CONGESTION AND INCIDENT MANGEMENT APPLICATIONS FOR DISTRIBUTED ACOUSTIC SENSING TECHNOLOGY – NZTA CASE STUDY

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Abstract

The Distributed Acoustic Sensing (DAS) System has the ability to convert a longitudinal fibre optic cable into an array of virtual microphones – allowing users to monitor long linear assets in real time and detect acoustic events in the vicinity of the fibre. This technology has the potential to detect and measure vehicle movements as well as traffic patterns, such as congestion or queuing, directly and in real time at any point along the fibre installation. A key feature of the technology is it can be retrofitted on to existing communications fibre optic cabling running adjacent to road sections making it attractive for busy roads or where traffic management overheads are prohibitive for conventional in road detection, such as with installing loop detectors. While the technology's primary detection capabilities are mature and operational in areas such as security and asset protection, this project will be exploring how to translate this in to operational road traffic and incident detection ITS application.

Main Text

The New Zealand Transport Agency (NZTA) has commissioned a project to install a fibre optic Distributed Acoustic Sensing (DAS) detection system in Auckland, New Zealand. The project will evaluate the potential benefits of the DAS technology's ability to sense sub-pavement and ground level acoustic signals generated by passing traffic for traffic monitoring purposes. The initial installation site will be along State Highway 1 heading north from the Auckland harbor bridge to the Johnstone's Hill Tunnels, a distance of approximately 40 km. The installation will utilize existing unused communications fibre to assess the potential operational benefits for traffic monitoring and incident detection as well as performance characteristics and installation methods of the system.

PRINCIPLE OF OPERATION

DAS converts a standard fibre-optic cable into a Distributed Acoustic (or Seismic) Sensor. An Interrogator Unit (IU) fires a laser beam into a fibre and the system tunes in to and measures back scatter reflections from naturally occurring imperfections in the fibre-optic cable (refer to Figure 1 DAS Technology Concept Diagram below).

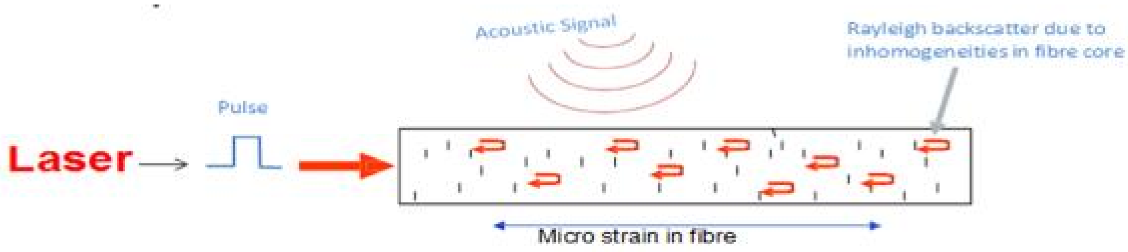

Figure 1 DAS Technology Concept Diagram

Acoustic or Seismic signals striking the fibre from local disturbances vibrate the imperfections and modulate the back scatter in the general location of the disturbance, which in turn is measured by the Interrogation Unit (IU).

The system uses DAS over single mode optic fibre (SMOF) cables. A SMOF cable transmits a single ray of light with very small dispersion of the light beam enabling interrogation over distances of up to 40 kms.

The Interrogation Unit passes the raw modulated disturbance signal on to signal processing functions and in turn on to higher level signature processing systems to determine the nature of the acoustic disturbance and to interpret and classify the output, for example a person walking or a vehicle traveling along (or adjacent to) the fibre.

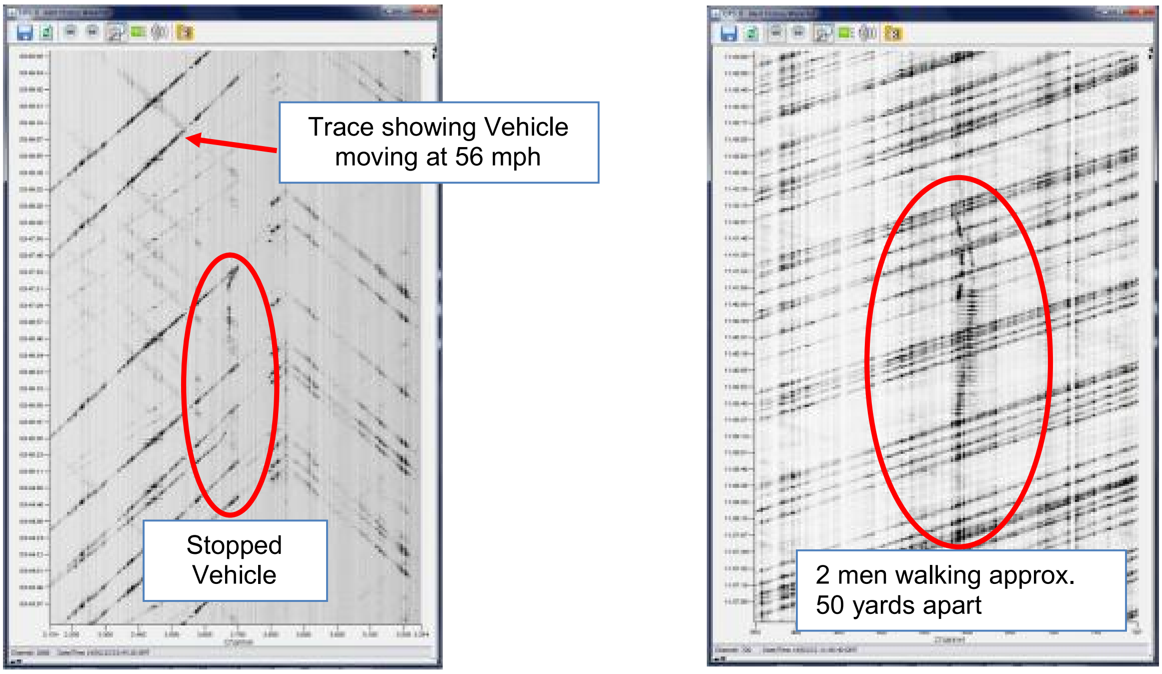

Figure 3 Examples of raw output traces from the Distributed Fibre Optic Detection system

Further by Co-locating detection heads there is potential to configure the system for sensing up to 80km from a single site, Figure 4 below illustrates this concept. The configuration requires significantly less infrastructure compared to conventional detection systems and reduced traffic management for installation and maintenance and is where the major benefits of this technology are expected to be realized.

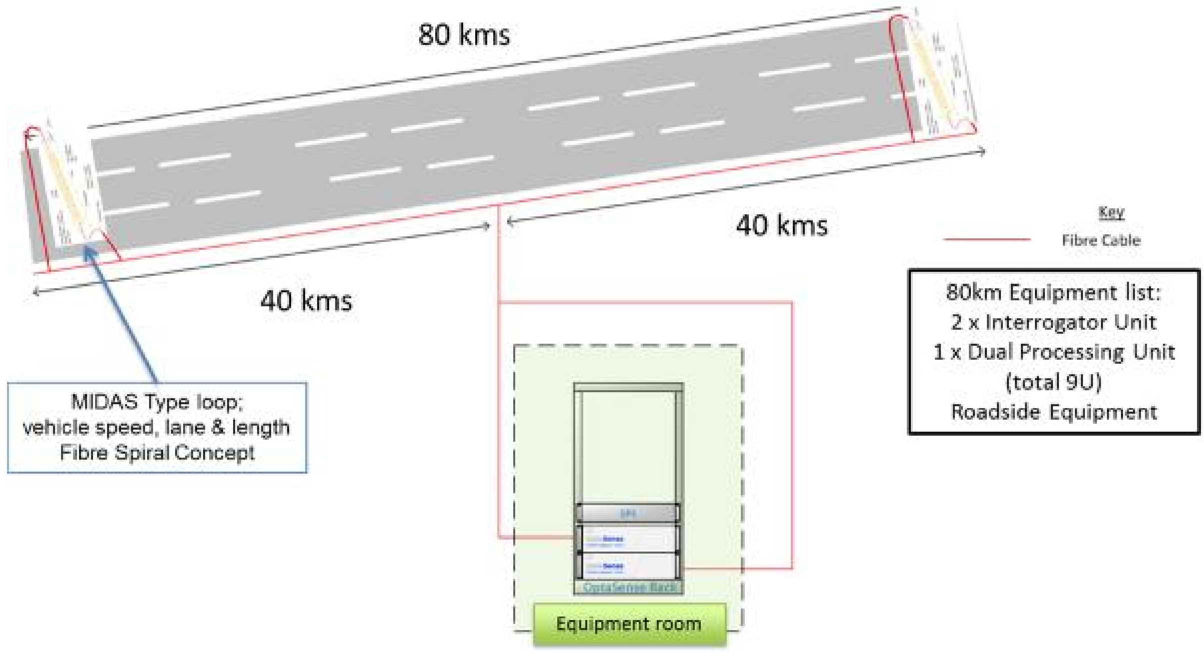

Figure 4 DAS concept and configuration diagram

ABOUT THE NZTA DAS PROJECT

As already demonstrated the technology has unique capabilities when compared with conventional point detection methods such as loops, or radar. Further the ability to monitor the entire length of the measured fibre in real-time present's new opportunities for incident detection and traffic flow patterns. The trial project will evaluate the application of the DAS technology for operational use. The key areas of focus for evaluation are

- The continuous detection of traffic flows and patterns along a measured fibre,
- Detection of incidents at any point along a monitored fibre, such as stopped vehicles or accidents
- Asset monitoring such as bridge joints or potholes.
- Assessment of installation conditions of the fibre for future application

The site selected for the DAS project is on State Highway 1 (SH1) running north from the Auckland Harbor Bridge to Johnstone Hill Tunnel (Puhoi) a distance of 40 kms, See figure 5 for an over view. The site was chosen as it has existing fibre running along it all the way up to the tunnels.

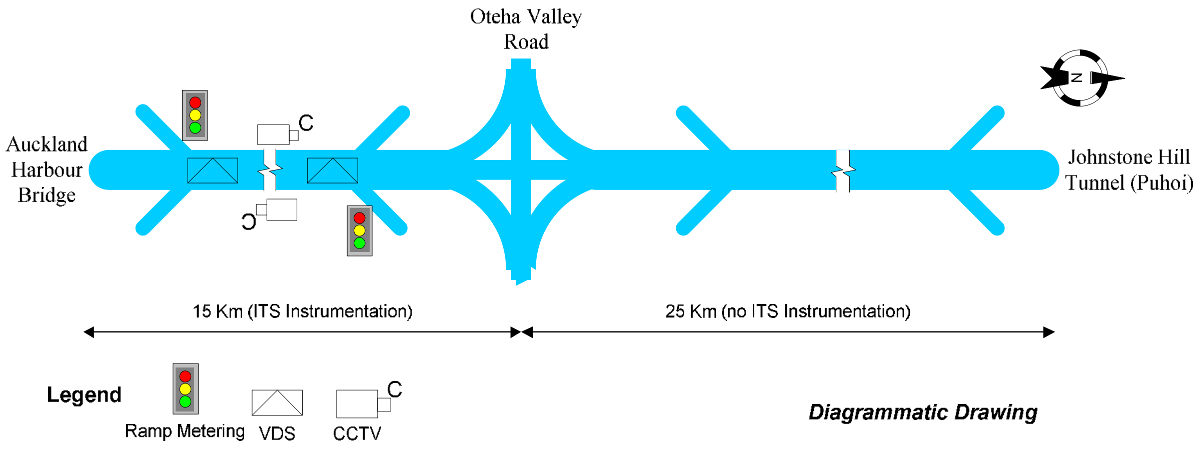

Figure 5Schematic Diagram of the baseline project trial site

Further the lower southern section of motorway as far as the Oteha Valley junction has existing ITS assets installed which will provide a known control against which the fibre optic system will be evaluated. The fibre cable continues on for the full distances to the Johnstone Hill Tunnel at Puhoi where there is currently no detection and will provide the opportunity to demonstrate retrofitting of the system and its ability to “light up” previously un-instrumented sections of the road, and establish one of the key previously stated benefits.

The project will run over three key phases

1. Install and commission: This phase will see the equipment delivered to site and installed and commissioned. Geolocating the sensor will be a key part of this process.
2. Off line evaluation: Once commissioned this phase will collect data for analysis and comparison against activity on the network. As part of the evaluation it will be important to demonstrate the system working and so it is the projects ambition demonstrate the system working in real-time. This will be standalone by means of a wed interface.
3. Subject to successful evaluation, interfacing to existing traffic management systems. Once the system is stable and proven the next stage is to explore interfacing to existing traffic management systems for real time operations and data warehouse for data storage and analysis.

While the ability to interrogate and measure the fibre is well developed and understood there will still be a need to learn how to use this technology due to its unique nature. It is expected that working with the vendor and stakeholders that there will be future developments that will enhance the system. For example developing queue detection algorithms, or developing tunnel incident detection systems off the back of this technology. This is just the first step in the journey.

WORKING WITH WELSH TRANSPORT AGENCY

NZTA have formed a pseudo DAS user group with the vendor where knowledge sharing and lessons learnt from other transport users of the DAS system are being shared. Introductions were made to the Welsh Transport Authority (WTA) DAS System project to enable sharing of knowledge between users of the system, both in delivery and operations. The insight gained from this has been incorporated into the NZTA project. Further the Algorithms and the web based user interface that had been developed for the WTA will be made available to the NZTA project.

The WTA project was initially to run for nine months and was kicked off in April 2013. Their project had two main installs one on a motorway and one on a busy ‘A’ road. Their primary goals were Incident Detection, Traffic flow and journey time measurements. By November 2013 they were on track with Speed of travel available and Queue detection being deployed and the Journey Time component expected by end of 2013 (refer to below figure).

It is intended to continue this relationship and share any learnings with the WTA once NZTA have an operational system.

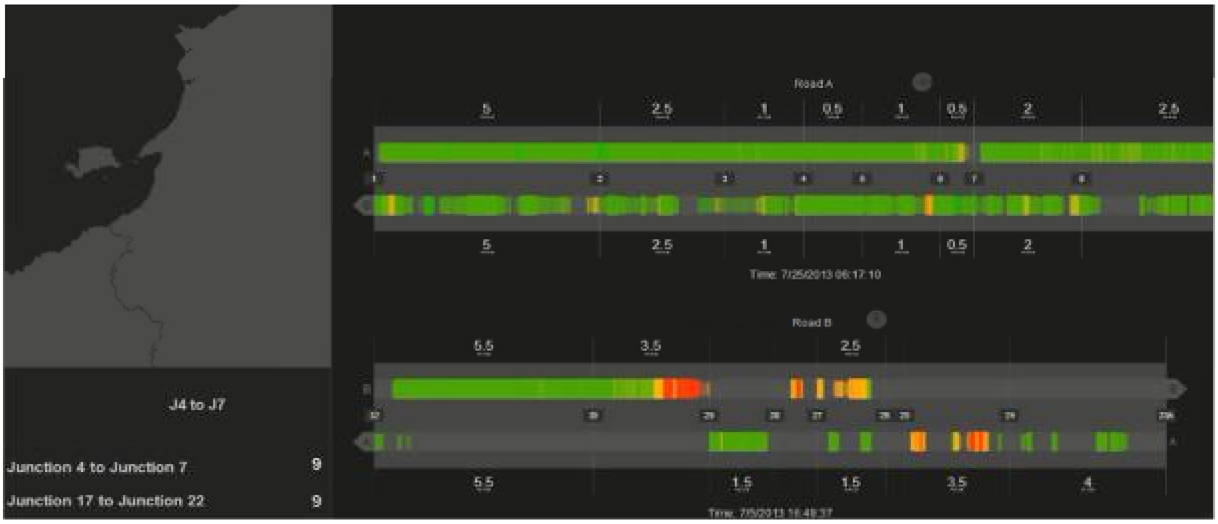

Figure 2 WTA Travel Time user interface

PROJECT TIMELINE UPDATE

The projects core objective is to demonstrate and realize the benefits that were stated in the business case that was signed off in July 2013. Based on what was known at the time the business case presented a conservative benefit assessment. The benefit was its self based on being able to, as a minimum, match current technology capability but with reduced installation and maintenance costs. This was enough to produce a viable benefit cost ratio to proceed at minimal risk. As already shown the technology is potentially capable of much more, and as this is learned and developed it is expected to exceed the stated benefit. A further intention of the pilot project was to make future delivery drops of this technology repeatable with in NZTA.

Early work was carried out during sign off of the business case to identify the best site to install the DAS System in order to demonstrate the benefits stated in the business case. The project management plan and procurement strategy were delivered and the contract negotiations (internal and external) commenced in October 2013. Standard project risk, issues, changes & decisions register were created along with a communications plan.

Key Stakeholder meetings were held in December at the Joint Transport Operations Centre (JTOC) in Auckland. The priority of the project was to prepare the business for the installation of the fibre optic detection system and its capabilities. Delivery and benefit realization will require support from key areas of the business such as access to the communications network and server rooms and the road side fibre itself.

Negotiations with the vendor started in December 2013 and were successfully concluded in February 2014, with sign off a master services agreement and statement of work. This also met with one of the key objectives of the project from a procurement perspective to make this a repeatable deployment as the MSA allows further installations. The project has now moved into a delivery phase with the NZTA system going in to FAT and all being well is expected to be delivered and commissioned by April 2014, hopefully in time for the ITS Asia Pacific forum.

REDUCED CAPEX / OPEX

Using the new cutting edge DAS there is an alternative means to meet the existing road network monitoring that enhances the capabilities in use today, with real cost benefits over the life of the project. From a CAPEX perspective there is a costs saving through reduced road side equipment, power or communications requirements usually associated with installation of conventional detection systems.

This technology is also a more cost effective solution when compared to conventional loop technology in terms of traffic management and longer term maintenance costs.

The economic evaluation described in this section follows the guiding principles set out in the NZTA Economic Evaluation Manual and the general concepts underlying economic efficiency.

The economic evaluation determines the economic efficiency of an investment or “activity” as part of the NZTA funding assessment. The key indicator used to assess economic efficiency is the benefit cost ratio (BCR).

The BCR analysis provides financial assessment for the implementation of the DAS for the state highway section from Puhoi to the NTMC situated at Stafford Street north of Auckland Harbor Bridge. This financial model assumes that the benefits are to be relatively uniform across the assessment period, with some allowances for escalation derived from a combination of increased traffic volumes, inflation and other factors which increase the value of the benefit.

The financial model utilizes the capital and operational cost estimates with values assigned against the year in which they are expected to be incurred, with allowances for escalation as considered appropriate. Once the above values are applied across the assessment period, they are discounted at 8%, with the cumulative total at the end of the period providing the Net Present

Value (NPV). It should be noted that the NPV is made up of both financial value captured within NZTA as well as economic value captured by the broader community. Based on the analysis, the NPV for the project is approximately $4.0m.

The investment represents a relatively modest outlay of capital by NZTA, and a low level of operational expenditure over the assessment term (30 years). Although conservative, the anticipated benefits represent a significant economic benefit over the assessment term, as indicated by the above NPV. For this reason, the analysis resulted in a positive BCR of 2.54 (Actual financial model figure is deemed confidential and as such have not been provided).

SUMMARY

The DAS System will be a beneficial tool for the Joint Traffic Operations Center (JTOC) and for the wider NZTA enhancing operational control and real-time understanding of dynamic network conditions. It will allow continuous, up to date and reliable point in time data on any part or the network covered by the DAS product. For network operators it will provide real time information about the network, with a higher granularity of information than previously achievable, for comparable cost of deployment, with conventional detection systems.

The NZTA's 4 stated strategic goals are:

- Shape smart transport choices
- Deliver Highway solutions for customers
- Integrate one network for customers
- Maximise returns for New Zealand

A key objective of the DAS project is to ensure that all operational benefits are ultimately aligned with NZTA corporate strategic objectives. The first area expected to see benefit is Traffic Incident Management (TIM) with the ability to detect an incident at any point along a monitored fiber to the nearest 10 meters. Some learning will be required to interpret the outputs and trigger appropriate alarms and there is also a need to establish the reliability of the system, however early indications are promising and this area is expected to deliver significant benefit.

The second key benefit with the DAS solution is Traffic and Traveler Information (TTI). Flows and vehicle counts are native outputs as is journey time due the ability to track vehicles continuously along the path of a fiber. Over time it is hoped that other traffic patterns such a queuing and congestion will be developed as well. Here again early indications are positive with trace clearly showing these events occurring, this now need to be turned into higher level information for consumption by traffic management systems

These link into the key strategic objectives by delivering enhanced and more granular information

1. In real time to operators and user helping shape smarter transport choices
2. Performance and analysis of the network, such as congestion to facilitate more targeted investment so maximising returns for New Zealand
3. And delivering new highway solutions for customers, internal and external to NZTA

This in is a new technology and due to its unique nature will mean we will need to learn how to use it. There are still challenges ahead and while this is an exciting new way to monitor the network with many instinctive benefits to be developed there are likely to be some area where it will not work as well as conventional technologies, for example the system cannot currently resolve down to lane level. Further there will be challenges ahead for integrating to traffic management systems and presenting information to users for operations and storing data for offline analysis, indeed the system has the ability to generate vast amounts of data. The trick will be in deciding what to store and in what format.

Acknowledgement

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