Distributed Fiber Optic Sensing for Telecom Networks

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ITU and IEEE Photonics Workshop on “Photonics for AI Infrastructure"
Montreal, Canada
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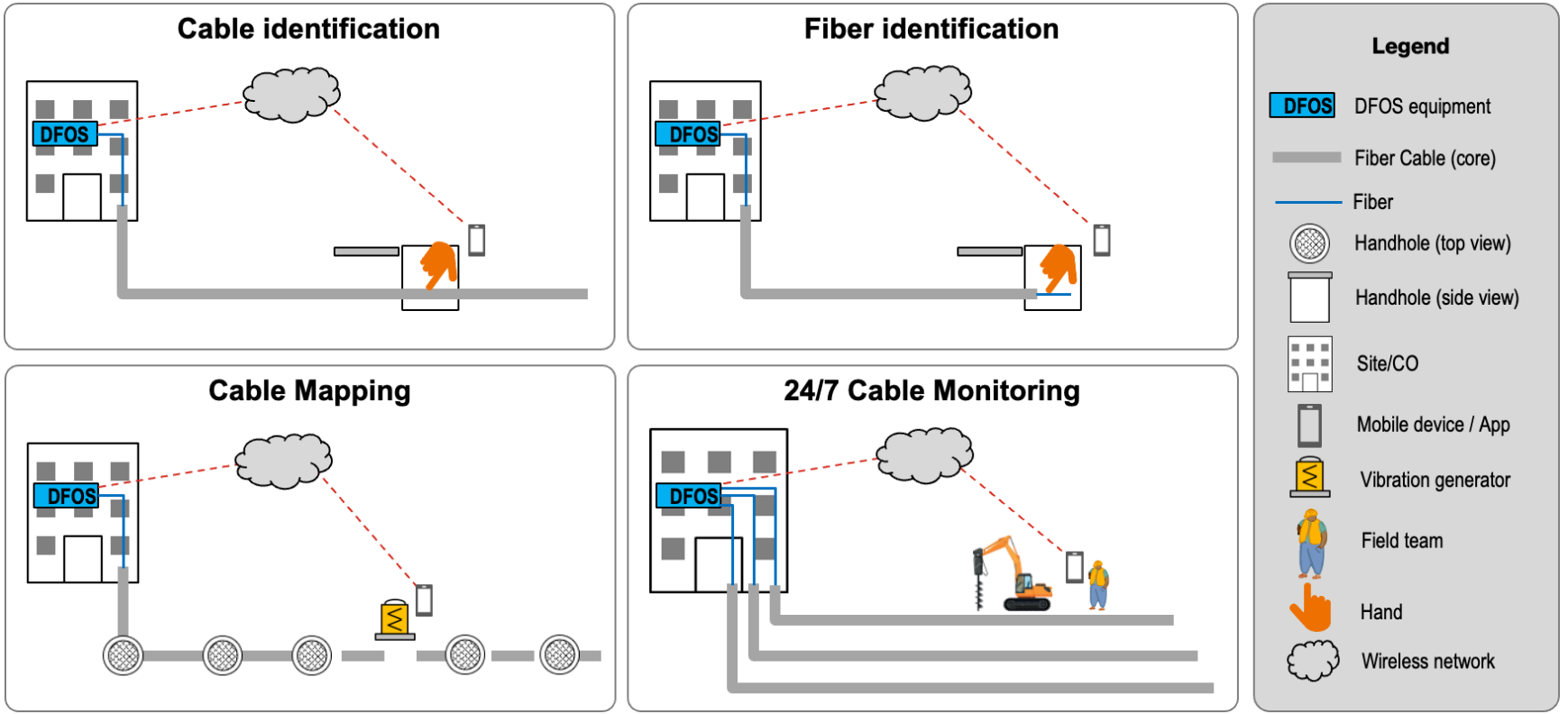
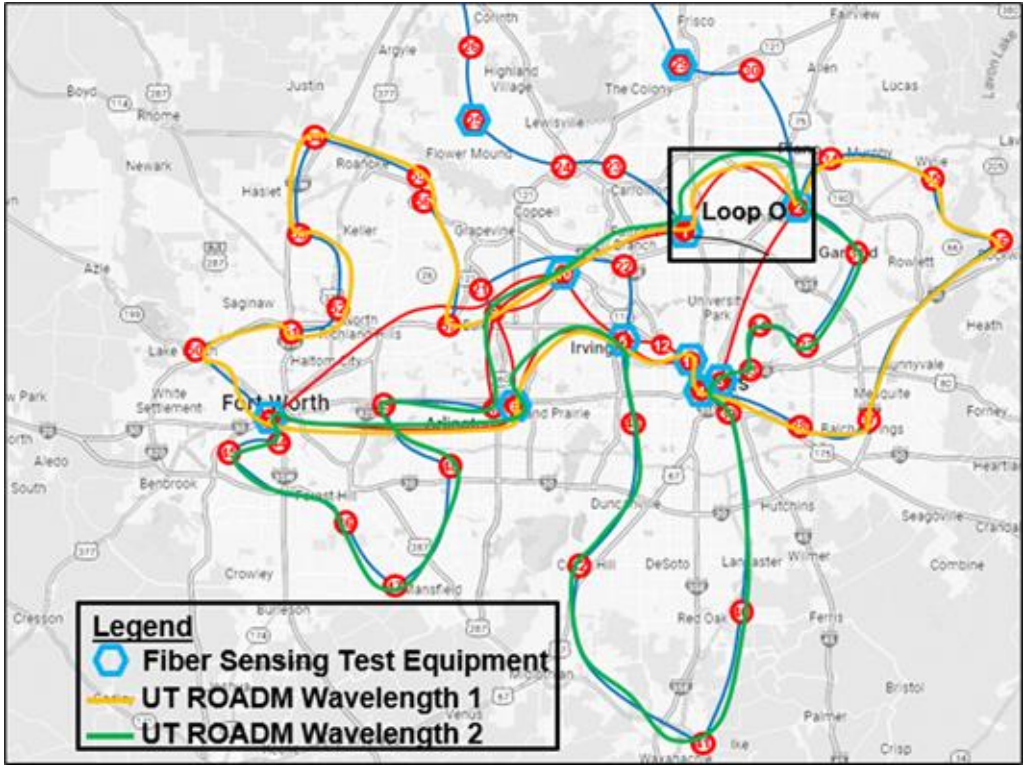
Telecom Application Examples



Verizon's Fiber Sensing Testbed



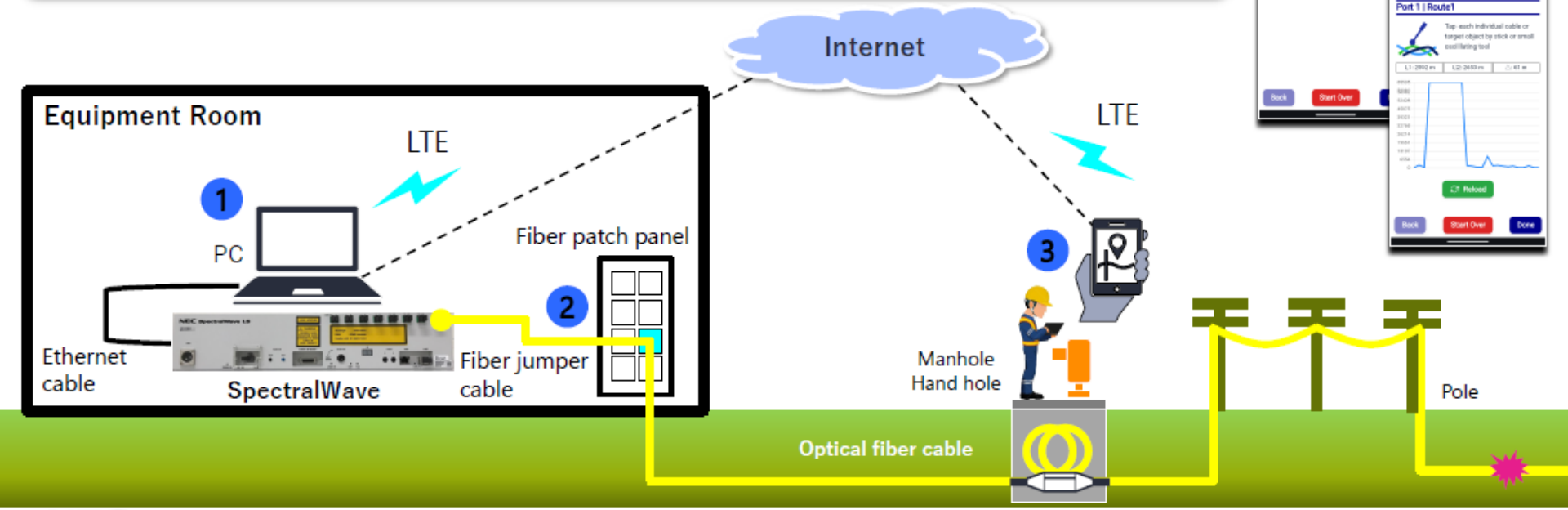
Multi-vendor Fiber Sensing test equipment tech trials on Loop O

Multi-vendor Coherent transponder Fiber Sensing data collection tech trials on DFW ROADM network (planned)

Field trial in 11 sites in DFW

NEC FOSS System Configuration

- ✓ Install the SpectralWave LS2000/3300 in the equipment room
- ✓ Connect it to the port on the fiber patch panel
- ✓ Field technician brings a smartphone to the work location
- ✓ Field technician operates the system via LTE



Graphics Source: NEC

Fiber Sensing Use Case: Cable & Fiber Identification

Identifying a cable in a manhole or a fiber in a splice enclosure normally requires two or more Field Engineers, one at the Central Office and one in the field, relying on the accuracy of labelling/coloring which may are may not be present or readable and/or the use of a visible light source

Utilizing fiber sensing equipment, a single Field Engineer can perform the task simply by tapping on the cables/fibers and monitoring the phone app for verification

Photo Source: NEC

Fiber Sensing Use Case: Cable Mapping

Engineers started from the known manhole as a reference point...

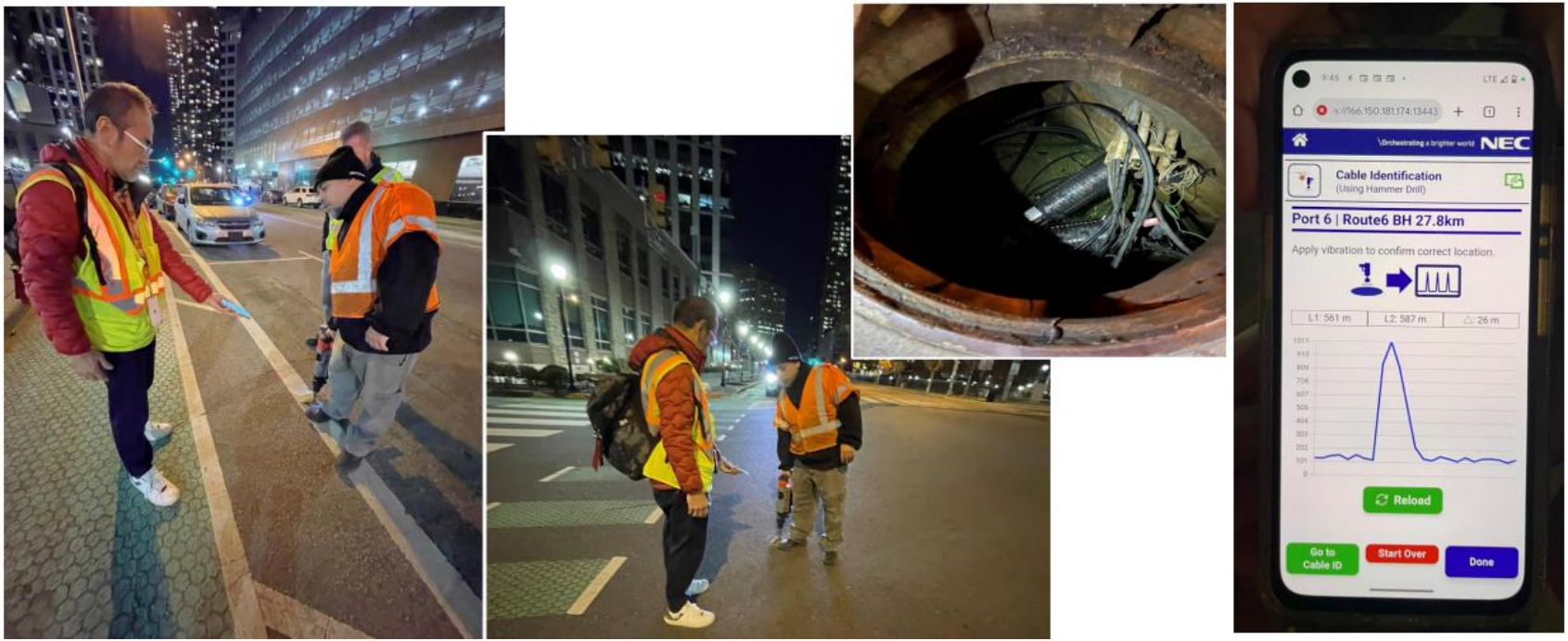
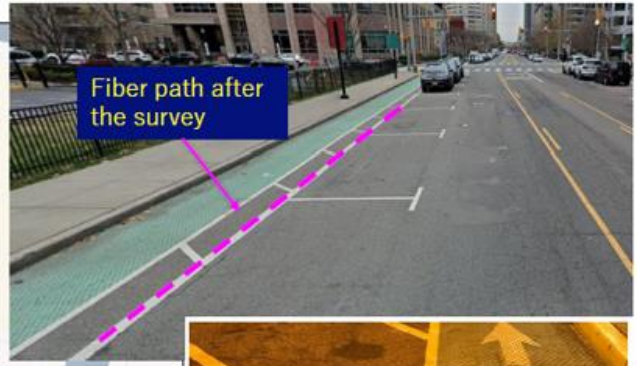


Photo Source: NEC

Fiber Sensing Use Case: Cable Mapping

.. and gradually extended toward the targeted manhole step by step

The targeted manhole was located with approximately 31 m (~100 feet) of slack fiber inside.



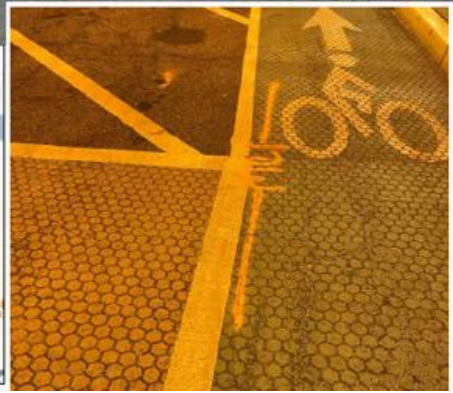


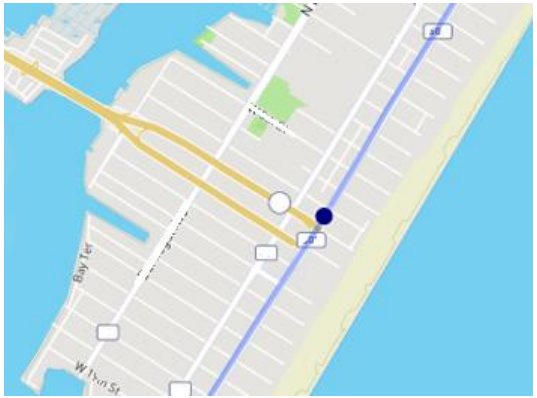
Photo Source: NEC

Fiber Sensing Use Case: Cable Monitoring

Data stream from NEC FOSS equipment is processed by an AI engine and events are categorized by risk level

Cable distance from the Central Office is provided along with coordinates; mapped location is displayed within the NEC Alert Viewer EMS if route KMZs are uploaded

High risk items are emailed/texted to Verizon Field Engineers for call out to investigate



Location Details

Risk

Index	ID	Date	Time	Route	Location (m)	Lat	Long	Risk Lev
1	272754	2025-03-12	12:32:14	LBI (port 1)	5,673	39.650	-74.17509	Moderat
2	272755	2025-03-12	12:33:03	LBI (port 1)	5,675	39.650	-74.17507	Moderat
3	272756	2025-03-12	12:33:52	LBI (port 1)	5,673	39.650	-74.17509	Moderat
4	272758	2025-03-12	12:34:40	LBI (port 1)	5,654	39.650	-74.17521	Moderat
5	272759	2025-03-12	12:35:29	LBI (port 1)	5,650	39.650	-74.17524	Moderat
6	272760	2025-03-12	12:36:18	LBI (port 1)	5,647	39.650	-74.17526	Moderat
7	272761	2025-03-12	12:37:06	LBI (port 1)	5,655	39.650	-74.17521	Moderat
8	273009	2025-03-13	08:18:20	LBI (port 1)	5,650	39.650	-74.17524	Moderat
9	273021	2025-03-13	08:25:38	LBI (port 1)	5,662	39.650	-74.17516	High
10	273022	2025-03-13	08:26:27	LBI (port 1)	5,665	39.650	-74.17514	High
11	273024	2025-03-13	08:28:04	LBI (port 1)	5,665	39.650	-74.17514	High
12	273025	2025-03-13	08:28:53	LBI (port 1)	5,665	39.650	-74.17514	High
13	273030	2025-03-13	08:32:08	LBI (port 1)	5,667	39.650	-74.17513	High
14	273031	2025-03-13	08:32:57	LBI (port 1)	5,665	39.650	-74.17514	High
15	273033	2025-03-13	08:33:45	LBI (port 1)	5,664	39.650	-74.17515	High
16	273035	2025-03-13	08:34:34	LBI (port 1)	5,665	39.650	-74.17514	High
17	273041	2025-03-13	08:37:48	LBI (port 1)	5,662	39.650	-74.17516	High
18	273072	2025-03-13	08:49:10	LBI (port 1)	5,652	39.650	-74.17523	Moderat
19	273076	2025-03-13	08:49:59	LBI (port 1)	5,650	39.650	-74.17524	Moderat
20	273077	2025-03-13	08:50:47	LBI (port 1)	5,650	39.650	-74.17524	Moderat

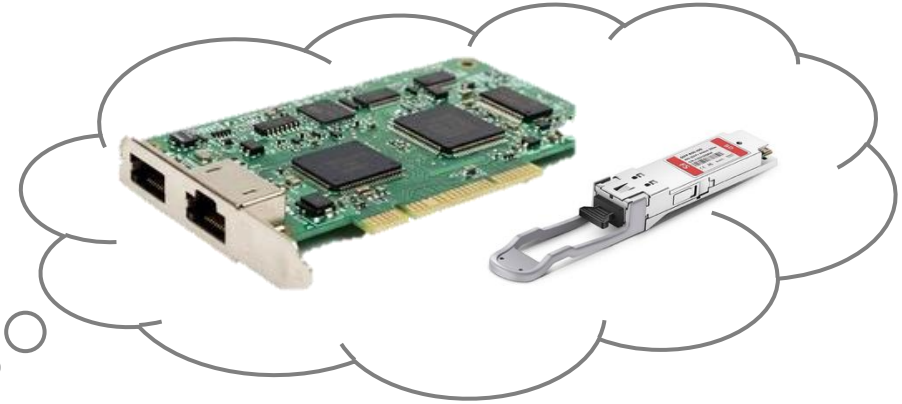
Graphics Source: NEC

Verizon Requirements

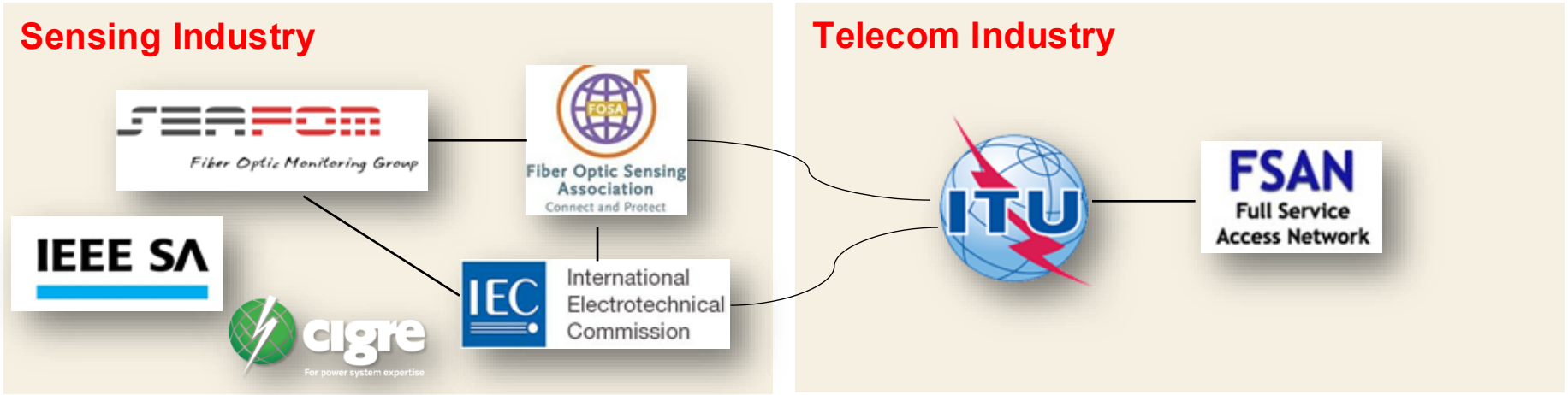
- Dark fiber and in-service fiber
- Within DWDM band or out-of-band wavelengths
- No interference to service traffic
- High-resolution localization accuracy < 10 meters
- Fiber distance > 50 km
- Risk level assessment methodology
- Timely risk alert to operations team

Cost reduction through industry standards to enable mass deployment

High Equipment Cost Hinders Mass Deployment



DFOS Standards Ecosystem



Operations, test, measurements, education

- Promotion, awareness, education (FOSA)
- Parameter definition and test procedure (SEAFOM, IEC SC86C)
- DAS terminology and definition (IEEE 3101-2023)
- Site acceptance tests in power cable industry (CIGRE)

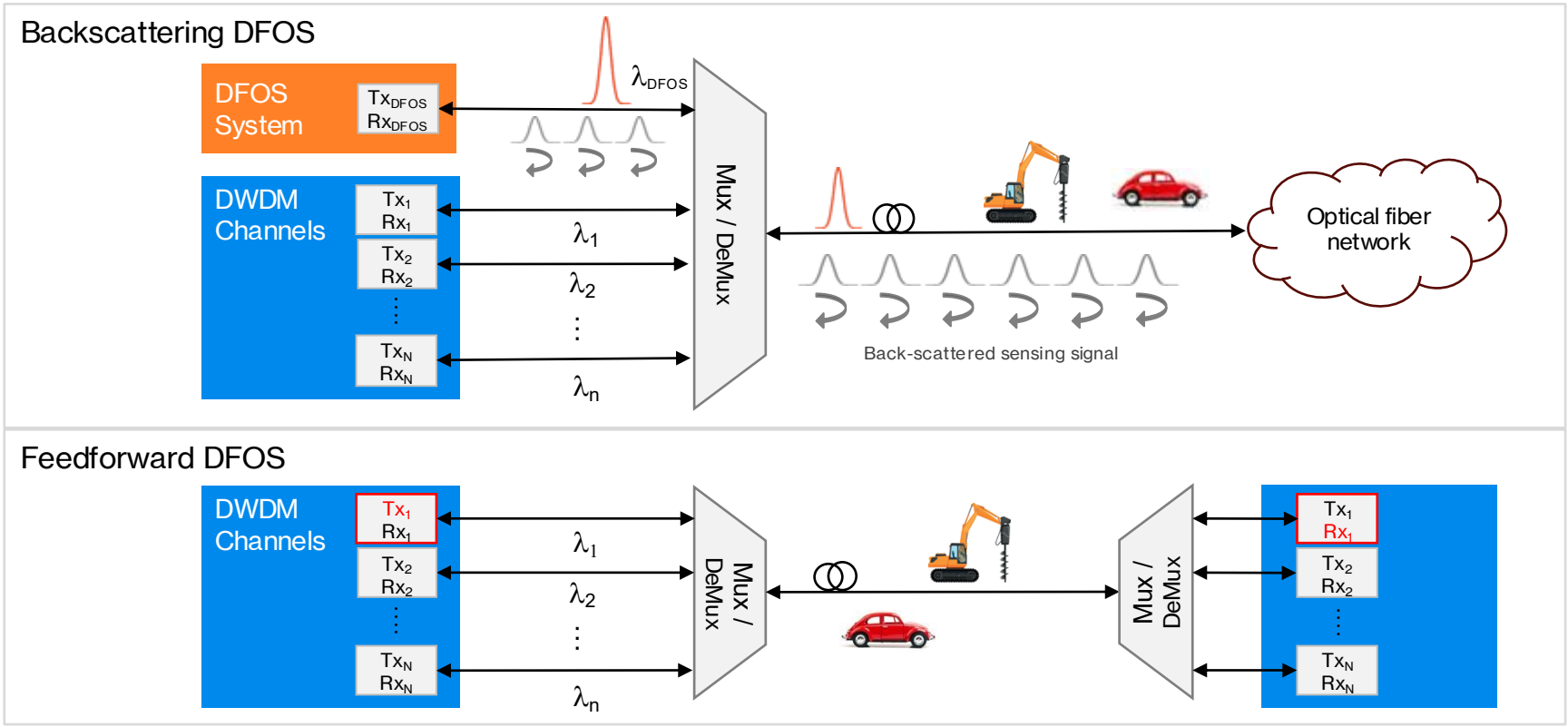
End-to-end standards for telecom

ITU-T Study Group 15

- Question 2 (optical access)
- Question 6 (metro, long haul)
- Question 7 (fiber & cables)
- Question 8 (subsea)

FSAN: Optical access network requirements

DFOS Technologies in Telecom Networks



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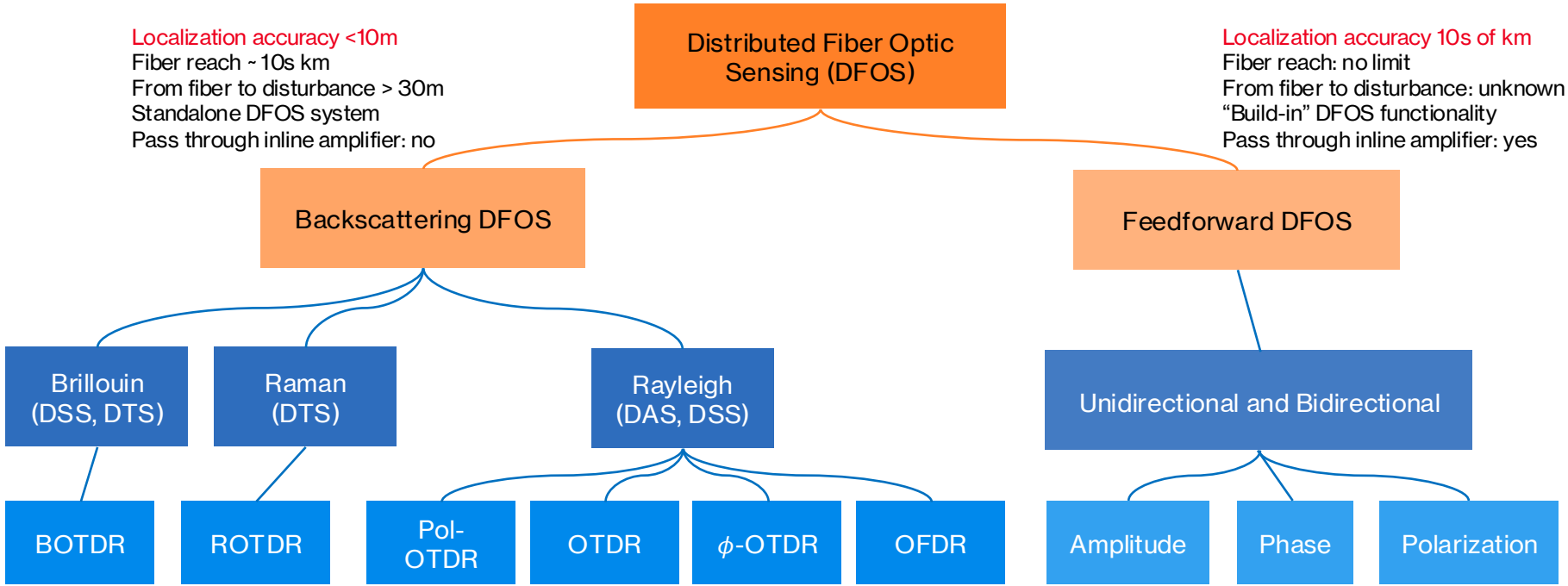
Ref: J. S. Wey, "Distributed Fiber Optic Sensing (DFOS) in Telecom Networks: Industry Trends and Standards Development," invited, J. of Lightwave Technol., Aug 2025. 10.1109/JLT.2025.3597192

Overview of DFOS Technologies



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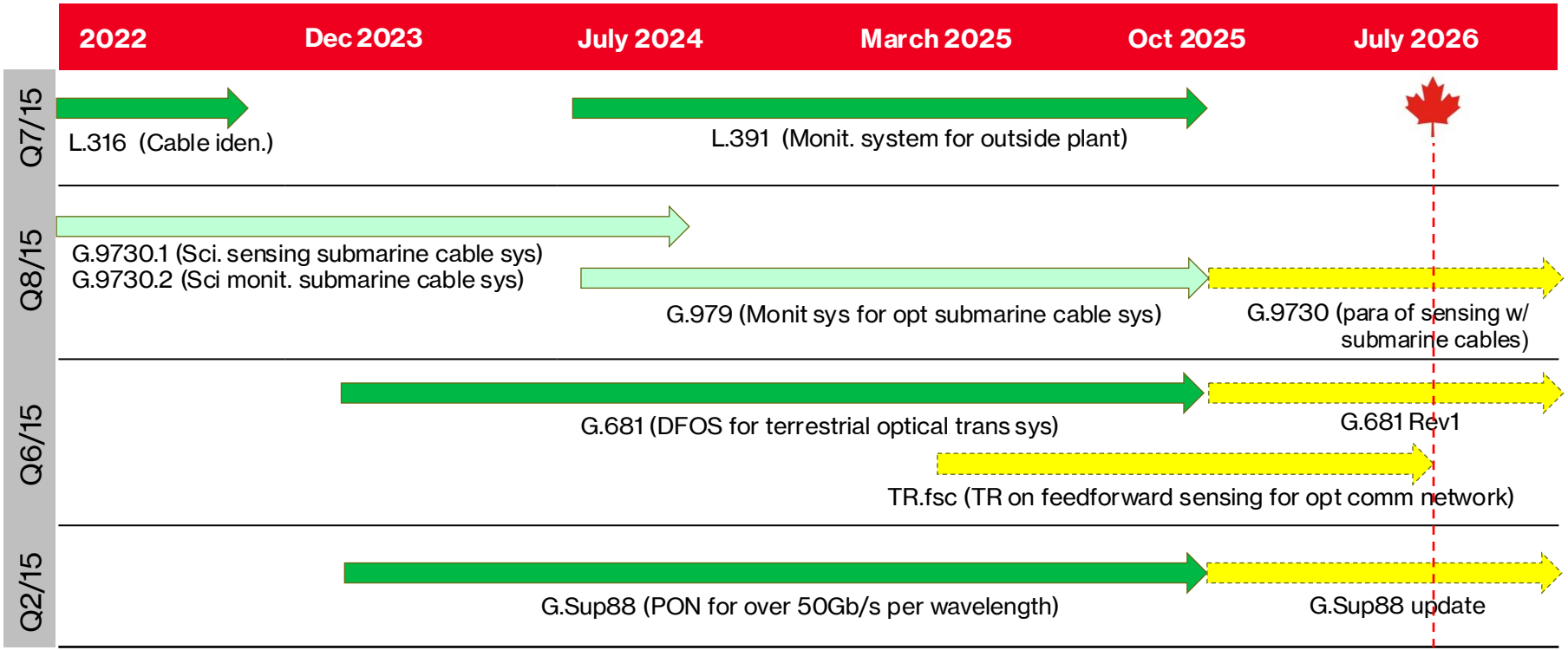
Adapted from presentation by B. Buscaino, OFC 2026 Panel "From Access Fiber to Awareness Grid: Deploying DFOS for Security, Reliability and New Services"

Fiber Sensing Standards in ITU-T SG15



G.681 Recommendation

First DFOS standard for in-service terrestrial optical networks (Nov 2025)

System Configuration:

- Backscattering DFOS
- Feedforward DFOS: informative Appendix

Fibre type: G.652, G.654, G.657

Wavelength allocation

Optical interface parameters

References:

- J. S. Wey, "*Distributed Fiber Optic Sensing (DFOS) in Telecom Networks: Industry Trends and Standards Development*," **invited**, JLT, Aug 2025. 10.1109/JLT.2025.3597192
- Y. Wakisaka, et. al, "*ITU-T G.681: the first distributed fiber optic sensing (DFOS) standard for in-service terrestrial optical networks*," JOCN SI on fiber sensing. 2026. 10.1364/JOCN.586758

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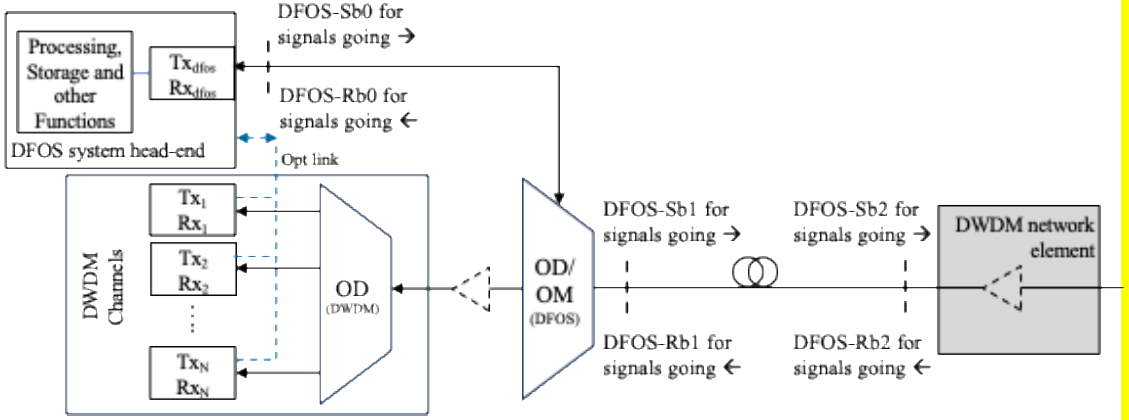
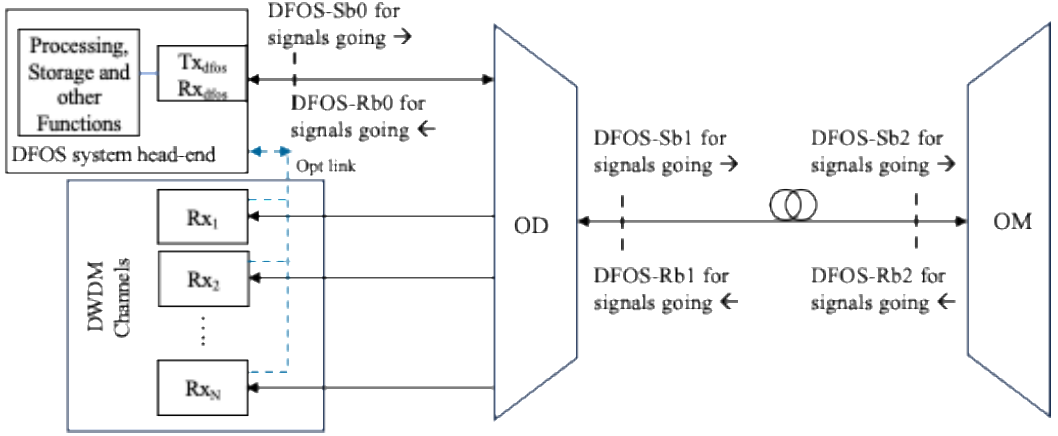
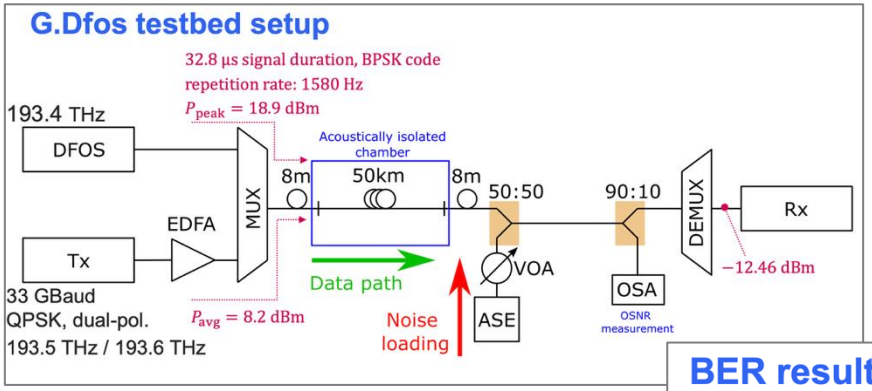
Backscatter DFOS: OOB, counter propagating



Backscatter DFOS: In-band, counter propagating



Nonlinear Interference from DFOS to DWDM signal



XPM dominant nonlinearity induced BER errors in co-propagating scenario

Tests performed by ADTRAN

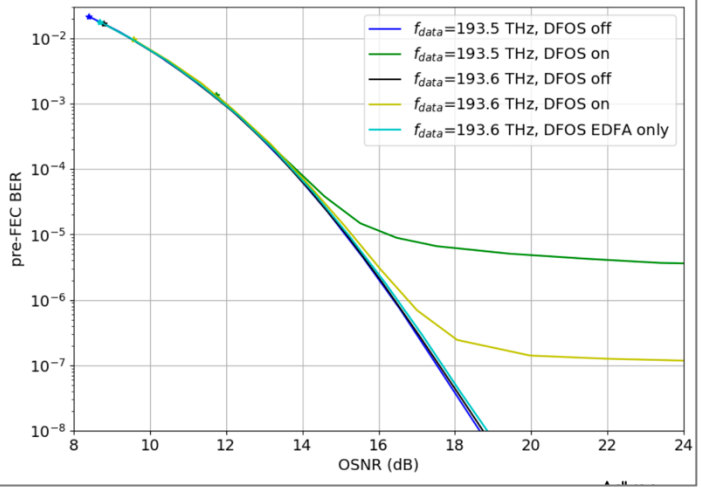
Ref: Y. Wakisaka, et. al, "*ITU-T G.681: the first distributed fiber optic sensing (DFOS) standard for in-service terrestrial optical networks*," JOCN SI on fiber sensing. 2026. 10.1364/JOCN.586758

BER results 200 GHz spacing

- Only EDFA of DFOS is switched on
- ASE noise is multiplexed at 194.3 THz

No input signal → EDFA → Circulator → to MUX

- ASE noise at DFOS wavelength does not impact BER



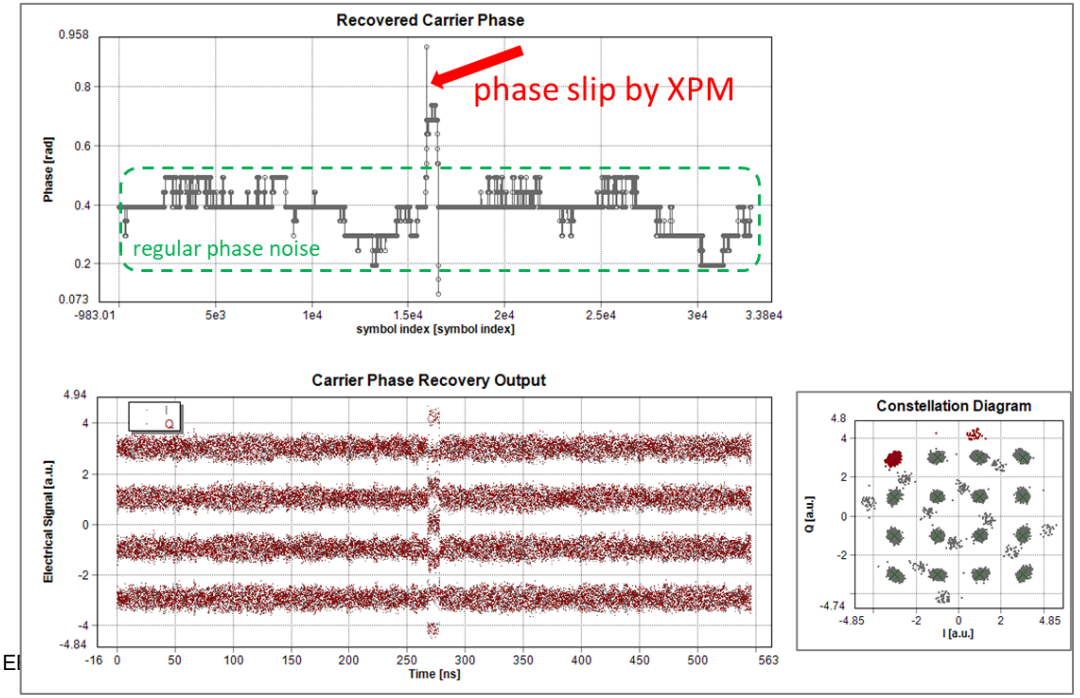
Nonlinear interference from DFOS to DWDM signal

Simulation setting:
- 40× 400ZR transceivers, 75 GHz spacing
- DWDM channel under test: 193.6 THz (center channel)
- DFOS signal frequency: 193.6 THz + 75GHz
- DFOS probe pulse: 10ns duration, 17dBm peak launch power (typical). Linewidth of 10 kHz, 1 MHz, 10 MHz

Simulation performed by HUAWEI

Ref: Y. Wakisaka, et. al, "*ITU-T G.681: the first distributed fiber optic sensing (DFOS) standard for in-service terrestrial optical networks*," JOCN SI on fiber sensing. 2026. 10.1364/JOCN.586758

- XPM from DFOS pulse introduces sharp carrier phase slips on adjacent co-propagating DWDM channel
- Negligible XPM penalty in counter-propagating scenario



Feedforward DFOS

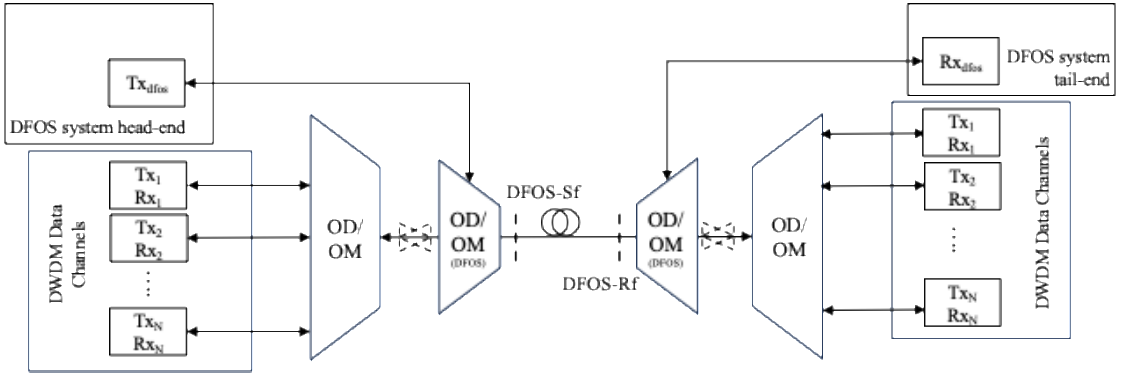
G.681 Recommendation

- In scope
- In an informative Appendix
- Not specified in the first release

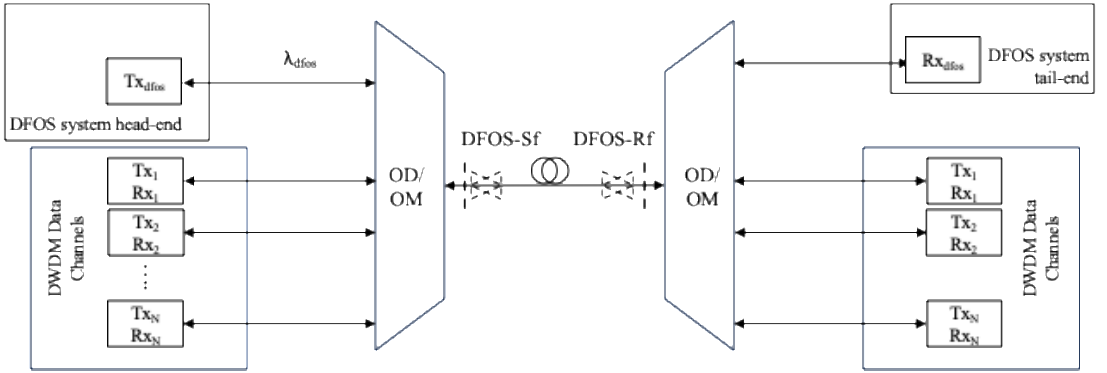
TR.fsc Tech Report

- Use cases
- Technology analysis
- Potential path to standardization
- Target agreement at this plenary

Out-of-band



In-band



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Interface Specification (in-band, counter propagation)

Parameter	Unit	Value
General information		
Fibre type	–	G.652, G.654, G.657
Allowable sensing distance	m	sba
Interface at point DFOS-Sb1		
Max DFOS signal peak power	dBm	sba
Min DFOS central frequency	THz	191.5 for (C) 186.0 for (L)
Max DFOS central frequency	THz	196.2 for (C) 191.5 for (L)
Max DFOS spectral excursion	GHz	±12.5 for 50 GHz grid ±25.0 for 100 GHz grid
Max duration of DFOS signal on-time	ms	sba
Mean power of DFOS signal during off-time	dBm	sba
Max impact to DWDM channel required OSNR in the presence of DFOS signal	dB	0.1

Parameter	Unit	Value
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Max DFOS signal peak power	dBm	sba
Min DFOS central frequency	THz	191.5 for (C) 186.0 for (L)
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Max DFOS spectral excursion	GHz	±12.5 for 50 GHz grid ±25.0 for 100 GHz grid
Max duration of DFOS signal on-time	ms	sba
Mean power of DFOS signal during off-time	dBm	sba
Max impact to DWDM channel required OSNR in the presence of DFOS signal	dB	0.1
Max impact to DWDM channel sensitivity in the presence of DFOS signal	dB	0.1

sba: specified by application

Interface Specification (OOB, counter propagation)

Parameter	Unit	Value
General information		
Fibre type	–	G.652, G.654, G.657
Allowable sensing distance	m	sba
Interface at point DFOS-Sb1		
Max DFOS signal peak power	dBm	sba
DFOS central wavelength	nm	S-band wide: 1504.5–1517.5 (197.69–199.40 THz) S-band narrow: 1508-1514 (198.15–198.94 THz) L-band: 1614–1617.4 (185.35–185.75 THz) U-band: >1635 (183.49 THz)
Max duration of DFOS signal on-time	ms	sba
Mean power of DFOS signal during off-time	dBm	sba
Max impact to DWDM channel required OSNR in the presence of DFOS signal	dB	0.1

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Mean power of DFOS signal during off-time	dBm	sba
Max impact to DWDM channel required OSNR in the presence of DFOS signal	dB	0.1
Max impact to DWDM channel sensitivity in the presence of DFOS signal	dB	0.1

sba: specified by application

DFOS in Access Network

G.Sup88

Very High Speed PON (> 50Gbps PON)

Requirements:

- In-service ODN
- No interference to service traffic
- High localization accuracy

Technology analysis:

- Backscattering & feedforward DFOS
- Direct & coherent detection

Challenges:

- Splitter port differentiation
- ODN power splitter insertion loss

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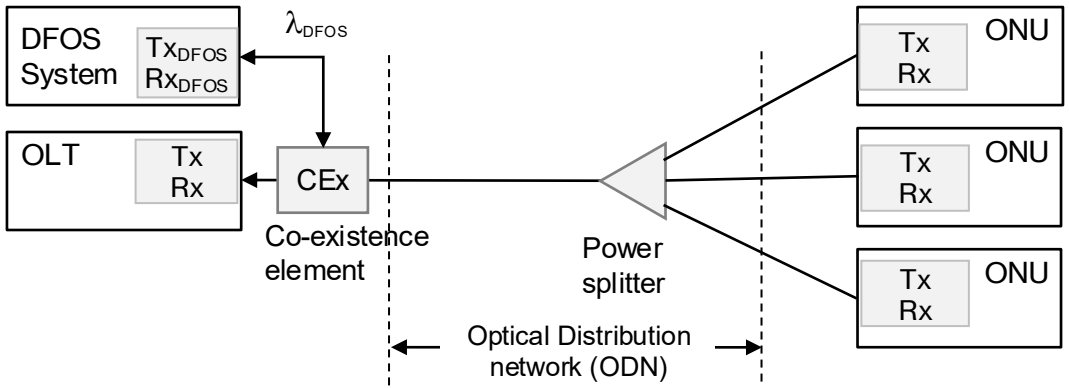
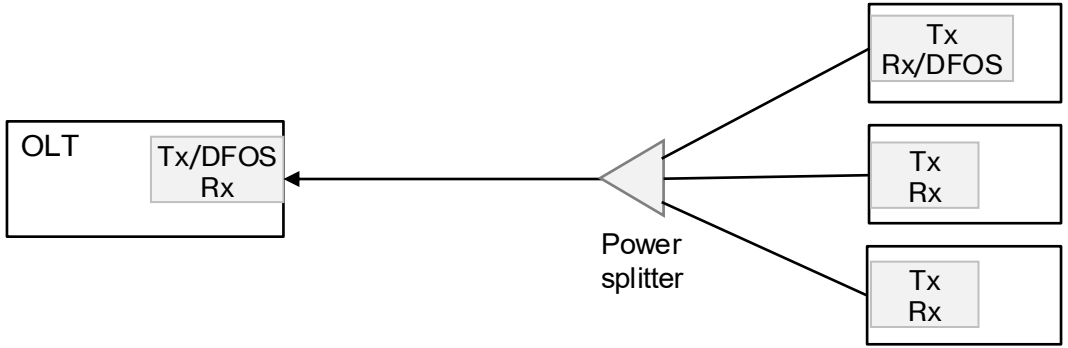
Backscattering DFOS



Feedforward DFOS



Closing Remarks

1 Performance metrics

- Sensing distance: up to 50km without in-line amplifiers
- Localization accuracy: less than 10m

2 Interoperability

- Metro. LH, subsea: common interface requirements
- Access: common operating requirements and interop

3 Deployment guidelines

- Reduce equipment cost: DFOS on Line Card… pluggable module?
- Develop standards for control & management interface, data model, etc.
- Expand collaboration with other fiber sensing industry groups and research institutes