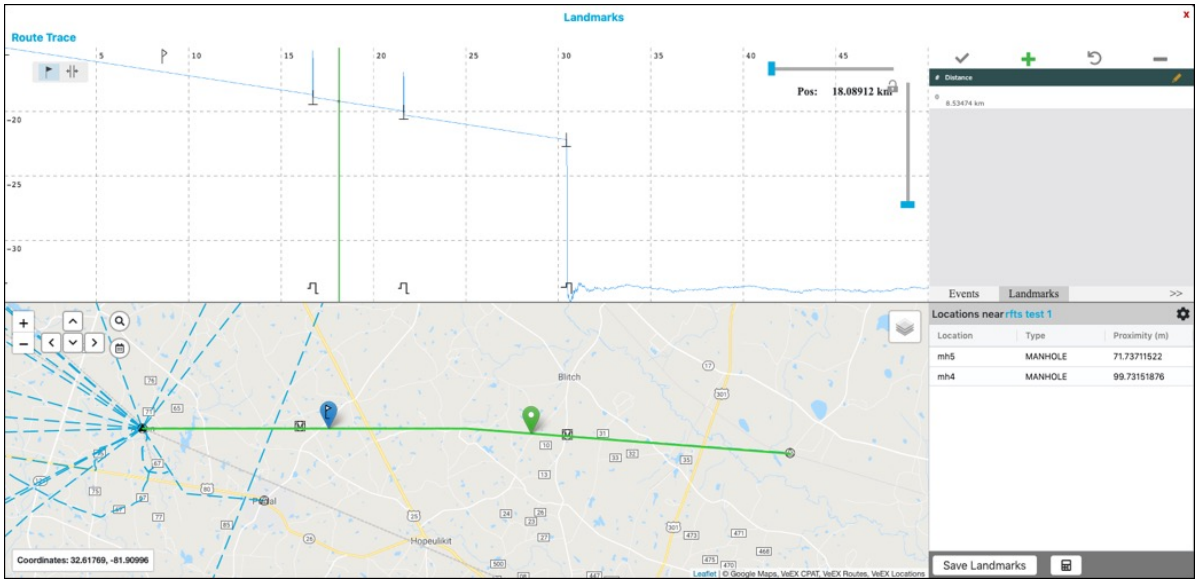
Geographic Information System (GIS) - What is a GIS used for?

GIS is a software platform that captures and analyzes data and displays geographically related information – it is an effective problem solving and decision-making tool used to improve the operation and maintenance of a fiber optic network. Geo-spatial data helps visualize network attributes such as cable routes, workforce, and other resources - fiber monitoring systems use this data to correlate fiber events/alarms with physical locations on a map so technicians and managers can provide more effective follow up.

OTDR technology evaluates the fiber plant to identify any fault/s that disable, disrupt, or could potentially degrade a transmission link. An OTDR however only provides the optical distance to a fault and although this information is very useful, technicians still need to know the exact physical location of a problem. Combining the OTDR's optical distance measurement with GIS data allows the fault location to be mapped more accurately on the fiber route.

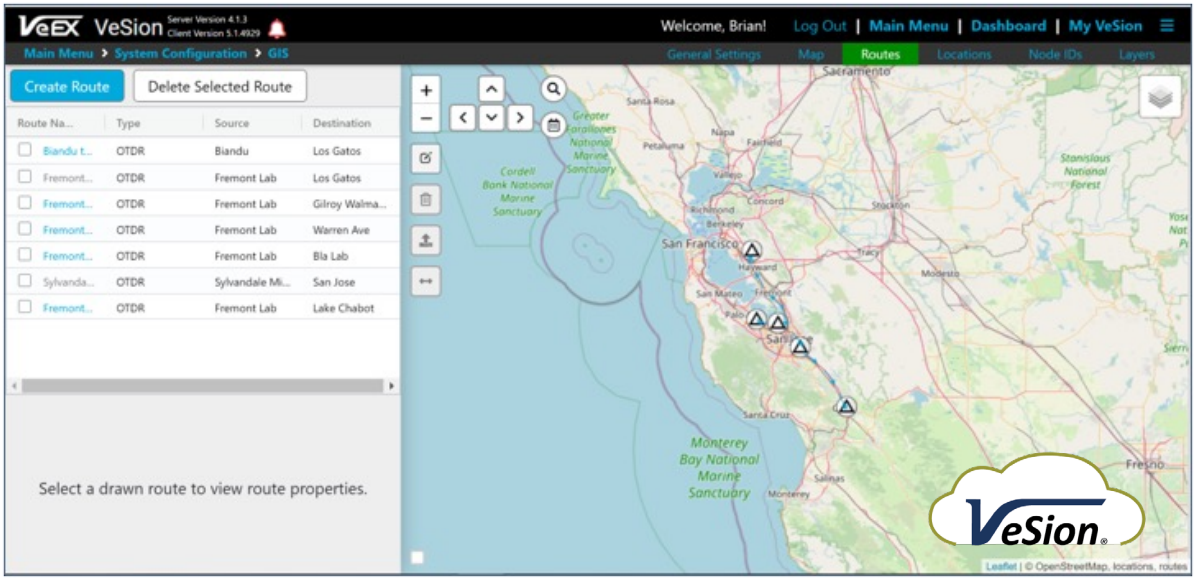


Optical distance and actual physical distance are very much influenced by cable slack in manholes and aerial routes – these coiled-up cables left intentionally for repair purposes contribute to fault distance uncertainty. The slack difference makes it difficult for technicians to identify the fault location precisely. VeEX's trace/GIS split view along with a unique Landmark feature enables the provider to document optical to physical route differences by inserting landmark references along the fiber route and SOR diagrams to improve location accuracy.



VeSion® and GeoServer

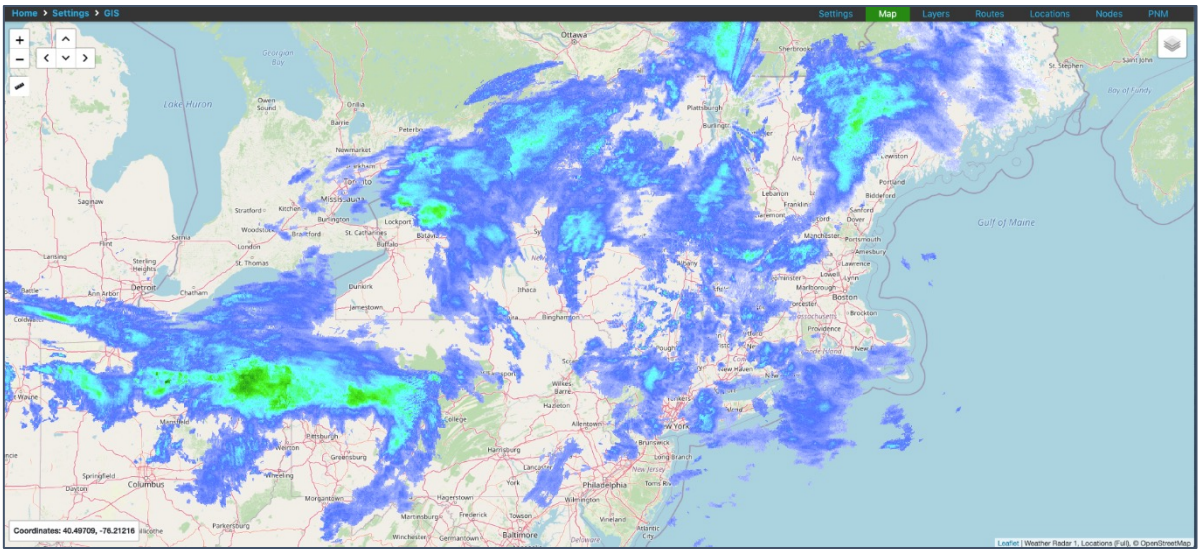
VeEX offers both integrated and 3rd party GIS support options for its VeSion based fiber monitoring system. The VeSion eco-system employs a GeoServer allowing you to document your fiber route or infrastructure directly - or you can import spatial information (KML files) and other network attributes from compatible 3rd party vendor systems such as OSPInsight, IQGeo or Google Earth. GeoServer also works with freely available maps such as OpenStreetMap or any proprietary mapping data provided by the user.



Web Map Service (WMS), an industry standard open protocol implemented by most major GIS providers is also supported - this allows you to integrate environmental data such as geography and weather conditions to your visualizations.

Severe weather events are occurring at an alarming rate and the frequency and duration is expected to increase due to the effects of climate change. Adverse weather events such as hurricanes, floods, ice storms and more leave a trail of devastation often impacting fiber networks which serve thousands, if not millions, of people.

VeEX's embedded GIS technology equipped with dynamic Web maps make it possible to display and correlate real-time weather information versus network outages – this information is immediately accessible to network managers and fiber technicians using their smartphones, tablets, and laptop computers. Web maps enables service providers to predict possible disruptions based on weather events, buying them valuable time to react and restore service in an organized and timely manner. Relying only on call centers to respond to customer complaints concerning outages, occupies a lot of costly human resources.



VeEX Fiber Monitoring System

The Key Components

Remote Test Unit (RTU) – comprises the OTDR hardware and software that performs the optical fiber measurement. Available in 1625nm or 1650nm filtered or 1310 or 1550nm unfiltered versions up to 45dB dynamic range

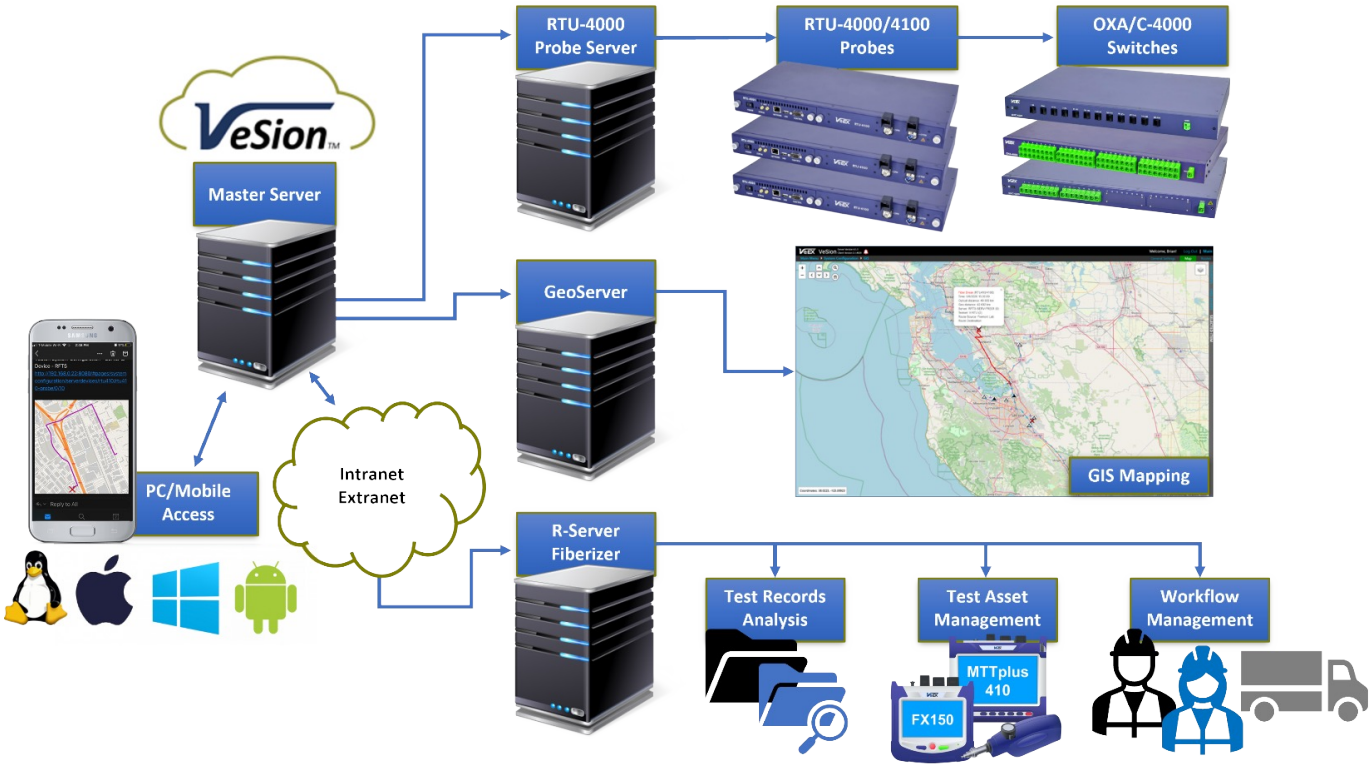
Optical Switch – enables connection between the RTU and multiple fibers under test. Optical switches can be cascaded and/or equipped with SCA, LCA or MPO-A connectors to support very high fiber counts. Select VeEX switches offer built-in FWDM capability simplifying installation and eliminating cable routing errors, minimizing rack space requirements while also reducing optical loss.

FWDM – optical coupler combining the RTU test signal with live traffic onto the fiber to be monitored. Required for out-of-band, in-service fiber monitoring at 1625nm or 1650nm ITU-T wavelengths.

Passive Reflector – reflects the OTDR's test wavelength only and serves as demarcation device. Used for PON construction and monitoring, to identify service handoff points of individual monitored ONT/ONUs, and/or to protect remote sensitive network equipment during live monitoring.

Servers - Depending on network complexity, service providers can choose to deploy test probes (RTUs) and optical switches at a central test location or at strategic points throughout their optical network. VeEX's VeSion server architecture supports both centralized or de-centralized architectures and manages system information and configuration.

- **VeSion Server** - continuously polls RTU measurements, comparing live test data with baseline traces. Any deviations are flagged immediately, triggering powerful alarm management functions and alerts. SNMP and other protocol services support northbound communications and integration with provider's Network Management System (NMS).
- **Test Probe (RTU) Server** – controls up to 75 individual fiber test probes, including measurement setup, monitoring cycles and optical switch configurations.
- **Geo-Server®** – supports GIS functions to pinpoint fiber cuts geographically and allows users to create and document fiber routes using spatial information (KML files). Geo-server adds value to the fiber monitoring system but is not required for the system to operate.
- **R-Server®** – Workflow and Asset Management system to manage teams of technicians, test equipment inventory, archive test results, create reports, streamline workforce operations, and test procedures. R-server works independent of the VeSion server architecture - although it is not required for the system to operate, it adds great value to the fiber monitoring system and repair/restoration workflow.
- **Fiberizer®** - embedded access within the R-server, serves as a repository for fiber test results including OTDR LinkMap and SOR files. Fiber traces can be analyzed or organized into custom collections for record keeping. Fiberizer adds value to the fiber monitoring system but is not required for the system to operate.

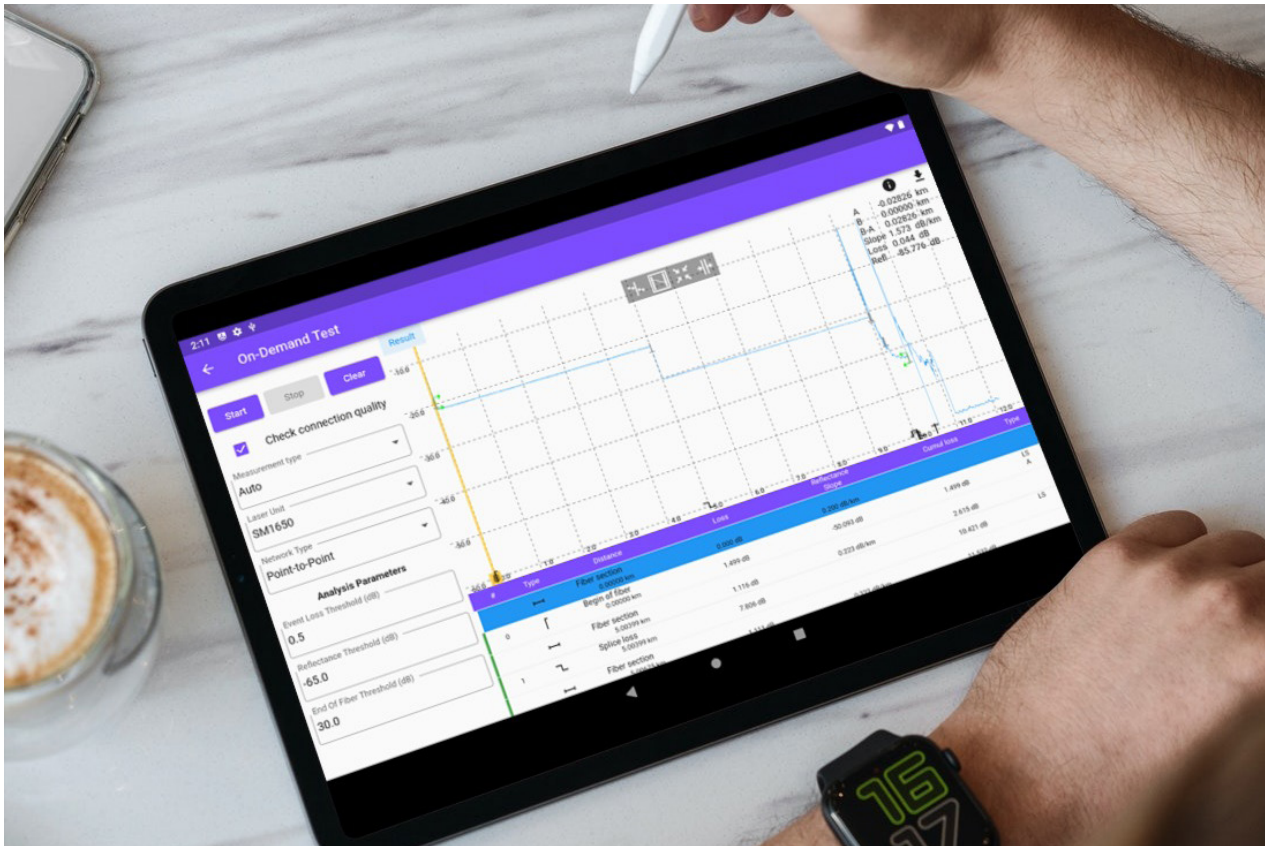


System Accessibility

Web Access - Anywhere, Anytime

Managers and field technicians often have to make informed decisions regarding fiber cuts while on the road or when away from the office or network operations center (NOC). The ability to access the monitoring system online to perform an on-demand test or retrieve alarm information greatly expedites troubleshooting including dispatching repair crews to minimize network downtime.

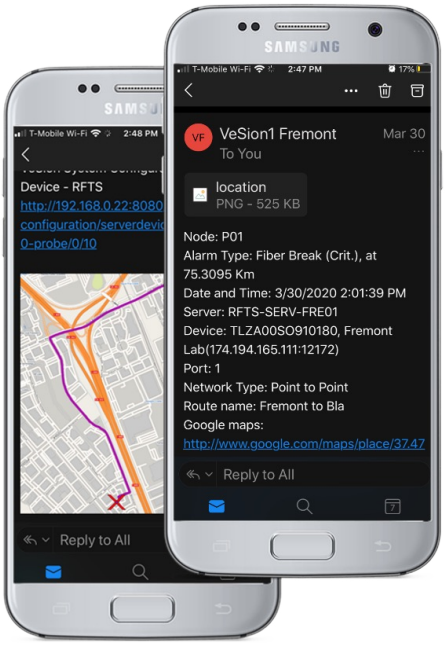
VeSion along with its GIS applications employ a rich collection of HTML5 resources enabling remote mobile access to the monitoring system via any available internet connection using a laptop PC or mobile device irrespective of operation system or browser type.

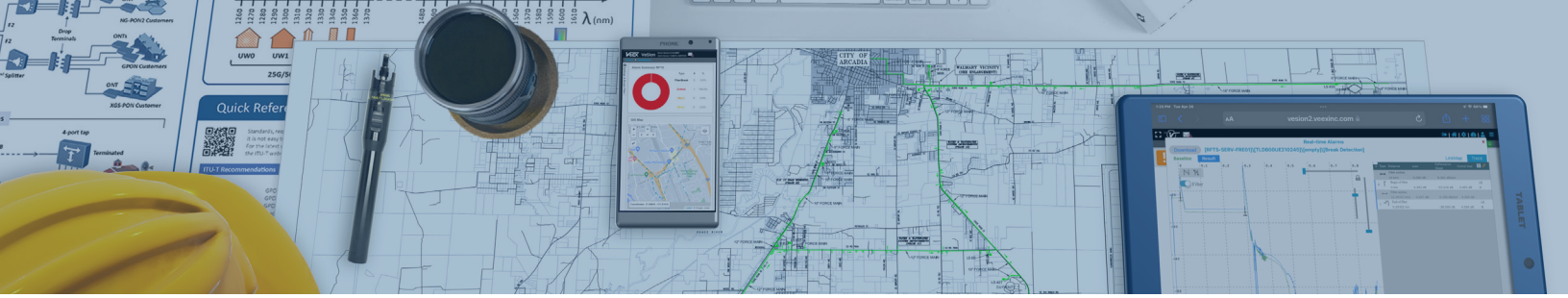


Enabling an Agile Response

VeEX's fiber monitoring system enables service providers to quickly disseminate fiber alarm information to both internal and external stakeholders so that responsible teams can assess the point of failure and take effective decisions regarding service restoration. Key capabilities include:

- Outage Information - displays fiber cut details with geo-coordinates, map hyperlink, date, time, and route information
- Automatic alarm notification – alerts sent via e-mail, text or through the provider's workforce management system
- Operations dashboard – monitors outages and restoration activities analyzing their customer impact
- Real-time integration with other monitoring systems – correlate fiber outages with Ethernet and RF networks
- Workforce Management - interfaced with VeEX's R-server, network assets and active crew locations can also be displayed to prioritize incident response





The VeEX Total Commitment

Support Services

VeEX offers a variety of services to ensure the fiber monitoring solution meets customer requirements and that the implementation goes as smoothly as possible. To achieve this objective, the following services are offered:

System Evaluation and Assessment - our experienced team of field application engineers work diligently with customers worldwide to fully understand their network architecture, fiber counts and distances to be monitored – this enables us to propose the best and most economical solution for current needs and future expansion.

Installation and Commissioning – each project is managed carefully from start to finish by qualified fiber and network experts ensuring each monitoring system performs as required and that integration is as seamless as possible and not too disruptive to daily operations. This includes initial assistance benchmarking the system and preparing proper fiber baselines in order to limit false alarms.

Training – several on-site or remote training options are available. We evaluate and consider the skill sets available and necessary to operate the fiber monitoring system effectively and propose a curriculum that meets customer expectations. These options include a "Train the Trainer" program so users can educate their own resources in order to maximize the features of the system.

Maintenance – we conduct scheduled system check-ups and offer software upgrades to fiber test probes and servers as necessary to ensure the monitoring system performs as intended and that new features enhancing the overall operation are implemented. Flexible and budget friendly software licensing options support licenses and subscriptions needed for current and future business requirements.

Repairs – the monitoring system has been designed to operate reliably for many years without calibration. In the unlikely event of failure due to abnormal operating conditions and/or significant environmental events, loaner RTU and switch modules are available to minimize downtime.

Conclusion

Your Choice, You are in Charge

VeEX fiber monitoring systems are totally scalable based on customer applications and budget. Solutions can range from a single, standalone RTU that monitors a few fibers only, to a complete VeSion eco-system supporting thousands of fibers using multiple RTUs and optical switches. Ultimately the choice of monitoring system and solution depends on you, but we are at your disposal to offer expert opinion and guide you through that important decision-making process.

About VeEX Inc.

VeEX Inc., a customer-oriented communications test and measurement company, develops innovative test and monitoring solutions for next generation telecommunication networks and services. With a blend of advanced technologies and vast technical expertise, VeEX products address all stages of network deployment, maintenance, field service turn-up, and integrate service verification features across copper, fiber optics, CATV/DOCSIS, mobile 4G/5G backhaul and fronthaul, next generation transport network, Fibre Channel, carrier & metro Ethernet technologies, WLAN and synchronization. Contact us to learn more.

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