UDOT
Keeping Utah Moving
TRANSPORTATION TECHNOLOGY

Utah Connected Webinar Series: Webinar #5 Questions & Answers

With over 3,250 miles of fiber, UDOT has one of the most robust, DOT-owned fiber optic networks in the nation. Distributed Acoustic Sensing (DAS), or “fiber sensing”, uses fiber optic cable buried alongside the road to monitor roadways in real time by detecting acoustic events in the vicinity of the fiber, like crashes, avalanches, vehicle speeds and travel times. This information can then be efficiently transmitted to UDOT’s Traffic Operations Center (TOC) where it can be used to assess traffic conditions, dispatch response vehicles or warn motorists of hazardous conditions. This UDOT fiber sensing project is one of the first in the nation. It aims to provide critical safety and maintenance information. This webinar provided an update on the project’s progress and highlight next steps. Some of the key takeaways included:

- Distributed Acoustic Sensing (DAS) uses fiber to bring situation awareness, monitoring traffic and detecting incidents, crashes, rockfall, and avalanches.
- Roadside fiber is critical to many use cases, including connected vehicle technology implementation.
- Real-time reporting through a robust DAS system can identify system outages within seconds.
- Acoustic sensing can detect crashes immediately, improving emergency response times that can help to save lives.
- Innovative utilization of DAS can maximize investments made in existing transportation infrastructure.

Q1: How were these fiber cables installed? Were they directly buried, or were they installed within conduits? What conduit material did you use, if so?

A1: They were installed inside conduit units. The conduits used were typical telecommunications continuous type conduit, composed of polyethylene.

Q2: What is the depth under the ground to deploy the fiber? Various states have various requirements for depth. Can this technology count vehicles?

A2: Most of our fiber is two to three feet deep. I can't speak to rules in other states. The technology can count vehicles.

Q3: How would you rank Fiber Optic tech vs Satellite communication for resiliency (danger to external harm)? For example, the satellites are proving very robust and no breakage of communication in the current war. Also, satellites are being developed with advanced sensing technology. What's the view of the fiber optics industry and the cost vs benefits applications?

A3: There are many categorizations of resiliency. The pros and cons of fiber optics vs. satellites is beyond the scope of the intention of the presentation. For the purpose of this presentation and the technology presented, the intention for "resiliency" is the ability to provide live detection for damage prevention, thus enabling the ability (through classified and rapid alerts), to stop damage before it happens.

Q4: Can the direction of traffic be determined from the waterfall video?

A4: The area of traffic counting is being actively investigated. The direction of traffic can be easily determined by the trajectory it creates on the waterfall.

Q5: How does it work with aerially installed fiber cable?

A5: Aerial fiber cannot be used for road monitoring as there is no route for the signal to couple into the fiber. Aerial fiber can be used for other applications; some areas that have been considered are for the detection of network 'flapping' - where the flow of information along a fiber gets interrupted.

Q6: Is fiber primarily picking up vibrations thru ground or thru air? Assuming ground, why would fence block it?

A6: Signals are primarily transmitted through the ground. Depending on the construction of the fence, or indeed any other solid object, between an event and the fiber, the signal may not reach the fiber with sufficient energy to be detected.

Q7: Can DAS be used with fiber optic cables that are deployed on the surface or aerial mounted? ie. for pipelines, fences, bridges, etc.

A7: Pipelines and perimeter fences are both active areas of DAS use. The application areas are different to those for road monitoring - we are primarily concerned with third-party intrusion and leak detection. Aerial mounted cables can be used for some niche applications - such as network 'flapping' and cable-cut detection.

Q8: I know Utah DOT is proactive in collaborating with private fiber optic companies. How much of existing fiber optic installations are able to be used for this type of sensing?

A8: We have fiber along many of our roadways, both urban and rural. Along major highways, like freeways, our fiber is often placed near the right-of-way fence which is too far away to be conducive for DAS. In smaller roadways, fiber is often at the roadway edge or, in some cases, under the pavement. Those are good candidates. As has been described, fiber type and placement make a difference. So even when the location is good, the fiber may not be adequately coupled to provide good response. I don't have a good, quantitative answer to your question, but we will have many areas where DAS could be used - mostly on smaller roads, and many where it will not be.

Q9: Has anyone had experience with a fiber installation running underneath the roadway, perpendicular to the direction of travel, and if so, would it be possible to get lane-by-lane volumes and speeds?

A9: Yes, count can be estimated if the fiber runs perpendicular under the roadway. The spatial resolution of the technology is linked to the overall monitored distance. Therefore, for typical lengths monitored of say 25 miles then 30ft is the resolution which wouldn't be good enough for lane-by-lane resolution. Single lane on / off ramps can be accurately counted though when monitoring long distance. if a shorter monitored fiber length is monitored then lane by lane counting could be possible

Q10: What was the delay between the events (avalanche) and the alert emails sent to UDOT personnel?

A10: Broadly speaking, the alert in the system was generated within 15 seconds of the first detections of energy we detected. Therefore, allowing 15 second latency for the email to be sent I would estimate the email was received within 30 seconds of the avalanche starting.

Q11: What is the cost per mile to install these systems?

A11: It is hard to identify a cost per mile because there are two components to an installation: 1) the cost of fiber installation (which is a per-mile cost) and 2) the cost of the interrogator hardware (which can monitor many miles of fiber. If the roadway being monitored is relatively short, the cost per mile will be high. If it is a long stretch, the cost will be relatively low. Another person has asked about overall cost. I will provide some additional insight in that response.

Q12: Under ideal conditions (depth and distance), how many lanes of traffic can be successfully detected by this technology?

A12: Using an existing fiber an installation within another state was able to monitor 4 x 4 lanes with a fiber that was buried at 1.5 ft and was uniformly within 10ft of the side of the interstate.

Q13: Can you please talk about the cost components of installation, integration, and data processing in more detail?

A13: On this project, UDOT invested about $500,000. We already had fiber in place in the canyons, so that cost isn't included (that is actually the beauty of the system - it makes use of existing fiber). This project included a lot of "research-type" efforts - developing new algorithms for avalanche detection and crash identification. We also spent considerable effort evaluating problems with the fiber installation. Optasense tells me that the cost of the equipment we purchased has gotten less expensive, as well. So, it is difficult to extrapolate the cost of this project to other installations. The value comes when the cost of continuous monitoring along a long corridor (up to 20 miles) can offset more frequent installation (including power service) of cameras and other sensors. We are still evaluating that cost / benefit scenario.

Q14: How much increase in strain sensitivity is expected due to future technology improvements in interrogators — should we expect longer fiber and shorter gauge lengths or are we physics limited?

A14: The Interrogator Units that were deployed for this project are intensity-based DAS. More advanced quantitative DAS could greatly improve the sensitivity that was seen in this deployment and provides us with a much greater range of tools to analyze and identify events. In general, yes, I would say that we haven't yet hit the limitations imposed by physics and so longer ranges and shorter gauge lengths are certainly possible.

Q15: What is the percentage of captured vehicles on the road?

A15: Within this project there were high percentages of captured vehicles (>90%) for the American Fork Canyon where the fiber position and installation were favourable and the canyon road was 1 x 1 lanes. For Big Cottonwood Canyon where the fiber install was backfilled with concrete the sensitivity was vastly reduced and the percentage of captured vehicles was very low. In our experience this has been an atypical fiber installation. To give an idea vehicle detection rates seen on multi-lane highways, sensing a uniform fiber install in a different state that was within 5 ft of the interstate edge we were able to see a significant percentage of captured vehicles across the 4 x 4 lane interstate. Traffic queues and congestion were easy to detect and track as they evolved.

Q16: Is ML or AI being considered for any research project planned or under execution, for the large data lakes created from the fiber optics (data acquisition system) to extract key messages or alerts in autonomous manner?

A16: Yes, ML or AI has been considered and is indeed implemented in other industries for detection algorithms. An example is within the rail industry where we use supervised ML for train detection.

Q17: Is the signal processing algorithms publicly available or proprietary?

A17: The signal processing algorithms are proprietary but there are a number of tap off points within some of the algorithms which are freely accessible. For example, the averaged vehicle speed algorithm can also tap off the instant vehicle speeds before any averaging is applied. The raw sensor data can also be tapped off in order to apply externally developed algorithms if this is desirable too.