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Executive Summary

This deliverable reports on the developments from the point of view of standards as well as legal and regulatory considerations related to project case studies. It gives an overview of monitored standards as well as contributions to standards in the framework of ICON. In particular, the contributions to ITU-T G.681 (ex. G.dfos), which focuses on the integration of sensing in dense wavelength division multiplexing (DWDM) networks without impacting the quality of transmission, are highlighted. This standard was consented in November 2025. Furthermore, relevant standardisation and recommendation activities are monitored and adopted standards are highlighted. In addition, an initial assessment of legal and regulatory implications that need to be considered for the ICON field trials is made.

This first report on standardization/certification activities is the output of T7.4. An update on the standardisation and certification activities will be reported at the end of the project in M36 in D7.7.

1. Introduction

Standardisation and certification activities are an important component of the ICON project, as they support the transfer of research results into interoperable solutions, industrial best practices, and future commercial deployments. The project addresses the integration of fibre-optic sensing into optical communication networks, which is an area of growing interest within the telecommunications industry and standardisation bodies. This integration has the potential to use the already deployed fibre network with more than 8 Gigametres of optical fibre, not only for data transmission, but also for sensing to protect the fibre infrastructure itself and other critical infrastructure deployed alongside the fibre cable.

This deliverable provides an overview of the standardisation landscape relevant to ICON and summarises the project's contributions to ongoing standardisation activities. Emphasis is placed on contributions to ITU-T Recommendation G.681, which establishes a framework for the integration of distributed fibre-optic sensing systems into optical transmission networks. In addition, the report highlights adopted standards and other relevant standards and organisations that are monitored by the consortium to ensure alignment of project developments with ongoing industry activities.

Besides technical standardisation, the report also addresses legal and regulatory aspects associated with the deployment of fibre-sensing technologies in the ICON field studies. As sensing technologies become increasingly capable of detecting acoustic and environmental events, considerations related to privacy, critical infrastructure protection, cybersecurity, and national security become relevant. The document therefore outlines the main legal frameworks that may affect sensing deployments and discusses their implications for the project use cases.

The objective of this deliverable is to provide a snapshot of the standardisation, certification, legal, and regulatory activities relevant to ICON during the first half of the project.

Table 1: Monitored standards and recommendations, as well as contributions relevant to ICON

Standardization Body	Standard	ICON Contribution	Partners
ITU-T	G.681	Technical and experimental contributions	ADTN, VPI
IEC	IEC 61757	Monitoring only	ADTN
ETSI	GS F5G 011 V1.1.	Monitoring and telemetry pipeline adoption and implementation	ADTN, TCD, LSAI
IETF	RFC 6241– NETCONF	Monitoring and adoption for device configuration and state retrieval	ADTN
IETF	RFC 7950 – YANG 1.1	Monitoring and adoption for network configuration and state modelling	ADTN
IETF	RFC 8040 – RESTCONF	Monitoring and adoption for REST access to YANG-modelled data	ADTN
OpenConfig	gNMI	Monitoring and adoption for model-driven management and telemetry	ADTN, TalTech
MCP Community	Model Context Protocol	Monitoring and adoption for read-only AI access to control-plane data	ADTN

Standardization Body	Standard	ICON Contribution	Partners
ONF	Transport API(TAPI)	Monitoring and adoption for transport topology and service interaction	ADTN, TCD, LSAI
Other organizations	**Recommendation**	**ICON Contribution**	**Partners**
SEAFOM	DAS best practices	Monitoring only	ADTN

2. Contributions to Standardisation

ADTN is involved in the ITU-T Study Group 15 Question 6, which is focused on characteristics of optical components, subsystems and systems for optical transport networks. Its work covers the specifications needed to ensure interoperability and performance of optical transmission systems. In the framework of ICON, ADTN contributed to the draft of ITU-T G.dfos, which was consented in November 2025 and is now published as ITU-T G.681. ADTN is further contributing to the first revision of the standard.

These contributions are linked to WP3 task T3.4 “Investigation of coexistence of sensing and communication signals”, which is also a prerequisite for the planned field demonstrations in WP6.

2.1. ITU-T G.681 (ex. G.dfos)

The recommendation ITU-T G.681 “Distributed fibre optic sensing system for terrestrial optical transmission systems” focuses on the seamless integration of distributed fibre sensing in DWDM networks without impacting the transmission quality.

ADTN made several contributions to support the development of ITU-T G.681, which include experimental studies. The focus was the evaluation of performance impact when adding a DFoS probing signal on a separate wavelength in the same fibre. Therefore, a probe signal from a DFoS system was multiplexed on the same fibre at a separate frequency in C-band in the neighbouring channel (in-band sensing). In this configuration, co-propagation of the data and sensing signals as well as counter-propagation were evaluated as shown in the corresponding testbed setup in Figure 1.

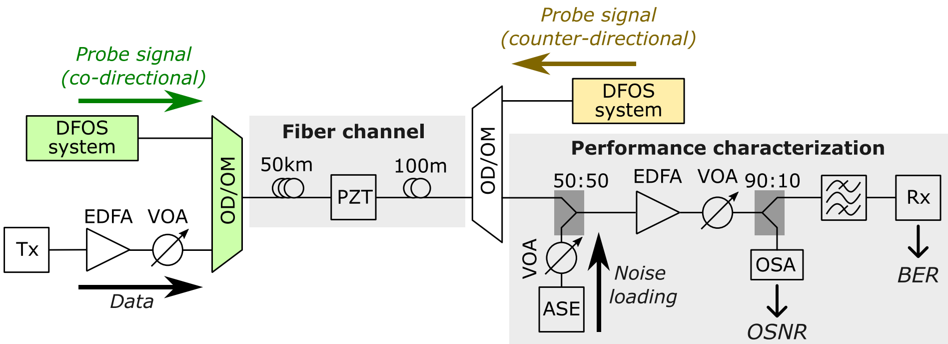

Figure 1: Experimental setup to evaluate the impact of co- and counter-propagating DFoS signals on the data transmission performance

In this configuration with small frequency separation, impacts from cross-phase modulation (XPM) and cross-polarisation modulation (XPolM) were observed. The measured pre-FEC BER shown in Figure 2 highlights that no impact is observed for counter-directional integration. In contrast, for co-directional integration, a significant impact is observed. This is a result of fast power changes of the bursty DFoS signal, which lead to fast phase transients in the data signal due to XPM. These fast phase transients cannot be compensated in the receiver digital signal processor (DSP), as they lead to burst errors and at low optical signal-to-noise ratios (OSNR) they cannot be compensated by the receiver forward error correction. Thus, it leads to a degradation of the required OSNR, i.e. the minimum OSNR needed to have practically a bit-error-rate-free transmission. For counter-directional propagation, no impact on the required OSNR is observed, since each symbol virtually sees the DFoS burst only for a short time and the effect averages over all symbols. These results were published in the Journal of Optical Communications and Networking in April 2026[1].

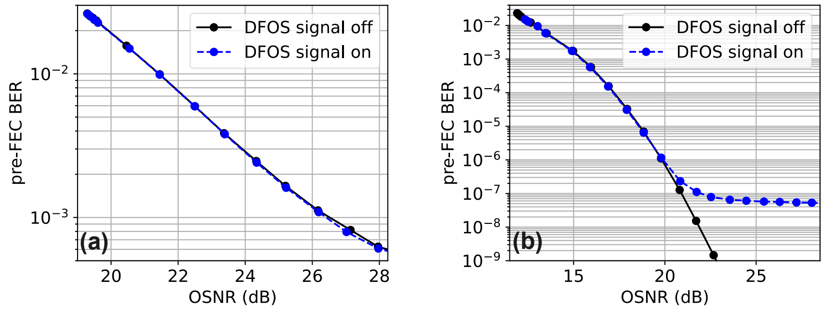

Figure 2: Measured BER versus OSNR for (a) counter-propagation of a 200 Gbit/s DP-16QAM data signal and the DFoS signal at 50 GHz spacing and for (b) co-propagation of a 100 Gbit/s DP-QPSK data signal and the DFoS signal at 100 GHz spacing.

It was further observed that the nonlinear impact from XPM and XPolM reduces with increased wavelength spacing. In addition to XPM and XPolM, Raman-induced power transfers need to be considered for higher spacings between data signals and the DFoS channel, with the Raman gain spectrum peaking at an offset of 13 THz. This can become significant when the data signals are in L-band, and the sensing signal is in the C-band. In this configuration, the DFoS burst temporarily amplifies the data channels, leading to power fluctuations in the data signal. In a configuration where the data channels are located in C-band and the sensing signal in L-band or U-band, power from the data channels is transferred to the DFoS wavelength, leading to OSNR degradation.

Furthermore, Adtran made several contributions on the nonlinear interference of the DFOS signal on the DWDM signal as well as for the parameter definitions.

In the first version of G.681, counter-directional integration was standardised since no impact on the transmission performance could be observed in measurements and simulations. When integrating DAS, the penalty on the required OSNR (or receiver sensitivity in case of unamplified links) of the DWDM channels should be lower than 0.1 dB. Furthermore, G.681 defines the applicable wavelengths for integrating sensing in a transmission link. Here, two variants are distinguished. Firstly, in-band sensing utilises a free wavelength channel to accommodate the DFoS signal, which can be a free wavelength channel in C- or L-band according to the wavelength grid definition in ITU-T G.694.1 “Spectral grids for WDM applications: DWDM frequency grid”. Secondly, out-of-band sensing is considered where the sensing signal is located outside of the commonly used wavelength bands, which can be in the S-band or upper L- or U-band.

The current work for revision 1 of G.681 focuses on the more complex parameter definitions for co-directional integration.

[1] Y. Wakisaka et al., “ITU-T G.681: the first distributed fibre optic sensing standard for in-service terrestrial optical networks”, JOCN, vol. 18 no. 4, 2026, https://doi.org/10.1364/JOCN.586758

3. Monitored and adopted standards and relevant organisations

3.1. IEC 61757

The IEC 61757 series, “Fibre optic sensors”, provides the international standardisation framework for fibre-optic sensing systems. The generic specification IEC 61757 defines the terminology, classification, performance parameters, and measurement methods used to characterise fibre-optic sensors and their components. In addition, the IEC 61757 series contains application-specific standards covering sensing modalities such as strain, temperature, acoustic sensing, vibration sensing, current measurement, voltage measurement, and displacement monitoring. The series establishes a common basis for performance evaluation, interoperability, and specification of fibre-optic sensing systems across different application domains.

Currently, no partner of ICON contributes to this IEC standard.

3.2. SEAFOM

SEAFOM describes itself as “[…] an international Joint Industry Forum, which had an original vision to promote the growth of fibre optics in subsea applications. As time has moved on, this vision has been enlarged to encompass what can be considered as the stepping stones to such challenging applications, and so now encompasses all upstream oil and gas industry applications” [2].

The organisation develops recommended practices, performance definitions, and test procedures for distributed fibre-optic sensing technologies, including Distributed Acoustic Sensing (DAS), Distributed Temperature Sensing (DTS), and distributed strain sensing. Recent activities have focused on harmonised methods for sensor-performance characterisation and the definition of common performance metrics for DAS systems.

Currently, no partner of the ICON project is a member of SEAFOM.

3.3. ETSI

The European Telecommunications Standards Institute (ETSI) develops standards for information and communications technologies, covering areas such as fixed and mobile networks, network automation, cloud technologies, and cybersecurity.

3.3.1. ETSI Standard data collection pipeline

The telemetry and data-collection pipeline is based on the implementation example presented in Annex B of ETSI GS F5G 011 V1.1.1, within the broader F5G telemetry framework. In this pipeline, Apache Kafka acts as the telemetry broker, Telegraf consumes and transforms the telemetry events, and InfluxDB provides time-series data storage.

The pipeline implementation has been enhanced with additional plugin capabilities. Redis is used for low-latency caching and rapid access to recent telemetry measurements, while the Mosquitto MQTT broker provides lightweight messaging suitable for IoT and edge devices with limited processing power, memory, bandwidth or energy resources.

Redis and Mosquitto are implementation-specific additions and are not part of the pipeline described in ETSI GS F5G 011. These additions do not represent modifications or formal contributions to the ETSI

[2] https://seafom.com/about/, Online, Accessed 2026-07-13

specification. The specification is used as a reference for the telemetry architecture and data-collection approach.

3.4. IETF

The Internet Engineering Task Force (IETF) is an open international standards organisation that develops and maintains the protocols and architectures that form the foundation of the Internet, including widely adopted management and configuration technologies.

3.4.1. NETCONF for Network Configuration

NETCONF, defined in IETF RFC 6241, is used for the configuration and retrieval of operational information from network devices. Together with YANG-based data models, it enables the control plane to retrieve, install and modify device configurations through a structured management interface. NETCONF is adopted as an implementation technology, with no formal contribution to the standard.

3.4.2. YANG-Based Data Models

YANG 1.1, defined in IETF RFC 7950, is used to model network configuration, operational state, remote procedure calls and notifications. The use of YANG provides structured and machine-readable data models that support consistent interaction between control-plane components and network devices. No formal contribution to the standard has been made.

3.4.3. RESTCONF for TAPI-Based Management

RESTCONF, defined in IETF RFC 8040, is used to access ONF TAPI data represented through YANG models. It provides an HTTP-based interface for retrieving and modifying transport-network topology, connectivity and service information. RESTCONF is adopted as an implementation interface, with no formal contribution to the standard.

3.5. OpenConfig

OpenConfig is an operator-led initiative that develops vendor-neutral data models and interfaces to support automated, model-driven network management and telemetry.

3.5.1. gNMI for Network Management and Telemetry

The gRPC Network Management Interface (gNMI), specified by OpenConfig, is used for model-driven interaction with network devices. It supports configuration retrieval and modification, operational-state access, and subscription-based streaming telemetry through a common gRPC interface. In the control plane, gNMI enables structured and vendor-independent communication between management components and supported network devices. No formal contribution to the specification has been made.

3.6. Agentic AI Foundation

The Agentic AI Foundation promotes open standards and interoperability for AI agents and related ecosystems, including specifications that enable interactions between AI agents, tools, and data sources.

3.6.1. Model Context Protocol for AI Interaction

The Model Context Protocol is used to provide a controlled, read-only interface between the AI assistant and authorised control-plane resources. Through MCP, the assistant can access selected network information and invoke permitted data-retrieval capabilities without receiving configuration or modification privileges.

MCP follows a host-client-server architecture and uses JSON-RPC 2.0 messages for communication between clients and servers. Its use represents adoption of an open specification, with no formal contribution to MCP.

3.7. Open Networking Foundation

The Open Networking Foundation (ONF) develops open networking frameworks and specifications that support programmable, automated, and interoperable network infrastructures.

3.7.1. Transport API for Control-Plane Interaction

The ONF Transport API (TAPI) is used for communication between the network orchestrator and domain-specific controllers. It provides model-driven access to transport network topology, connectivity and service information. TAPI is adopted as an implementation interface, with no formal contribution to the specification.

3.8. Suboptic open cable management group

An initiative is being taken within Suboptic and the Open Cable Management group for an Open standard on State of Polarisation (SOP) data collection. The purpose is to initiate standardisation initiatives achieving similar formats and methods for SOP data collection from coherent transponders and instruments in telecom infrastructure for SOP monitoring.

4. Legal and Regulatory considerations for project case studies

The considerations presented in this section do not constitute legal advice.

With fibre sensing, existing fibre infrastructure can be used to monitor environmental effects that occur in the vicinity of the cable. This includes vibrations, acoustic events and temperature events, which lead to measurable changes in the fibre properties. In particular, phase-based sensing schemes are highly sensitive, and it has been demonstrated that they are able to detect human voice[3]. Furthermore, these schemes enable the detection of acoustic signatures of vessels[4], which is critical considering military vessels. Human voice recognition and vessel signature detection need to be considered from a legal and regulatory point of view. Both applications are summarised under the term acoustic profiling.

4.1. Acoustic profiling

In Table 2, a list of sensing schemes for detecting dynamic events is provided, together with their sensitivity levels and localisation capabilities. Despite the low sensitivity of state-of-polarisation (SoP) sensing, it has been shown that it allows voice recognition when a long fibre on the kilometre scale is located next to the sound source[5]. However, this scenario does not occur in practice.

Table 2: Sensing schemes that enable the detection of dynamic events

Fibre sensing scheme	Acoustic sound sensitivity	Localization possible
Feed-forward Phase	High	Yes, coarse localisation in kilometre range (bi-directional)
Feed-forward SoP	Low	Yes, coarse localisation in kilometre range (bi-directional)
DAS	High	Yes, fine localisation in meter range
OFDR	TBD	Yes

Furthermore, acoustic signature measurements, combined with the ability to detect the location of the sound source, need to be considered from a profiling perspective. Back-scattering-based sensing schemes like DAS allow the spatial localisation of acoustic sources within the meter range along a fibre cable with a length of 120 kilometres or more. Feed-forward sensing techniques, where a signal is transmitted at one end of the link and received and processed at the other end, may allow for spatial localisation of the event along the link by measuring the change in different wavelengths and using the timing walk-off between the wavelengths due to dispersion differences [Skarvang]. Furthermore, emerging techniques, e.g., bi-directional feed-forward sensing, allow for coarse localisation along the link [6]. Furthermore, the potential integration of SoP and phase feed-forward sensing into future commercial transceivers could enable sensing on all fibres in metro and core networks.

Other sensing schemes that require signal averaging to enable measurement of weak scattering signals, e.g. Brillouin-OTDR and Raman-OTDR, only allow the detection of events on long timescales,

[3] C. Franciscangelis, "Real-time distributed fibre microphone based on phase-OTDR", Optics Express, vol. 24 no. 26, 2016, https://doi.org/10.1364/OE.24.029597
[4] Erick Eduardo Ramirez-Torres et al., "Vessel Detection and Localization Using Distributed Acoustic Sensing in Submarine Optical Fibre Cables", 2025, https://doi.org/10.48550/arXiv.2509.11614
[5] Hamze Ghorbani Koujani et al., "Covert Speech Detection via Polarization Dynamics in 10 Gbps IMDD Optical Fibre Links", ECOC 2025, https://doi.org/10.1109/ECOC66593.2025.11263157
[6] B. Buscaino et al.," Vibration Detection and Localization with Coherent Optical Transponders Operating at 200GBd-1.6Tb/s", Advanced Photonics Congress, SPPCom, 2025, doi.org/10.1364/SPPCOM.2025.SpW4E.2

such as temperature changes and slowly changing strain, and thus do not allow for acoustic signature profiling.

4.2. Legal and regulatory aspects

The legal implications of fibre sensing depend on the sensing scheme, the type of information that can be extracted and the intended application. In general, the measurement of environmental parameters on a long timescale such as temperature and strain does not raise significant legal concerns. However, sensing techniques that enable acoustic and vibration detection, classification, or profiling of human activities or vessels may be subject to additional legal and regulatory requirements.

The reconstruction of speech or the recognition of human voices may result in the processing of personal information and therefore raise privacy and data-protection concerns. Similarly, the extraction of acoustic signatures that enable vessel classification or tracking can have implications from a national security and defence perspective, particularly when military vessels are involved.

Furthermore, fibre-sensing systems deployed on telecommunications networks or submarine cable infrastructure may fall within regulatory frameworks related to the protection of critical infrastructure. The collection, storage, and sharing of voice recordings, vessel-signature databases, or other derived information may also be subject to restrictions depending on the deployment scenario and jurisdiction. In addition, advanced sensing technologies with the potential to support surveillance, maritime monitoring, or security-related applications may be subject to export-control regulations.

Relevant legal and regulatory frameworks that may need to be considered include:

- **General Data Protection Regulation (GDPR)** for deployments where voice reconstruction, voice recognition, or other sensing-derived information could include personal data
- **NIS2 Directive (Directive (EU) 2022/2555)** relating to cybersecurity and resilience requirements for operators of essential and important entities, including telecommunications and digital infrastructure providers
- **National critical infrastructure protection regulations**, which may impose additional requirements on sensing systems deployed on telecommunications networks, submarine cables, or other critical infrastructure assets
- **National security and defence regulations**, particularly where sensing data may enable the identification, tracking, or profiling of military vessels or other defence-related assets
- **Maritime security and surveillance regulations**, where sensing capabilities are used for vessel monitoring, maritime domain awareness, or the protection of territorial waters and strategic infrastructure

Consequently, legal and regulatory assessments should consider both the sensing capability and the deployment conditions of a given technology. In particular, sensing techniques capable of speech reconstruction, voice recognition, high-sensitivity acoustic detection, or spatial localisation may require additional consideration from a privacy, national security, critical infrastructure, and export-control perspective. The applicable legal framework may therefore depend not only on the sensing technology itself, but also on the type of information that can be extracted and the potential use of the resulting sensing data.

4.3. Impact on the ICON field studies

Measured datasets need to be handled carefully, and data that includes potential for acoustic profiling cannot be shared or needs to be filtered accordingly before sharing. No personal data processing is foreseen within ICON field trials. Where sensing data could indirectly enable identification of individuals, data minimisation and access-control measures will be applied.

Table 3: Applicable regulatory frameworks

Topic	Risk level	Applicable framework	Mitigation
Voice reconstruction	High	GDPR	Data minimization
Detection of human presence/activity	Medium/High	GDPR	Aggregate data, avoid individual-level monitoring
Vessel detection	Medium/High	National security regulations	Restricted access or data filtering
Temperature monitoring	Low	None identified	No specific action
Fibre sensing on public telecom networks	Medium	Telecom regulations, NIS2	Operator approval and security assessment
Sharing raw sensing datasets with third parties	Medium/High	GDPR, contractual requirements	Data filtering and anonymisation

4.3.1. Subsea network monitoring

The subsea fibre monitoring field trial is conducted in the network of TN. As the trial is performed on critical telecommunications infrastructure and involves subsea cable assets, all activities must comply with applicable telecommunications, cybersecurity, critical infrastructure, data protection, and maritime regulations. Particular care must be taken to ensure that sensing data collected during the trial are used exclusively for the objectives defined within the ICON project and do not disclose commercially sensitive information, security-related information, or information that could enable the identification of individuals or military vessels.

Any trials involving recording of audio, e.g. DAS trials using subsea cables, require approval from the Norwegian coastal authority. By ensuring secure data collection and data storage, as well as data access limited to qualified personnel only, allowance for trials may be given.

All activities are coordinated with TN. In addition, the requirements of governmental and regulatory authorities must be complied with, and applications and approvals for conducting measurements in TN's network must be obtained.

4.3.2. Terrestrial network monitoring

For field demos in terrestrial networks, legal and regulatory considerations need to be aligned with the network operator/ owner and corresponding entities.

4.3.3. Demo in the TCD campus network

The field demo in the campus network of TCD involves sensing of the deployed underground cable in the University campus. Similar to the subsea network monitoring field study, care must be taken to ensure that sensing data collected during the trial are used exclusively for the objectives defined within the ICON project and do not disclose commercially sensitive information, security-related information, or information that could enable the identification of individuals. Accordingly, data set pre-processing is considered to filter sensitive information as well as restricting access. Accordingly, all activities are coordinated with TCD, and the requirements of governmental and regulatory authorities will be complied with.

5. Certification

Certification activities are not applicable during the first project phase. The technologies developed within ICON are currently being researched, validated, and demonstrated in laboratory and field-trial environments.

6. Summary

During the first reporting period of ICON, standardisation activities focused on contributions to ITU-T G.681, the first Recommendation addressing the integration of fibre sensing into telecommunications networks. These contributions, centred on experimental interoperability studies and validation tests, supported the development of ITU-T G.dfos, which achieved consent in November 2025 and was subsequently published as ITU-T Recommendation G.681. For the ongoing Revision 1 of the standard to include co-propagation of data and sensing signals, ICON will continue to contribute. Furthermore, ICON partners adopted standards and recommendations in the processing pipeline. In parallel, the consortium continues to monitor relevant standardisation activities.

The project has also identified legal and regulatory considerations associated with sensing deployments and data collection in the ongoing and planned field trials, particularly concerning privacy, critical infrastructure protection and maritime monitoring. These activities will continue throughout the project and will be updated in Deliverable D7.7 at project completion.