# Modern applications of total network awareness

**Nate Lindsey, Mark Englund**
*FiberSense Ltd, Mosman, Australia*
*nate.lindsey@fiber-sense.com*

**Abstract:** Recent advances in distributed fiber sensing allow new forms of total network awareness and intelligence to be added to layer 1 of optical fiber networks for material improvements in network protection, performance, resilience, and maintenance.

## 1. Introduction

Considerable progress has been made in software defined networking where all modules of the network transmit and receive section of a network are now visible in the network management layer. The one element that has remained invisible to the network management layer is layer 1, the fiber cables that run in to public spaces on land and across oceans, until now.

Distributed fiber sensing (DFS) is a technology that allows the entire length of the fiber cable to be monitored in a gapless view. Distributed acoustic sensing (DAS) as a particular form of DFS, provides extraordinary awareness capabilities that allow the monitoring system to sense beyond the fiber cable to the objects and events occurring around the optical fiber cable.

Recent algorithmic advances have dramatically improved the quality and number of event and object detections and classifications that can be deduced from DAS data in real time. In particular, the ability to achieve low false positive and false negatives for events and object detectors against a city background is a key performance requirement for an effective application built on DFS data. The live feed of objects and events around an optical fiber cable can be used to form a live dynamic digital twin in map-based user interfaces for rapid and automatic mitigation of events on or proximate to the optical fiber cable. The range of objects and events that are relevant to the protection, performance, resilience, and maintenance are continuing to grow but include excavation, cable hauling in ducts, cable movement or perturbation, animal and pest activity, flood, fire, earthquakes, subsidence, electrical shunt fault, cable unearthing and cable strumming.

The real time event and object data feeds are placed in a broader context of data to arrive at actionable information a network operator can use to avert a potential network outage event before it happens, for example excavation damage.

## 2. Applications

### 2.1. *Terrestrial cable excavation damage prevention and recovery*

Excavation damage is one of the leading causes of layer 1 outages in a network. In the event there was an excavation related network break there are several operational advantages of having a DFS overlay, including;

- Rapid determination of layer 1 being the cause of the NW outage, saving time in diagnosing the issue and generating a restoration solution;
- Precisely locating the break immediately, which enables the restoration crew to be directed to the point of layer 1 failure;
- Culpability hand off – with instant awareness of a break event by precise location, the likelihood of getting to the location while the excavation party are still present is high, leading to clear culpability hand off.

One of the primary causes of excavation related network outages is parties that have not registered their excavation activity with the other asset owners in that area. As a result, these “rouge excavations” are digging without accurate views of what linear infrastructure is below the digging site. Real time detection and classification of rouge digging can be delivered to the network operators field teams and an interdiction at the digging site can be carried out before the cable break event occurs.

A related benefit of real time interdiction is the deterrence effect that accumulates for excavation crews who learn that any activity is going to be visible immediately. The combination of network intelligence and culpability hand off generates a culture of higher standards to avoid excavation damage.

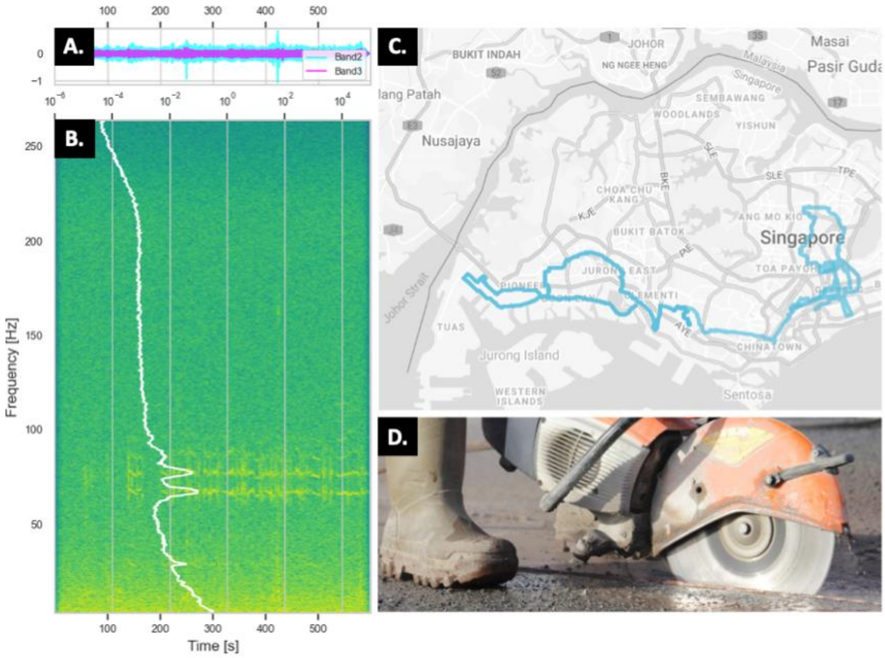


Fig. 1. DFS monitoring of excavation activity in Singapore. A.) Channel level data in two different frequency bands; B.) Spectrogram showing unstable tonal activity; C.) Network dashboard map; D.) Excavation type identified.

*2.2 Intelligent selection of path in diverse path networks*

The network threat posed to a given fiber cable segment evolves over time as a function of the activity type, proximity, frequency, and proximity to the cable path. DFS provides the unprecedented ability to quantify a risk quotient by accumulating a heat map of objects and events by cable path in a multi path view and advising the network management layer which path has the lowest risk of an outage from excavation damage.

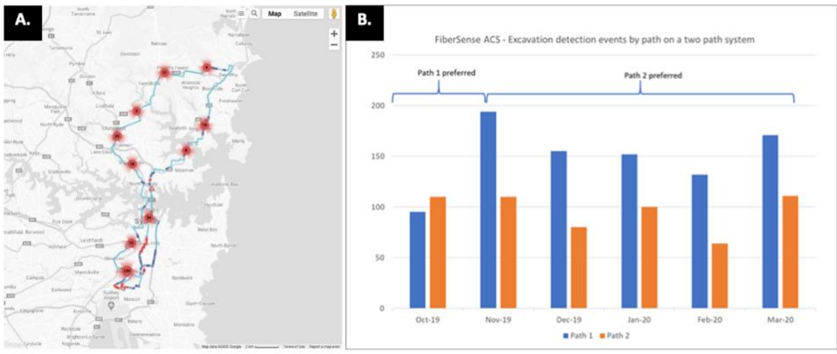


Fig. 2. A.) Network dashboard map showing DFS threat user interface in Sydney, Australia; B.) A real-time excavation detection event dashboard enables operations teams to readily capture relative risk quotients along redundant paths.

*2.3 Submarine cable outages from anchors, fishing nets, cable strum and shunt faults*

DFS has a wide range of protection and maintenance advantages on the high value submarine cable elements of international networks. With recent advances in the optical architecture of DFS systems, DFS can now be deployed over existing submarine cable without the need for a dedicated dark fiber strand.

70% of submarine cable breaks are anchor drag or fishing net related, occurring in the shore-end region from beach manhole to first repeater. To mitigate these hazards, DFS can provide real time awareness of ships and their movement patterns in the vicinity of submarine cables. Anchor drops, drags, and fishing net related threats can be identified, and a range of contact approaches can be made to the ship in the vicinity of the cable, even if their AIS beacons are disabled to avert a cable break and network outage. In the event a cable break did occur, the ship and ocean floor event can be tied together for culpability hand off for the first time. The precise location of the cable break and the nature of the break is a significant advantage in accelerating network repair and return to service.

Additionally, DFS is now capable of detecting submarine cable strumming and cable unearthing events which are both know precursors to submarine cable failure. Maintenance activities can be queued to the precise location for mitigation. Submarine cable shunt faults can also be detected, classified, and located precisely resulting in rapid restoration compared to conventional approaches.

*2.4 Network condition monitoring*

As-built drawings provide a snapshot of network burial conditions, but these conditions evolve continuously and if not monitored can end up negatively impacting the health or value of an asset. Network terrain and soil condition information is expensive to obtain, especially in submarine cable networks. DFS captures the geophysical properties around and below the network, providing dense in situ characterization of soil conditions below the entire network. This stream affords network operators added asset context, complementing pre-commission geotechnical surveys and providing regularly updated path health information. As soil conditions change, due to subsidence, burial, seasonal freeze/thaw, rainfall and storm activity, these changes may be reflected in changing geophysical properties.

*2.5 Environmental event warning and management*

Network hazards posed by earthquakes, landslides, tsunami, and cyclones are a constant threat in many urban areas. Telecommunications networks generally perform well during earthquakes relative to gas, power and other utilities, but during major seismic events some path failure is expected. Using DFS, the peak ground acceleration along the network immediately provides feedback to network operators about the possibility of failure points. An added benefit of gapless, total cover grids is an extension of seismic networks into nearfield regions and offshore, providing 10-15x reduction in warning time for earthquake early warning in many earthquake hazard zones globally.

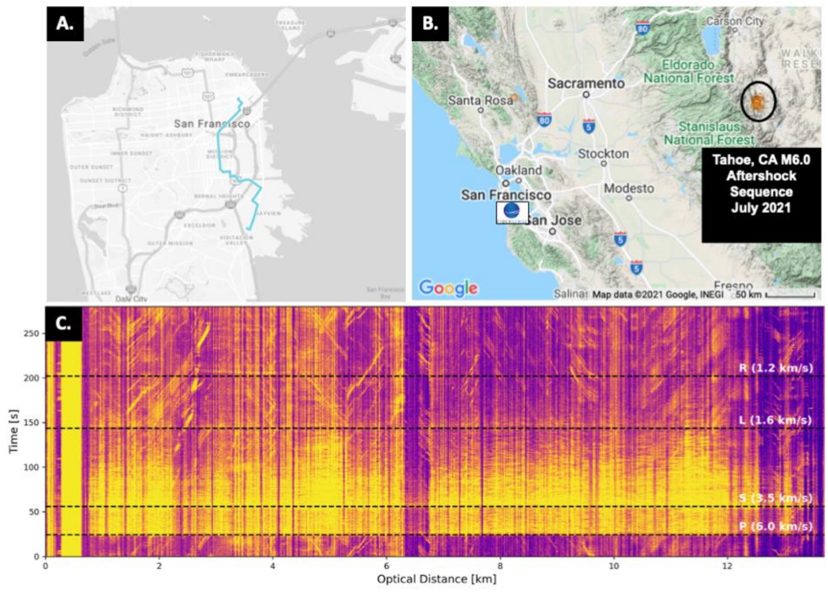


Fig 3. A.) Network dashboard map in San Francisco, CA; B.) Regional seismic activity map showing the Tahoe, CA M6.0 mainshock and aftershock sequence; C.) Array level data for M6.0 mainshock earthquake with main seismic phase arrival times overlaid.

## 3. Conclusion

Recent advances in DFS are enabling the entire physical layer and the surroundings of the optical fiber networks to be digitised in real time and brought into the total network management layer for the first time. There are several proven use cases that are commercially available which include detection, classification, and mitigation of threats due to excavation, cable hauling in ducts, cable movement or perturbation, animal and pest activity, flood, fire, earthquakes, tsunamis, subsidence, electrical shunt fault, cable unearthing and cable strumming.