Fiber Optic Sensing: New Applications and Revenue Opportunities for CSPs and Fiber Providers in North America

Unlocking the Full Potential of Fiber Infrastructure

With Commentary from Dr. Paul Dickinson,
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Summary

Fiber-optic cables are evolving beyond their traditional role as data conduits to become sophisticated distributed sensor networks. This multi-functionality provides Communication Service Providers (CSPs) and fiber infrastructure owners with situational awareness, allowing them to monitor their networks and other infrastructure in real-time, enhance physical security, and develop new revenue streams through sensing-as-a-service offerings.

By leveraging existing fiber deployments with specialized interrogator units, providers can detect vibrations, temperature changes, and strain along conduit and fiber routes both above and below ground, effectively creating a "nervous system" for physical infrastructure, "listening" and detecting anomalies before they become impactful.

This document explores the practical applications and business opportunities of fiber optic sensing technology for Communication Service Providers, highlighting how this innovation can transform standard telecom fibers into valuable multi-purpose assets.

Fiber Optic Sensing 101: Turning Fiber Cables into Sensors

Fiber optic sensing harnesses the physical properties of light within optical fibers to detect environmental changes along the cable's path. When laser pulses are sent down a fiber, a tiny fraction of light scatters back. By analyzing this backscattered light, sensing systems can measure variations in vibration (acoustics), temperature, or strain continuously along the entire cable length, effectively transforming the fiber into thousands of distributed sensors spanning many kilometers.

Distributed Acoustic Sensing (DAS)

Turns a spare fiber into a real-time microphone array, detecting and pinpointing vibrations and acoustic events along 50+ km spans with high spatial resolution. This allows for situational awareness and identification of activities like digging, vehicle movement, or physical tampering.

Distributed Temperature Sensing (DTS)

Measures temperature at every meter of fiber, immediately identifying "hot spots" or thermal changes along utility lines or in data center conduits. This capability is crucial for detecting potential fire hazards, equipment overheating and for monitoring conductor temperature for power grid optimization.

Unlike traditional sensor networks requiring numerous individual devices, fiber sensing is passive and continuous, only requiring an interrogator unit (a specialized laser/receptor device) as part of the fiber path. Advanced signal processing, often enhanced by machine learning, interprets the backscatter signal to classify event types and pinpoint their precise locations.

> "A conduit and fiber cable that's previously been used just for telecom becomes a very valuable asset" when used for distributed sensing.
>
> — Paul Dickinson, Founder and Principal at Smart Infrastructure Solutions and Chair of the FOSA Advisory Committee

With nearly 92 million kilometers of fiber installed in the U.S. and Canada by 2022, and federal, state and provincial programs funding new deployments, CSPs are increasingly viewing their fiber networks as multi-purpose infrastructure. As Dickinson notes, "The telecom industry is in a fantastic position to benefit not only for their networks, but also their adjacent utility assets." This positions communication service providers at the forefront of a technological revolution that transforms passive infrastructure into active sensing networks.

Enhancing Network Reliability and Maintenance

One of the most immediate applications for fiber sensing is protecting and monitoring the CSP's own network infrastructure. Telecom operators can deploy sensing to gain real-time awareness of physical issues affecting their fiber plant, enabling faster response and even prevention of outages.

Rapid Fiber Break Detection

Sensing systems can pinpoint fiber cut locations within minutes instead of hours, allowing field teams to dispatch exactly where needed. This shortens repair times, minimizes downtime, and is especially valuable for mid-mile and transport fiber as well as subsea cables where repair costs and outage impacts are high.

Preventative Maintenance

By continuously measuring strain, operators can identify segments of fiber that are overstressed or degrading due to age, ice accretion, interference by trees, and so on, before they fail. This enables proactive maintenance and provides evidence to hold third parties accountable for damage.

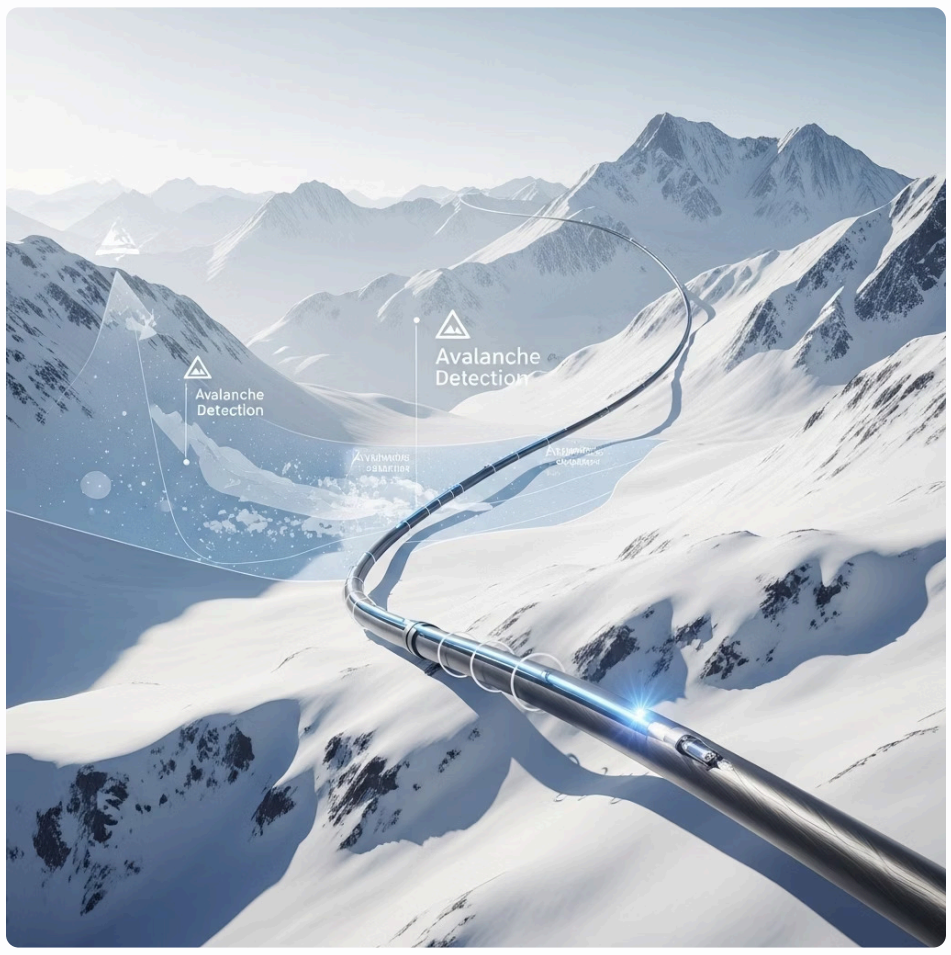
Digging Alerts

DAS systems recognize vibrations from excavation near cables, triggering immediate warnings before a cable is cut. With U.S. infrastructure damages from excavation estimated at $30 billion annually, this "dig once" early warning system protects not only telecom assets but adjacent utilities. The outcomes are amplified with the integration to single point of contact "One Call" systems.

Environmental Hazard Detection

Fiber networks often traverse harsh or remote environments where they can be exposed to natural hazards. Distributed sensing provides an added layer of awareness for such scenarios:

- **Seismic vibrations** for early warnings of earthquakes or landslides
- **Detection of undersea earthquakes** and tsunamis via ocean-floor cables
- **Sensing of rockfalls, avalanches**, or heavy storms that might threaten infrastructure



In a recent deployment in Utah's mountainous canyons, telecom fiber was used to detect avalanches in real time, providing highway authorities early warning to close roads and protect travelers.

By integrating these environmental alerts, network operators can respond faster to natural events that might damage their cables or affect service. Temperature spikes along a fiber could indicate a nearby fire or overheating equipment, which a DTS system would immediately flag, allowing for preventive action before catastrophic failure occurs.

Strengthening Physical Security and Data Integrity

Communications infrastructure is a critical asset that needs protection from intentional tampering or unauthorized access. Fiber optic sensing offers unique tools to bolster physical security for network operators and their clients.

Fiber Intrusion Detection

Optical intrusion detection equipment can surveil up to 100 km of fiber and immediately detect disturbances or vibrations - both along the cable and within the right of way proximity to the cable as well . This provides visibility into any attempts to access or tamper with fiber links - whether it's a malicious actor clipping onto a line or even an "overzealous groundhog," gnawing at a buried cable or conduit.

For data center operators and enterprises leasing fiber, such monitoring is invaluable. Service providers could deploy these systems on sensitive routes and offer a "secure fiber" service, guaranteeing clients immediate alerts to any physical intrusion on their circuits.

Perimeter and Facility Security

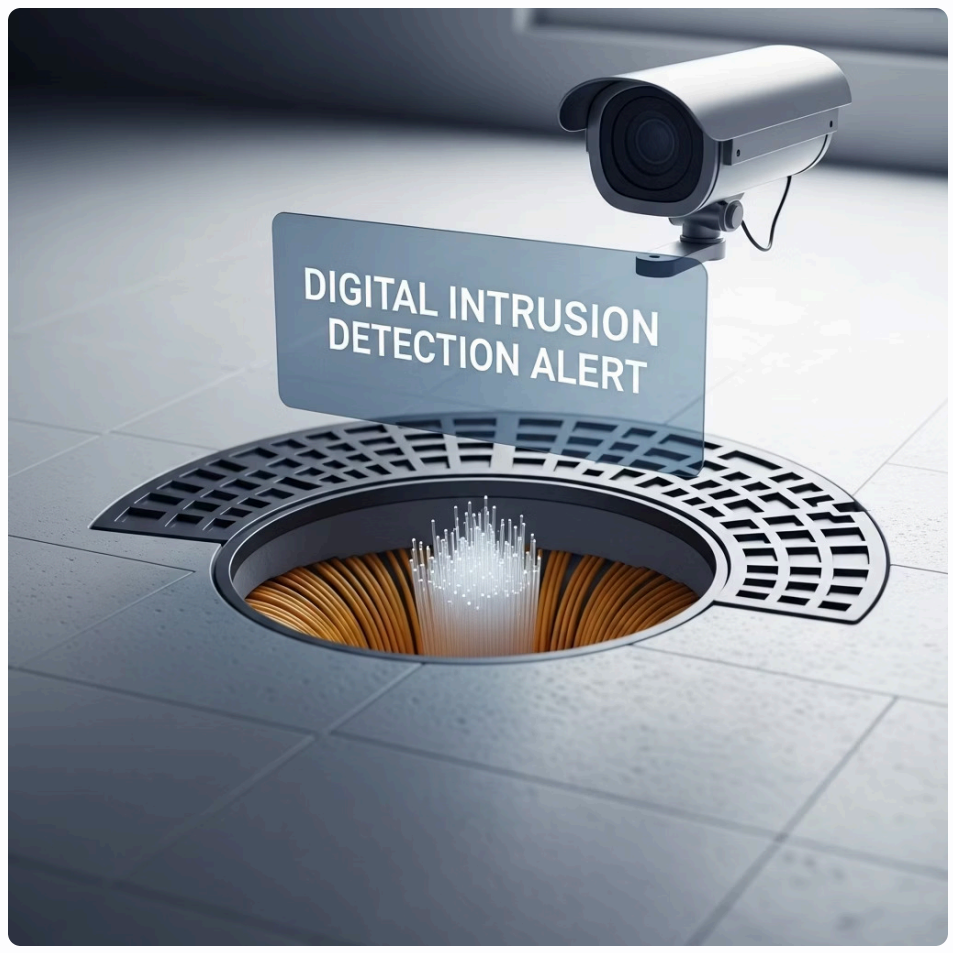
Fiber sensing can safeguard facilities by detecting activity around the fiber. Perimeter intrusion detection systems (PIDS) use fiber laid along fences or buried around a property to detect footsteps, vehicle movement, or digging.

Fiber-based PIDS are already used to protect critical infrastructure like power stations, military bases, and border lines. A CSP could collaborate with government agencies to utilize existing fiber runs along border regions as part of a "smart border" solution.

Preventing Cable Theft and Vandalism

In some areas, fiber optic cables (especially in remote or rural rights-of-way) face threats from vandalism or theft. Fiber sensing offers a deterrent and detection mechanism:

- If someone starts to excavate a cable for theft, the DAS system will detect the digging immediately
- Attempts to deliberately cut the cable or conduit produce a distinctive acoustic shock that can be detected seconds to minutes before the cable goes dark
- Documented cases show fiber surveillance systems detecting people opening handholes, vaults or manholes to access cables, enabling security teams to catch perpetrators in the act. Alerts can also be tied to other monitoring systems, such as cameras and can be used to trigger autonomous drones to be deployed for physical inspection.



This capability is highly relevant along long fiber routes in North America, such as isolated highway ducts or railroad-adjacent fiber where response times by law enforcement might otherwise be slow.

By advertising that their fiber routes are "alarmed" with sensing, service providers can dissuade tampering and reassure customers of improved reliability and security. The fiber essentially self-monitors its own physical integrity, creating a comprehensive security solution that protects both the infrastructure and the data it carries.

New Revenue Opportunities: Fiber Sensing as a Service (FSaaS)

Perhaps the most exciting aspect of fiber optic sensing for CSPs and fiber owners is the chance to unlock new services and revenue streams beyond residential and commercial connectivity. Many fiber providers have extensive cable networks along public infrastructure that can be leveraged to provide valuable data and insights to other industries and vertical markets.

By deploying sensing equipment on existing fiber and packaging the insights as a service, network operators can become solution providers in sectors like transportation, energy, and smart cities. **This transformation from pure connectivity provider to data and insights provider** represents a significant business opportunity with relatively low incremental costs.

Smart Traffic Monitoring

Real-time vehicle detection, speed monitoring, and accident alerts

Smart City Applications

Gunshot detection, infrastructure monitoring, and pedestrian counting

Railway Safety

Track and wheel condition monitoring, train tracking, and hazard detection

Pipeline Monitoring

Leak detection, third-party intrusion alerts, and ground movement sensing

Enterprise Security

Fiber intrusion detection and perimeter monitoring services

These applications allow CSPs to monetize their fiber assets in new ways, creating recurring revenue streams from sectors beyond traditional telecommunications. The value proposition is compelling - customers gain access to sophisticated monitoring capabilities without having to deploy their own sensor networks, while CSPs maximize the return on their existing infrastructure investments, sometimes defraying the costs of greenfield rural builds or brownfield expansions.

As fiber networks continue to expand across North America, particularly through federal, provincial and state funding initiatives discussed earlier, the potential for these multi-use applications grows. Forward-thinking providers are already exploring partnerships with transportation departments, energy companies, and municipal governments to develop these new service offerings.

Smart Traffic Monitoring and Road Safety

Fibers running beneath roadways can be used as continuous traffic sensors, offering a complementary alternative to installing thousands of physical traffic detectors, cameras or microwave sensors. Distributed acoustic sensing along highways can monitor vehicle movement in real time with low latency, detecting the speed and flow of cars, helping to identify heavy trucks, and even capturing events like accidents or hard braking, avalanches and rockfalls - events with possible catastrophic live impacting outcomes.

Real-World Implementation

Luna Innovations recently partnered with the Utah Department of Transportation to use an existing roadside fiber to monitor traffic in mountain canyons. The system provides real-time data on average speeds and alerts the DOT to slow-downs or stops, integrating directly into the state's traffic management dashboard.

It even gave early warnings of avalanches and rockfalls impacting the roads, allowing quick closures and coordination with emergency responders. Similar pilot deployments have rolled out in states like Georgia, Florida, and Nevada.

For telecom companies, this represents a template: by using fibers along major corridors, they can offer "smart highway monitoring" services to transportation agencies with broad coverage and no new sensors in the field.

City planners and highway authorities in North America are keen on improving traffic flow, reducing incident response times, and even enabling future autonomous vehicle infrastructure. Fiber sensing data (e.g., high-resolution traffic counts, incident alerts with exact location) can feed into those initiatives.

A CSP could contract with a city to provide 24/7 traffic analytics as a managed service, possibly funded by smart city grants or federal infrastructure programs. The U.S. SMART grant program specifically encourages innovative technology for transportation, creating a potential funding source for these deployments.

Railway Monitoring and Safety

Many telecom providers' fiber routes parallel railway lines, often using railroad rights-of-way. These fibers can be tapped to enhance railroad safety and operations. Research backed by the U.S. Federal Railroad Administration has confirmed that fiber acoustic sensing (sometimes called Fiber Optic Acoustic Detection, FOAD) can continuously monitor rail conditions and detect critical events.

Broken Rail Detection

Fiber sensing can identify rail breaks or cracks by detecting the distinctive acoustic signature they produce when trains pass over them. This early warning can prevent derailments and improve safety.

Real-Time Train Tracking

The fiber can detect the sound of a train's wheels, allowing precise tracking of position and speed without additional trackside equipment. This improves operational efficiency and scheduling, complimenting other IoT solutions.

Rolling Stock Health

Flat wheels or wheel defects create distinctive vibration patterns that can be identified by fiber sensing, allowing maintenance to be scheduled before catastrophic failures occur.

Track Intrusion Detection

The system can detect trespassers, potential vandals, vehicles at crossings, or unauthorized access to tracks, enhancing safety and security along the rail corridor.

A single fiber running along the tracks can pick up the acoustic/seismic signatures of various rail conditions. In effect, it's like having a stethoscope on the entire railway. Studies have shown that if existing fiber cables along tracks are utilized, fiber sensing could cut monitoring costs by 62–72% compared to traditional detectors, by serving several purposes with one system.

Business Opportunity

Telecom providers can partner with railroad companies to offer "rail monitoring as a service." For instance, a telecom might install DAS units on new or existing telecommunication fiber that run along a busy freight corridor, providing the railroad with real-time alerts for any anomalies on the track ahead of a train while enhancing security, safety and value to their critical fiber transport routes.

Fiber sensing systems can also detect trespassers or unauthorized people near tracks and identify landslides or rockfalls in real time.

Given the critical importance of rail safety in North America, and recent pushes for better monitoring technology, fiber sensing is an emerging opportunity that fiber infrastructure owners should be ready to capitalize on. The technology not only helps avoid accidents but also improves operational efficiency, allowing higher train frequencies when you can ensure the track is clear.

Pipeline and Utility Corridor Monitoring

Oil, gas, and water pipelines are another domain where fiber sensing has proven its worth, and telecoms can contribute significantly. Distributed fiber sensors can detect minute changes associated with pipeline leaks (acoustic vibrations from escaping fluid, or localized temperature drops from a gas leak) long before traditional SCADA systems notice a pressure change.

1

Leak Detection

Fiber sensors can identify the acoustic signature of fluid escaping from a pipeline or temperature changes associated with gas leaks, providing immediate alerts with precise location information, preventing catastrophic environmental or life-safety issues.

2

Third-Party Intrusion Detection

The system can catch unauthorized digging, tapping, or construction activity above a pipeline, preventing accidental damage before it occurs - a leading cause of pipeline failures.

3

Ground Movement Monitoring

Fiber sensing can detect landslides, subsidence, or other ground movements that could threaten pipeline integrity, allowing preventive measures to be taken, including scheduling of required maintenance.

Many pipeline operators in North America have started embedding fiber optic cables along new pipelines specifically for leak detection and security. For instance, Canada's Enbridge and TC Energy have projects to validate high-fidelity fiber optic leak detection along oil pipelines in Alberta and along gas pipelines, respectively.

Implementation Models

- **Fiber Leasing:** CSPs can lease dedicated fibers to pipeline owners for their own sensing use
- **Turnkey Monitoring:** Telecom monitors the fiber and feeds alerts to the pipeline operator
- **Premium "Fiber Surveillance":** Add-on service to existing fiber leasing agreements

Telecom providers, especially those with long-haul fiber crisscrossing energy corridors, can offer their fiber routes for these purposes. By installing sensing interrogators, the same fiber that carries communication to remote pump stations could also serve as a continuous leak detector.

One case study notes that millions of kilometers of fiber already run alongside pipelines worldwide, and these existing fibers can be immediately "transformed into high-fidelity sensing assets" with the right DAS technology. The benefit for pipeline companies is enormous: instant leak alarms with precise location means faster shutdowns and less environmental damage.

In addition, power utility companies are using fiber sensing to monitor electric grid infrastructure. Fibers run along transmission lines can measure real-time line temperature (to dynamically manage grid load) and even detect downed lines or flashovers by the acoustic signature. A number of North American utilities already partner with communications companies for fiber; adding sensing capabilities could enhance grid reliability and open new business between telecoms and utilities.

Data Center Security and Enterprise Services

Beyond internal use, telecom operators can package fiber sensing for enterprise customers as a value-added service. This creates new revenue streams while addressing the growing security concerns of data-intensive businesses.

Intrusion-Detected Links

A bank, hospital, or hyperscale data center that buys dark fiber or wavelength services could be offered an "intrusion-detected link" where the carrier's fiber sensing system will immediately alert if the fiber is physically disturbed. This caters to customers with high security requirements (financial, government, etc.), providing peace of mind that any fiber tapping attempt or accidental damage will be flagged in real time.

Since many enterprises do not have the in-house expertise for such specialized sensing technology, they would look to service providers to deliver it as a managed solution.

Data Centre/Campus Perimeter Security

Data Centres and Large campus networks (universities, corporate headquarters) could deploy fiber sensors for perimeter monitoring, detecting unauthorized presence, access or suspicious activity around the property.

Critical Infrastructure Monitoring

Fiber sensing can detect if someone opens a handhole or disconnects a critical fiber patch, providing immediate alerts for potential tampering with network infrastructure.

This also includes critical fiber routes between data centres or to Internet Exchange and Peering points.

Data Integrity Assurance

For highly sensitive data transmission, fiber sensing provides an additional layer of security by ensuring the physical integrity of the transmission path.

Smart City Applications

As cities become smarter and more connected, fiber sensing has a role to play in public safety and municipal services:

- **Gunshot Detection:** Metropolitan fibers could detect gunshots or explosions through acoustic signatures, complementing microphone-based systems but covering a much larger area
- **Infrastructure Monitoring:** Fibers can monitor vibrations from heavy traffic that might damage bridges or historical buildings
- **Pedestrian Analytics:** Fibers under pavements can count pedestrians or detect if someone falls
- **Structural Health:** Early detection of unusual vibration patterns that might indicate tunneling or structural failures in subways

Telecom companies, as the owners of these fibers, are in an excellent position to partner with city governments to deliver such smart city sensor data. By doing so, they transition from simply bandwidth providers to essential data providers for city operations. This could be supported by public funding or smart city grants, making it financially attractive to deploy.

The Fiber Optic Sensing Association has emphasized these possibilities, noting that integrating fiber sensing with IoT and smart city initiatives will unlock new use cases that we are just beginning to explore.

Implementation Considerations and Future Outlook

Deploying fiber optic sensing in a telecom environment requires careful planning, but recent advances have lowered barriers significantly. Compatibility with existing fibers is a key factor: existing solutions have shown that standard telecom fibers (including ones already carrying live traffic) can be used for sensing by operating in different optical bands, avoiding interference with data signals.

Fiber Compatibility Assessment

Evaluate existing fiber routes for sensing potential. In many cases, spare fibers in a cable or unused spectrum on a lit fiber can suffice, if the monitored asset is within reasonable proximity to the fiber

Future-Proof Network Design

When planning new routes, design with multi-use and proximity to capture FSaaS assets in mind. FOSA advocates adding extra fibers or fiber-friendly conduit in new builds, since the incremental cost is small compared to potential future value.

Data Management Strategy

The vast amount of data generated by continuous sensing networks is typically processed (AI/ML, filtering and analytics) remotely, with alarms, insights and other data delivered via API-based interfaces to the CSP. This will require integration into existing OSS and management systems.

Industry Momentum

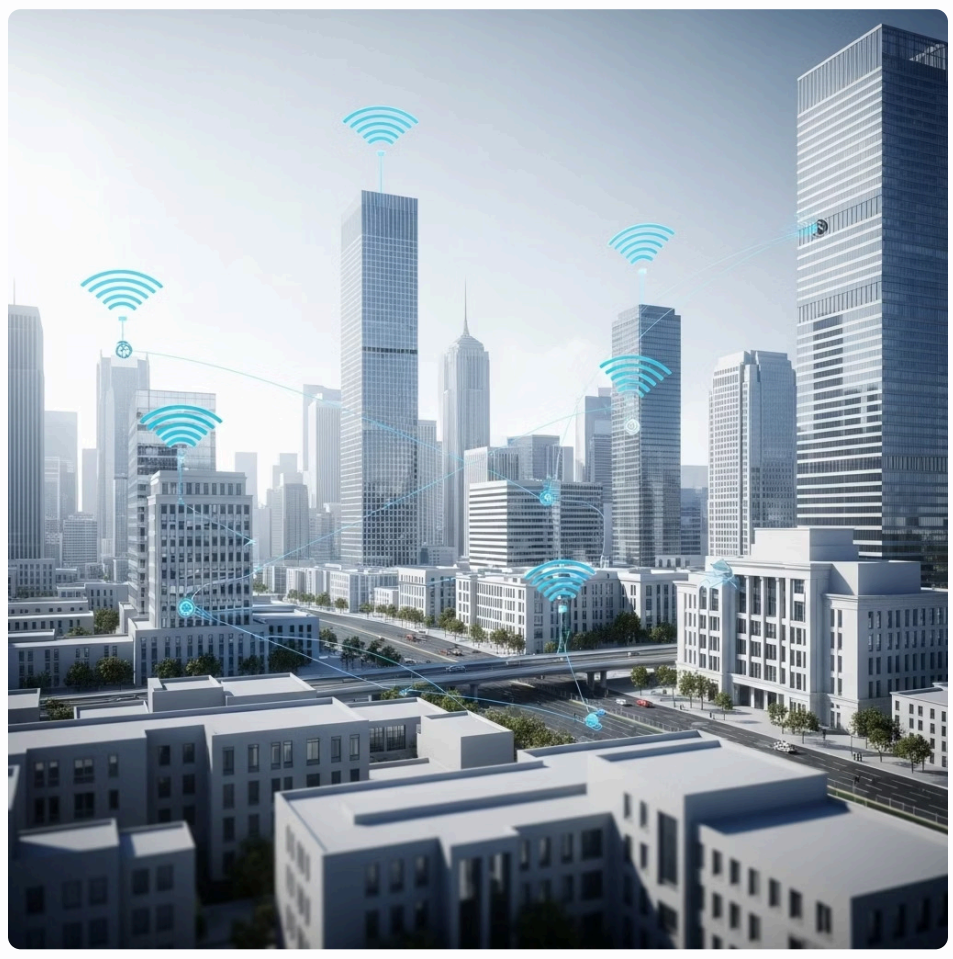
Looking ahead, the integration of fiber sensing into telecom operations in North America is likely to deepen. Major carriers are already investing in fiber monitoring for reliability (Verizon and other Tier 1 CSPs have shown interest in using advanced OTDR and DAS for network health), are active in standards bodies exploring how to best overlay existing systems, and some have begun offering commercial sensor services.

Competitive Advantages

- A provider that can say "our network can see problems coming and safeguard itself" stands out in reliability
- Offering to help city or industrial partners by sharing insights from fiber networks elevates providers beyond bandwidth suppliers
- Cross-sector collaborations (e.g., with transportation departments or energy companies) can unlock new funding sources and business models

For more information about distributed fiber optic sensing, please also see:

Fiberopticsensing.org and
SmartInfrastructureSolutions.biz



The Fiber Optic Sensing Association (FOSA), founded in 2017, has been actively promoting the technology and pushing for its inclusion in infrastructure policy and standards.

> "Distributed fiber optic sensing [is] the next big thing" alongside fiber broadband itself.

— Paul Dickinson, Founder and Principal at Smart Infrastructure Solutions and Chair of the FOSA Advisory Committee

Early deployments, from avalanche monitoring in Utah to leak detection on pipelines and train tracking systems, have demonstrated the feasibility and value of fiber sensing in the field. By embracing this trend, North American CSPs can future-proof their networks and play a key role in initiatives like smart cities, critical infrastructure protection, and climate disaster mitigation.

In a competitive telecom landscape, leveraging fiber in this new way can differentiate providers as innovative and solution-oriented. The convergence of communications and sensing is well underway, heralding a new era where a fiber cable is not just a conduit for information but a source of rich data about our physical environment. Service providers who capitalize on these applications and opportunities stand to improve their operational excellence and unlock fresh avenues for growth in the years ahead.

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