# Jun Shan Wey

## Distinguished Engineer, Verizon Communications, USA

Dr. Jun Shan Wey is a Distinguished Engineer at Verizon Communications, where her work focuses on standardization and ecosystem development in optical networking and video media. Her contributions in these areas have been instrumental in shaping Verizon's network strategy and architecture planning. Dr. Wey actively represents Verizon in major standards development organizations, including ITU-T, FSAN, and ATIS. She has served as an editor for multiple ITU-T recommendations pertaining to optical access networks and distributed fiber optic sensing (DFOS). Her contributions have been instrumental in the global adoption of passive optical networks and spearheaded the first DFOS standardization efforts for telecommunications operators, paving the way for wider adoption and innovation in this emerging field. Dr. Wey is deeply involved with the Optical Fiber Communications (OFC) Conference. Her roles include serving as the current OFC Steering Committee Chair, 2020 Program Co-Chair, and 2022 General Co-Chair. She also co-chairs the IEEE INGR Optics Working Group. Dr. Wey holds a B.Sc. in Electronics Engineering from National Chiao Tung University in Taiwan. She earned her M.S. and Ph.D., both in Electrical Engineering, from the University of Maryland, College Park. She is a Fellow of Optica and a Senior Member of IEEE.

# ITU Workshop on “Evolution of Optical Networks for IMT2030 and Beyond”

Charles K. Kao Auditorium, Hong Kong Science and Technology Park (HKSTP)
20 November 2024, 15:00 - 18:00

# Distributed Fiber Optic Sensing (DFOS) for IMT-2030 and Beyond

Jun Shan Wey
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Optical fibre infrastructure is the foundation of IMT-2030 networks.

Distributed Fiber Optic Sensing (DFOS) provides a new way to protect fiber infrastructure as well as enhance network operation and management.

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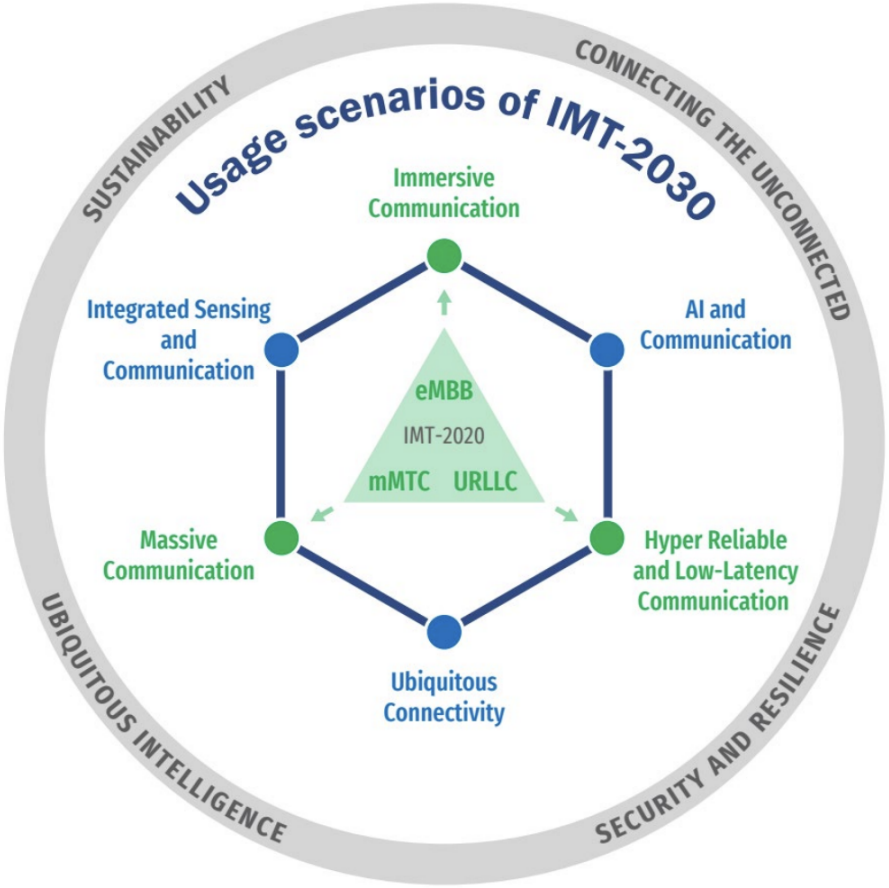
# IMT-2030 Usage Scenarios - ITU-R M.2160-0




So called "Wheel diagram"

## Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➡ Immersive Communication
- mMTC ➡ Massive Communication
- URLLC ➡ HRLLC (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- AI and Communication
- Integrated Sensing and Communication

Different from DFOS

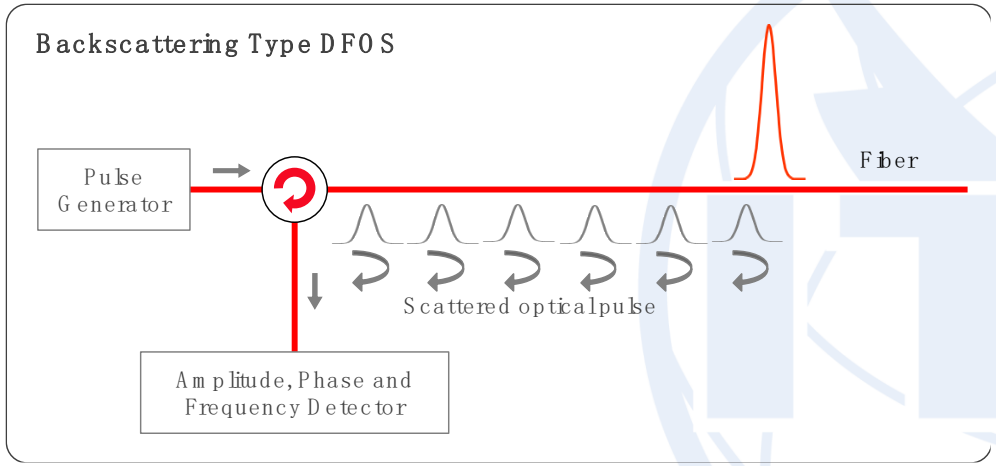
4 Overarching aspects:

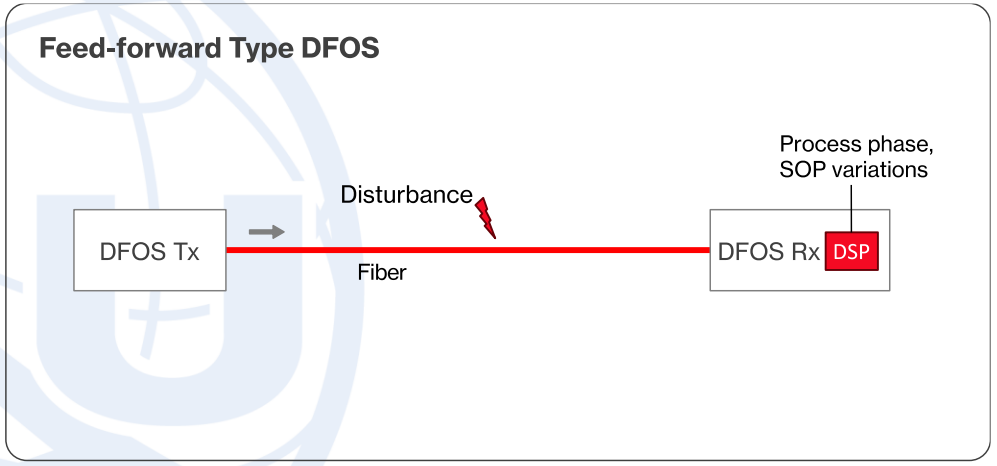
*act as design principles commonly applicable to all usage scenarios*

Sustainability, Connecting the unconnected,
Ubiquitous intelligence, Security& resilience

# What is Distributed Fiber Optic Sensing (DFOS)?

Detecting environmental disturbances along the entire length of a fiber optic cable by analyzing backscattered light or phase/SOP variations in forward transmission direction.




| Physical layer effect | Frequency shift in Silica fiber | Disturbance detection |
|---|---|---|
| Rayleigh backscattering | None | Acoustic, vibration |
| Brillouin backscattering | ~ 10 GHz | Strain, temperature |
| Raman backscattering | ~ 13 THz | Temperature |
| State of polarization variation | None | Vibration |
| Phase perturbation | None | Vibration |

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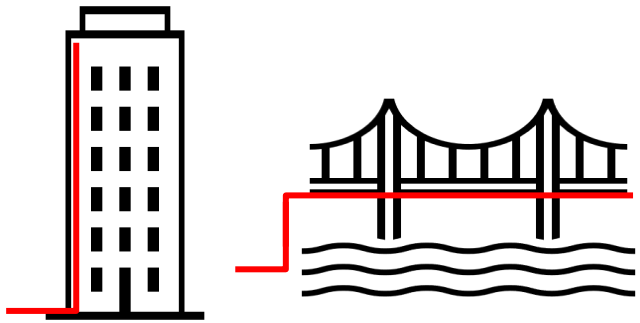
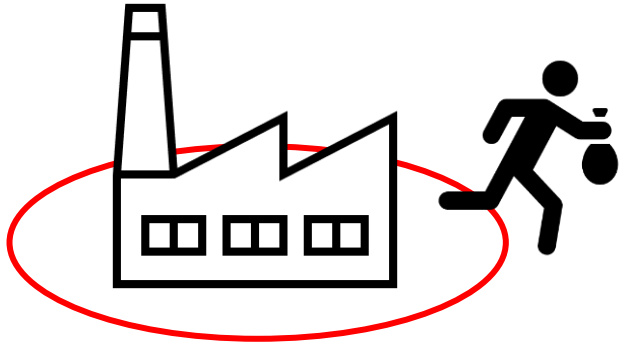
# Conventional Fiber Optic Sensing Applications

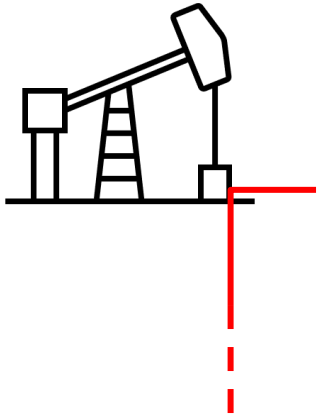
Structure Health



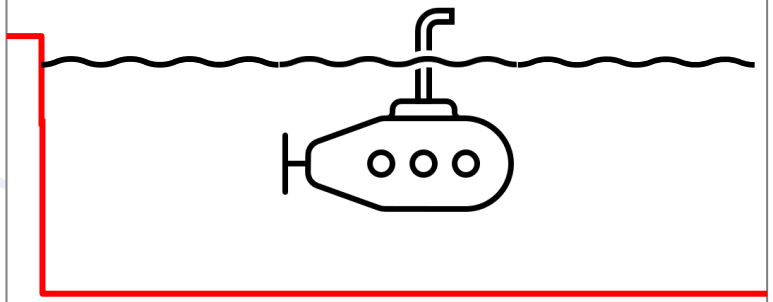
Security and Safety



Oil/gas Industry



Defense and Military



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# First Report of Fiber Sensing Field Trial in Telecom (OFC 2019)

OFC 2019 PDP Th4C.7

## First Field Trial of Sensing Vehicle Speed, Density, and Road Conditions by Using Fiber Carrying High Speed Data

**Glenn A. Wellbrock[1], Tiejun J. Xia[1], Ming-Fang Huang[2], Yuheng Chen[2], Milad Salemi[2], Yue-Kai Huang[2], Philip Ji[2], Ezra Ip[2], Ting Wang[2]**

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*[2]NEC Laboratories America, Inc., 4 Independence Way, Princeton, NJ 08540, USA*
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**Abstract:** For the first time, we demonstrate detection of vehicle speed, density, and road conditions using deployed fiber carrying high-speed data transmission, and prove carriers' large-scale fiber infrastructures can also be used as ubiquitous sensing networks.

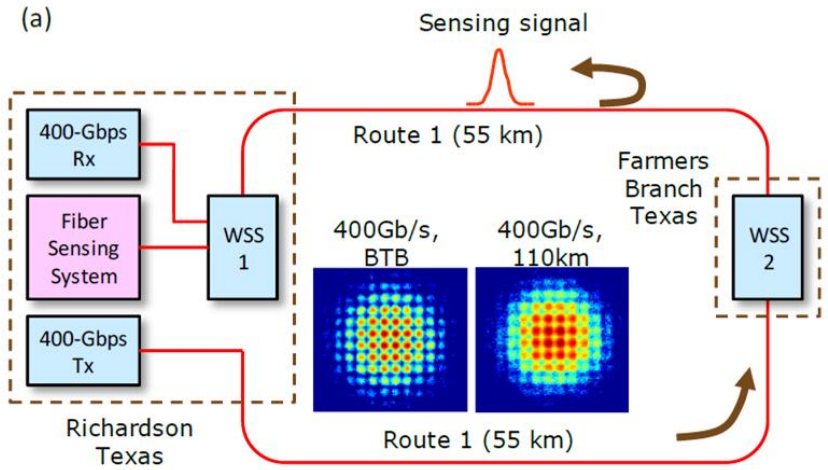
**OCIS codes:** (060.2330) Fiber optics communications; (060.2370) Fiber optics sensors

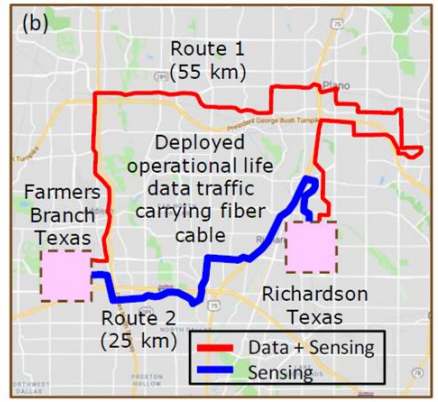
### 1. Introduction

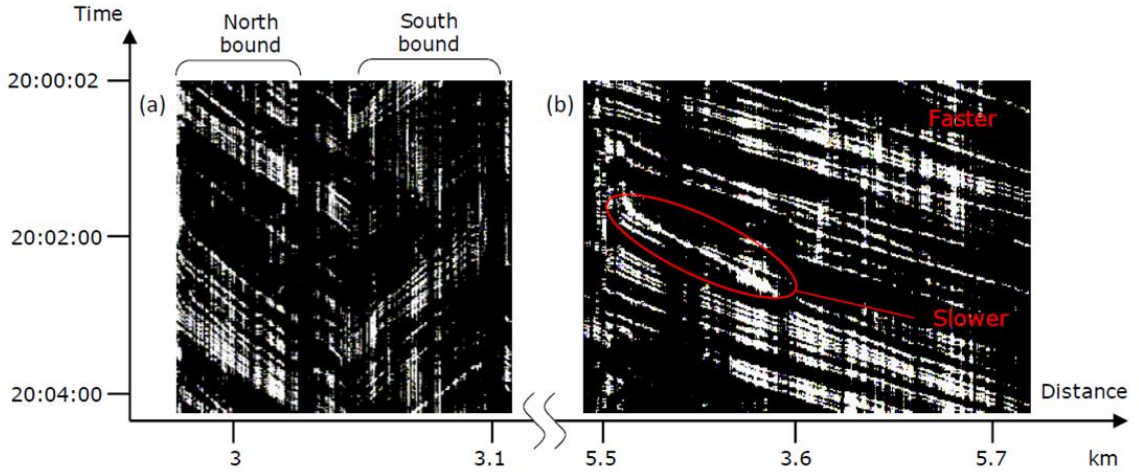
Global telecom carriers have built huge scale optical fiber infrastructures to support Internet [1]. Up to now, however, carriers' fiber infrastructures only provide the function of data transmission. Actually, optical fiber is a material which can be used as a sensor as well. If carriers' telecom fiber network can also function as sensor network, then the infrastructure will not only carry telecom data, but also generate various useful sensing data. This change will double the values of a carrier's fiber assets and provide a large-scale environmental monitoring system serving many applications, such as smart city and smart community [2, 3]. Specially deployed sensor fiber has been used for downwell monitoring in oil/gas industry [4], pipeline leak detection [5], and intrusion detection [6] by detecting changes in temperature, strain, vibration, etc. Recently, employing fiber sensors for measurement of road traffic have been reported involving fiber-optic interferometer or dedicated fiber near the road [7, 8]. Since carriers' optical fiber cables were not deployed for sensing purpose and enclosed in conduits normally, ultra-highly sensitive detection technologies must be developed to support the sensing functions.

In this paper, we report, for the first time, the results of detection of vehicle speed, density, and road conditions using fiber carrying high speed data transmission contained in deployed operational life data traffic carrying cable. The high speed data transmission has been reported previously [9]. The fiber sensing function is based on phase-sensitive optical time-domain reflectometer (OTDR) technology for vibration detection. The results show that operational fiber in carriers' network is fully capable to detect car speed, vehicle flow, and pavement deterioration of streets, such as pothole existence. More applications can be expected and will be reported in future.

### 2. Experimental Setup and Results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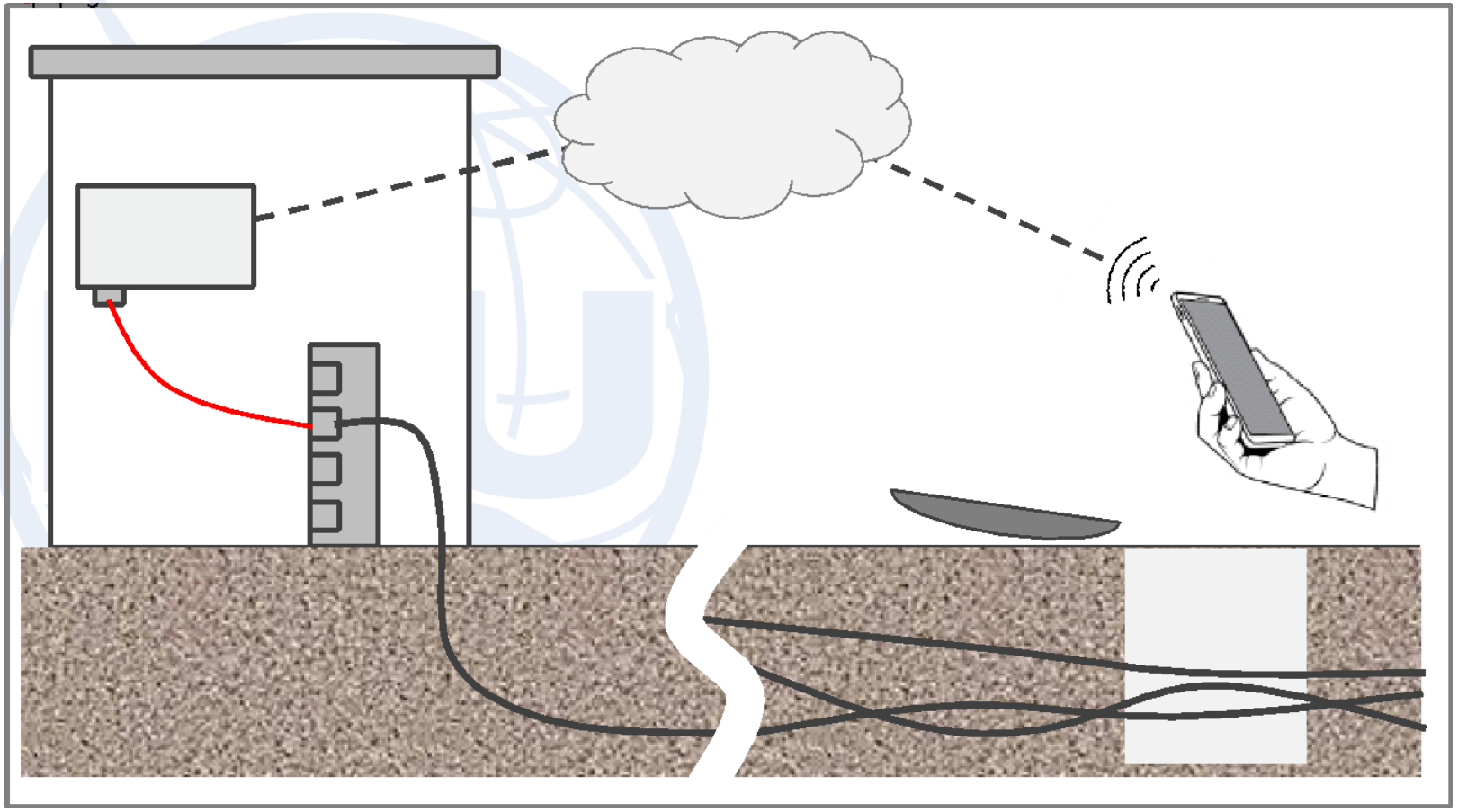
# Fiber Sensing to Identify Deployed Cables

Reduce the time to identify a cable in field from day(s) to a few minutes!



Ref: G. Wellbrock, OFC 2022, S2B

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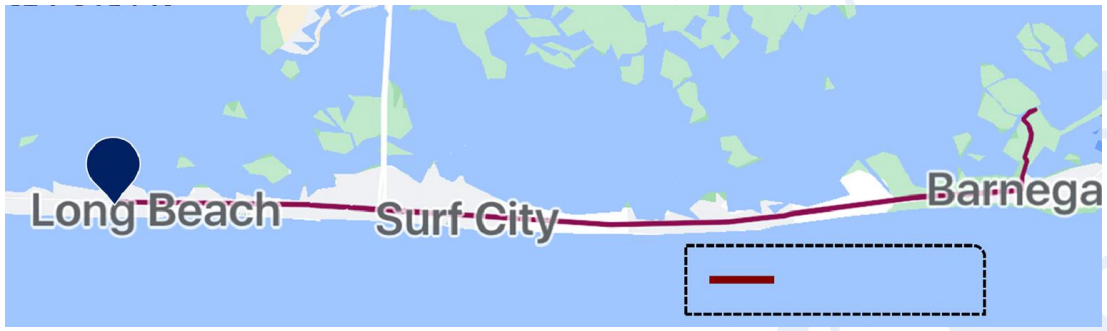
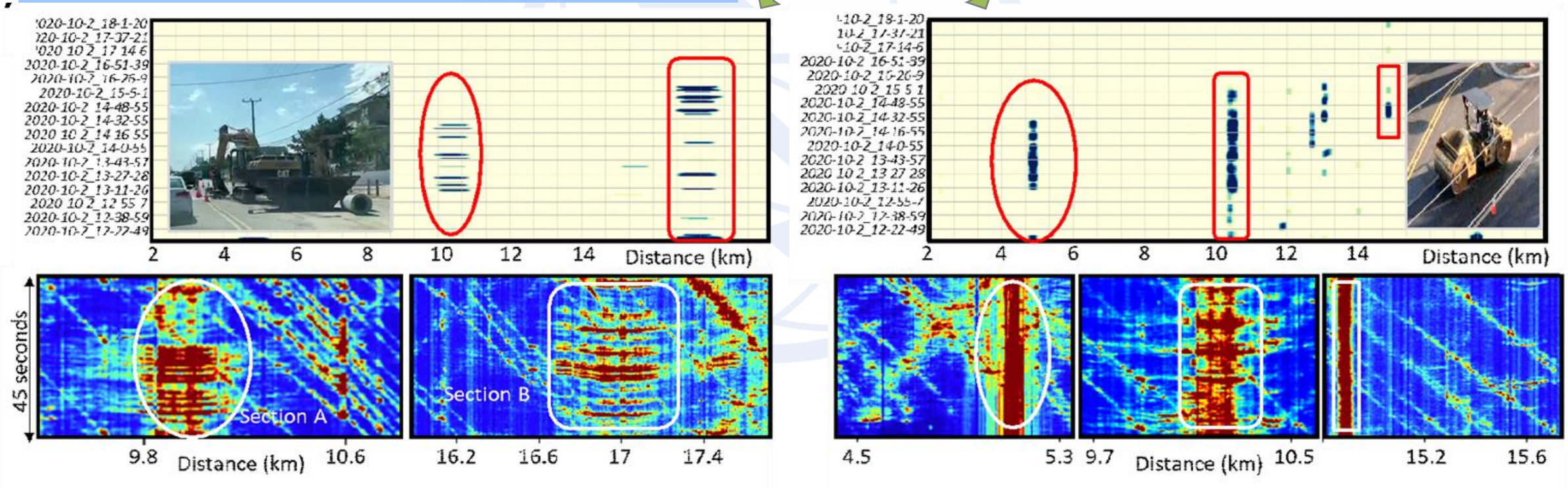
# Detection of Abnormal Activity Near Deployed Cable




Two digging machines are discovered

Three rolling machines are discovered

Ref: T. Xia et al., OFC 2021, Th4H.3

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# Opportunities and Challenges for Telcos

## Opportunities

- Enhance network operations and management
- Protect fiber infrastructure by preventing potential damage
- Sensing As a Service: telco fiber as an intelligent sensing network
  - Global Global fiber optic cables span > 4 Billion km (2.5B miles). Verizon deployment > 800,000 km

## Challenges

- Equipment cost
- Equipment portability
- Fiber availability

## Requirements

- Operate on in-service fiber
- Utilize out-of-band or in-band wavelengths
- No interference to service traffic
- High-resolution localization accuracy
- Support methodology for risk level assessment
- Timely risk alerts to operations team

## Growing ecosystem through standardization

- ITU-T Q6/15 G.dfos Recommendation for transport network
- ITU-T Q2/15 G.sup.VHSP Supplement for optical access
- Liaison with other SDOs developing DFOS standards

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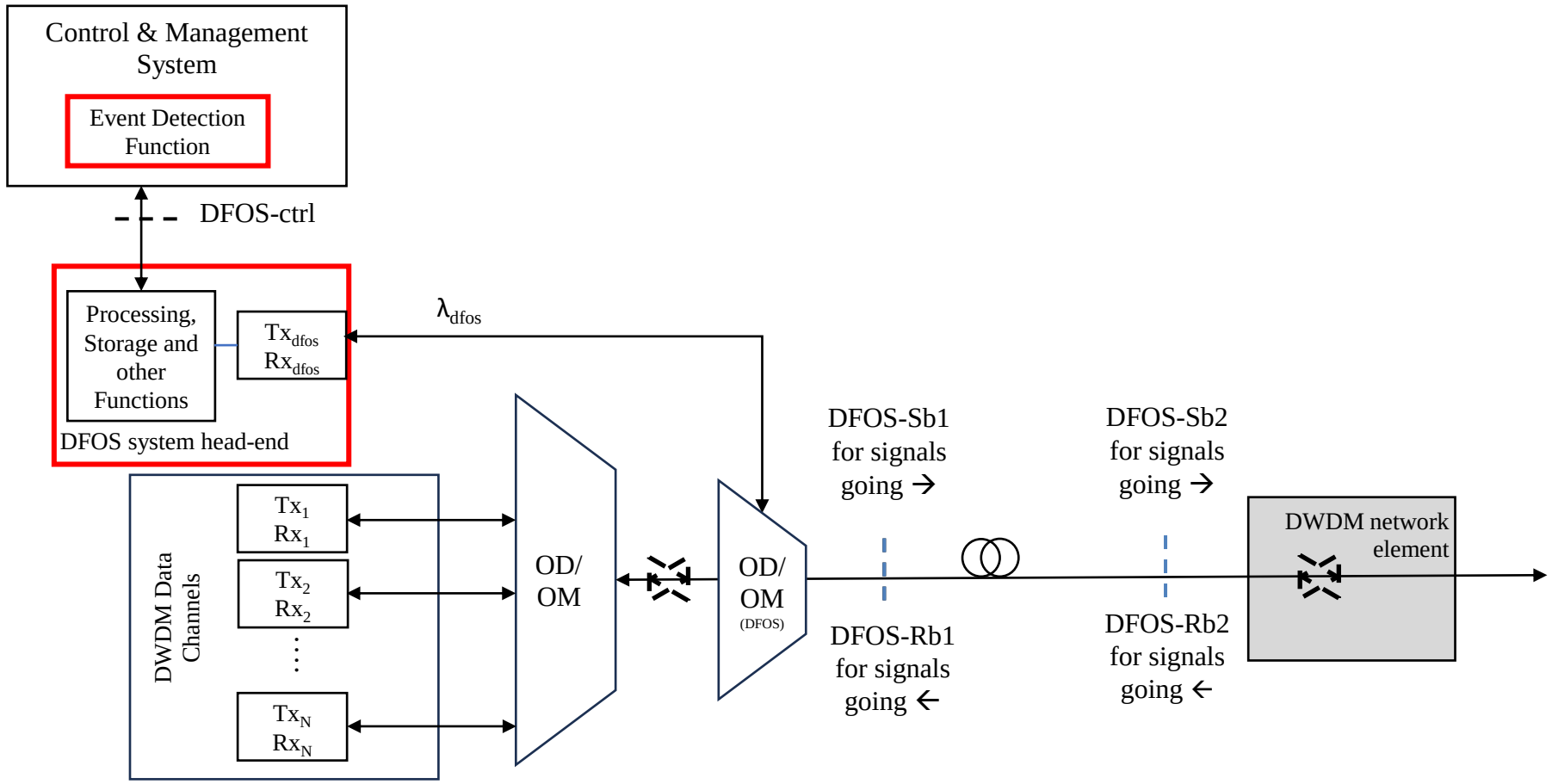
# System architecture example: Back-scattering Type




G.dfos Fig. 6-1

**Advantages:**

- High resolution ~5m within ~200m radius
- Reach ~100km w/o amplifiers
- Already used in the field

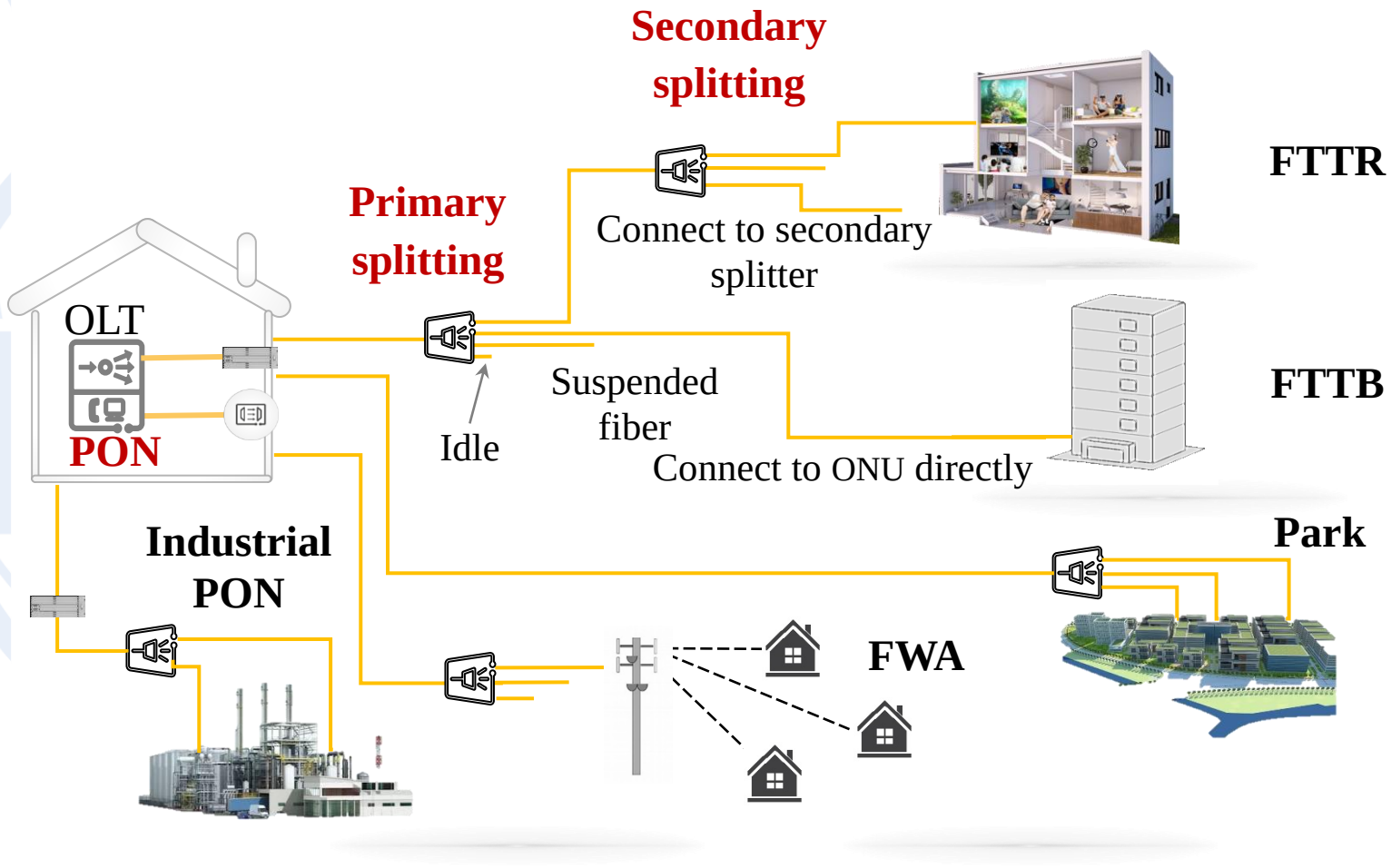
**Challenges:**

- Equipment cost
- Insertion loss of OD/OM (mux/demux)
- Wavelength bands
- Interference to live data traffic

ITU-T G.dfos Recommendation in progress in Q6/15

# Fiber sensing in optical access faces more challenges

- Additional loss from passive splitters
- Need to distinguish backscattering from different distribution fibers
- ITU-T G.sup.VHSP Supplement in progress in Q2/15




G.sup.VHSP Fig. 7-6.3

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# Closing Remarks

- Fiber optic sensing is not new, but doing it on a telecom network is, and could be extremely scalable
- Exciting applications are demonstrated by operators and continue to evolve
- Standardization helps create a healthy ecosystem to bring down costs
- ITU-T started the first DFOS standard (G.dfos) for telecom applications. Study of DFOS for access also started. Many open points to be addressed
- Specialized AI/ML algorithms can be developed targeting operational improvements and new services

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# Thank you !