Public Disclosure Authorized

Open Terrestrial Fiber Data Standard and Map ASA (P176146)

Guide to Online Resources and Standard Development Process Overview

Table of Contents

Executive Summary

Universal broadband connectivity is crucial for economic development, and the ongoing COVID-19 pandemic has highlighted the need for reliable and accessible broadband internet. However, the lack of standardized and easily accessible data on fiber optic infrastructure hinders effective decision-making for targeted and cost-efficient investments.

To address this problem, the World Bank Digital Development Unit, in collaboration with the International Telecommunications Union (ITU), initiated the development of the Open Fiber Data Standard (OFDS). OFDS can help to address the challenge of inadequate data on fiber optic infrastructure. The proposed solution follows open principles and aims to establish a global open standard for fiber optic infrastructure data. The adoption of this Standard would enable seamless data sharing among stakeholders, facilitate informed investment decisions, and reduce complexity in the digital ecosystem.

The process of developing the Open Fiber Data Standard involved several key stages, including developing a comprehensive glossary and list of stakeholders, demand-side research, supply-side research, prior art research, data modeling, schema and documentation development, and pilot testing. Stakeholder engagement was a vital aspect, with participation from civil society, private sector organizations, and international organizations to ensure the inclusivity and transparency of the standard development.

The purpose of this document is to serve as a guide to the online resources and information published regarding the Open Fiber Data Standard (OFDS). The two main online resources containing detailed information on the OFDS, technical and normative documentation, and related tools are the OFDS GitHub repository and OFDS documentation site. It includes key elements of the standard development process, as well as annexes containing relevant documentation. By following open standard good practices and making all relevant information and documentation available online, the aim is to promote transparency, public consultation, and building ownership of the standard among interested stakeholder groups.

This document provides information on each stage of the process, including the identification of stakeholders, use cases, user stories, and requirements for the standard, with detailed documentation provided in supporting Annexes. All documentation and consultation records are available publicly online following the open approach.

By adopting OFDS, stakeholders from the private and public sectors can make informed decisions about investments and improvements in the digital ecosystem. The standardization and transparency provided by the Open Fiber Data Standard will contribute to bridging the digital divide, promoting universal broadband connectivity, and driving economic growth and social development.

Background

Globally, universal broadband connectivity is a crucial component of a country's economic development. By promoting broadband infrastructure investment and deployment, governments can create a more inclusive and competitive environment that fosters innovation and economic growth. Access to high-speed internet is vital for improving the productivity of businesses, enhancing the delivery of public services, and empowering citizens to participate in the digital economy. In addition, universal broadband connectivity can help bridge the digital divide between urban and rural areas, promoting greater equity in access to economic opportunities and social services. Governments that prioritize universal broadband connectivity as a key policy objective can benefit from increased economic growth, improved citizen welfare, and enhanced global competitiveness.

The ongoing COVID-19 pandemic has underscored the importance of access to broadband internet connectivity to mitigate against its negative impacts. However, while digital connectivity and technologies unlocked opportunities for some during the pandemic, large portions of the population in developing countries remain unconnected to the internet. Given the scale of investment needs to fill access gaps for high-speed broadband services for all by 2030, the availability to adequate data on existing telecom infrastructure, particularly fiber optic infrastructure, can support decisions for more targeted and cost-efficient infrastructure investments by the private and public sectors.

Currently, the telecom sector lacks readily available and usable terrestrial fiber infrastructure data, and the data available is varied in format, scale of information, and ownership. These challenges of availability of usable data arising from distributed ownership of infrastructure, and lack of harmonization when available, creates a more complex digital ecosystem that requires a greater level of publicly available data with high levels of standardization and transparency to better understand the impact of existing and potential investments in fiber digital infrastructure.

The challenge of inadequate data on fiber optic infrastructure lies in the lack of standardization and duplication of information, as well as the restricted access to data due to security concerns and competitive advantages held by infrastructure owners. To address this issue, it is crucial to identify an open standard that can be adopted by all stakeholders to ensure seamless access and usage of the data. This would entail identifying reliable sources of Broadband Connectivity Maps (BCM) to mitigate the impact of limited data access.

The lack of fiber network data causes problems for a range of stakeholders. For example, network operators invest time and money in duplicating existing fiber network infrastructure, ultimately increasing costs for end users. Moreover, academics, researchers and policy analysts can’t assess the socioeconomic impact of high-speed broadband connectivity, which in turn means that governments can’t make informed decisions about investing in fiber infrastructure. Additionally, network operators, governments, and investors struggle to identify infrastructure gaps and

opportunities, which leads to communities and institutions remaining underserved and missing out on the benefits of access to high-speed broadband.

To address these issues the team has developed an Open Standard for fiber optic infrastructure data that can be used by everyone to allow ease of data sharing among sector stakeholders as well as other potential users of such infrastructure data. A common open standard for fiber optic infrastructure data would enable all parties, including private and public sectors, to make informed decisions about investments and improvements to the digital ecosystem. This would also reduce the complexity of the digital ecosystem by providing a unified and harmonized approach to data collection and dissemination. The adoption of a common standard would also encourage infrastructure owners to share data without hesitation, thereby reducing the risk of security breaches and protecting their competitive advantage.

Proposed Solution

The World Bank Digital Development Unit team in collaboration with the International Telecommunications Union (ITU) under Joint Declaration on Cooperation on the Advancement of the 2030 Agenda for Sustainable Development (Joint Declaration) initiated an activity to promote open data initiatives for telecommunications infrastructure, starting with fiber optic terrestrial infrastructure data, given the foundational role it plays in driving meaningful universal access to broadband. The objective of the joint initiative was to create an Open Standard for terrestrial Optical Fiber Cable (OFC) data and to create a digital map of terrestrial OFC infrastructure worldwide as a public good.

An Open Standard approach refers to the adoption of a standardized and transparent framework that is accessible to a wide range of stakeholders. It emphasizes collaboration, inclusivity, and the sharing of information and resources. Key elements of an open approach typically include:

- Collaboration: Multiple stakeholders, including infrastructure owners, government agencies, industry experts, and community representatives, work together to develop and implement the standard. This collaborative approach ensures that different perspectives and requirements are considered.
- Transparency: The development process of the open standard is transparent, allowing all interested parties to have visibility into the decision-making and implementation processes. This transparency helps build trust among stakeholders and ensures that the standard is not influenced by any single entity's interests.
- Accessibility: The open standard is designed to be accessible and usable by a wide range of users, regardless of their technical expertise or organizational affiliations. It aims to minimize barriers to entry and encourage widespread adoption and participation.
- Security: The Open Standard approach places a strong emphasis on security considerations. It includes robust mechanisms to protect sensitive information, prevent unauthorized access, and mitigate potential risks and vulnerabilities.

- Information sharing: The Open Standard promotes the sharing of information and data among stakeholders. It enables interoperability, allowing different systems and entities to exchange information effectively. This sharing of information facilitates better coordination, decision-making, and overall efficiency.
- Geographical coverage: The Open Standard is developed with a global perspective, considering the needs and requirements of various regions and jurisdictions. It aims to provide a framework that can be implemented and adapted across different geographical locations, ensuring widespread applicability and impact.

By embracing an open approach, organizations and stakeholders can foster innovation, encourage collaboration, and address complex challenges more effectively by leveraging the collective intelligence and expertise of a diverse community.

All documentation and consultation records are available publicly online following the open approach. Two main online sources for information related to OFDS can be found at OFDS GitHub repository and OFDS documentation site. The purpose of this document is to serve as a guide to the online resources and information published regarding the Open Fiber Data Standard. This document provides an overview on each stage of the standard development process, including the identification of stakeholders, use cases, user stories, and requirements for the standard, with detailed documentation provided in supporting Annexes.

This virtual technical review is for the Standard's technical and normative documentation available at the abovementioned public resources. Following this decision review meeting, feedback on the Standard and its documentation will be incorporated into the standard, and the team will present Standard demonstration use cases and Standard governance options for review and decision at a virtual decision review meeting planned for June 2023.

Process for Developing the Standard

Under a joint declaration, the World Bank and the International Telecommunications Union launched the activity, financed by the Digital Development Partnership Trust Fund. To research and develop an Open Fiber Data Standard, the World Bank contracted Open Data Services Co-operative. As part of the activity, a steering committee was established comprising members of civil society and private sector, such as Mozilla Corporation, the Internet Society (ISOC), Liquid Intelligent Technologies, CSquared, and Digital Council Africa to get their feedback and advice. At the World Telecommunication Development Conference in June 2022, steering committee members pledged to:

- promote the collaborative development of open data standards in the ICT infrastructure sector in order to better understand the challenges and opportunities of providing affordable access to communication for all;
- develop open data standards for describing terrestrial fiber optic networks;

- develop sustainable mechanisms for promoting public input, management, and adoption of these standards; and,
- promote a culture of openness and trust among regulators, infrastructure owners and operators.

The activity included following steps:

1. Standard development.
2. Pilot testing and production of demonstration use-cases.
3. Long term governance options and adoption.

The methodology for developing OFDS includes eight key stages:

- **Glossary and stakeholders**. It includes identifying stakeholders, understanding the policy context and designing a research process.
- **Demand-side research**. It includes understanding what data stakeholders need and developing use cases.
- **Supply-side research**. It includes understanding data availability and existing practices for data collection, storage, structure, and formats.
- **Prior art research**. It includes identifying existing standards and initiatives to inform the development of the standard.
- **Data modelling**. It includes developing a conceptual framework and data model based on the requirements identified in the research.
- **Schema and documentation**. It includes developing a schema and documentation for the standard.
- **Pilots and testing**. It includes supporting pilot implementations and capturing lessons learned for the development of the standard.
- **Tooling development**. It includes developing supporting tooling for data publishers and users.

Specific activities that were carried out at each stage of the process are described below.

Glossary and stakeholders

The World Bank worked with Open Data Services, ITU and Mozilla to identify stakeholders with an interest in open fiber data. They represented data publishers, data users and infomediaries. Each stakeholder's user group and role in relation to the Standard was analyzed. User groups covered included: Physical infrastructure and network providers, Telecoms consultants, Researchers, Regulatory agencies, Industry associations, Investors, Non-governmental organizations, Intergovernmental organizations.

To develop the understanding of the domain the team carried out background reading and desk research and populated a glossary for the Standard **(Annex 1**). Key elements of the glossary are listed in **Table 1**.

Table 1. Glossary for the Standard

Concept	Definition
Aerial cable	A fiber cable that is deployed aerially, usually along electricity power transmission lines.
Backhaul	A network path between base station systems and a core network.
Border crossing	The International Boundary, the point at which control transfers from one international operator to the next international operator, normally exists within the Inter Country Path Core Element (ICPCE). Generally, this would be half-way along a submarine cable or terrestrial border crossing ICPCE. The Border Crossing Point may coincide with the International Boundary (for example, for a terrestrial border crossing ICPCE) or, in the case of a submarine cable (for example), there would be two border crossings, corresponding to the coastline of the operator's country, which would not coincide with the International Boundary.
Co-operative	An autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically-controlled enterprise.
Contract	An agreement between the public and private sector to develop a network.
Data centre	Structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability. NOTE 1 – A structure can consist of multiple buildings and/or spaces with specific functions to support the primary function. NOTE 2 – The boundaries of the structure or space considered the data centre, which includes the information and communication technology equipment and supporting environmental controls, can be defined within a larger structure or building.
DWDM (Dense Wavelength Division Multiplexing)	A technology that multiplexes a number of optical carrier signals onto a single optical fibre by using different wavelengths.
End users	End users are private citizens, small or large companies or public institutions purchasing services over the network.
Equipped network capacity	The transmission rate of the links in the network, irrespective of the services (voice, data, Internet, other) which are delivered through it. This is a measure of throughput and is expressed in Gbit/sec (Gbps). The equipped capacity is the total capacity of the circuits (E1, DS3,

	STM-1 and so on) which have been activated in the network transmission equipment on that particular route.
Identifier	A unique identifier for an organization.
Internet Exchange Point (IXP)	A physical access point that Internet service providers (ISPs) and content delivery networks (CDNs) connect to for the purpose of exchanging traffic.
Internet Protocol (IP)	A network layer protocol that defines the addressing mechanism on the Internet to allow data to be transmitted.
Investor	An organization that provides financing for the development of a network.
Link dark fiber availability	Unused optical fibre, available for use in fibre-optic communication.
Link go-live date	Year the network went live.
Link length	The physical length of fibre optic cable between the endpoints.
Link network provider	The organization that operates the active network infrastructure, i.e. the electrical elements, such as lit fiber, access node switches and broadband remote access servers. The network provider delivers service providers' services to end users. It can own or lease the active network infrastructure.
Link number of fibers	The number of individual optical fibres in a cable.
Link physical infrastructure provider	The organization that owns and operates the passive network infrastructure, i.e. the non-electrical elements, such as dark fibre, ducts and physical sites.
Link route	A polyline showing a more detailed route of the span
Link route	The physical route of the link between its endpoints.
Multi-Protocol Label Switching (MPLS)	A routing technique that directs data from one node to the next based on labels rather than network addresses.
Network	A telecommunication network. A network consists of a set of nodes interconnected by links.
Network phase	A set of nodes and/or links deployed as a group.
Node	An access (entry or exit) point to a network. A node consists of active or passive equipment which is capable of providing access to the network. Sites at which there are no means of access to a network are not classified as nodes. Nodes can allow for interconnections to other networks, and/or connections to end users.
Node address	The physical address of the node.
Node location	The geographic coordinates of the node.
Node name	The name of the node.
Node power	Whether power for the operation of active network equipment is available at the node.
Node rackspace	The total used and unused rackspace available at the node.

Node services	The services available at the endpoint, using the open node services codelist.
Node type: Add Drop Site	A point at which individual digital bit streams can be added to or dropped from a multiplexed signal in order to redirect bit streams between network paths.
Node type: Aggregation	A point at which multiple fibre optic cables are spliced together. Typically located between an exchange or POP and GPON splitters or customer premises.
Node type: Cabinet	An distribution cabinet to which end users are connected by a standard phone line.
Node type: Cable landing	The location where a submarine or other underwater cable makes landfall.
Node type: CAI	Community anchor institution
Node type: Chamber	An optical cable connection chamber. Normally used to house splice closures or excess fibre optic cable.
Node type: exchange	A telephone exchange.
Node type: Peering Point	A point at which two or more networks agree to exchange their traffic.
Node type: Point of interconnection	A point at which networks interconnect. An interconnection point is a demarcation point between networks.
Node type: Point of Presence (PoP)	A demarcation point, access point, or physical location at which two or more networks or communication devices share a connection.
Node type: Pole	A pole used to support aerial fibre optic cable.
Node type: Repeater site	A site at which fibre optic signals are amplified or repeated. Also known as a regeneration facility.
Operational	The span is live and carries traffic.
Operational status	The status of the network infrastructure.
Planned	Financing for the link has been arranged. Advanced network plan for which financing has been finalized, but a contract may not yet have been awarded.
Private	A for-profit business that is not owned or operated by the government.
Proposed	An early network plan for which financing is being sought.
Public Private Partnership (PPP)	A long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility and remuneration is linked to performance.
Service providers	Sells services (e.g. Internet, TV, telephony, etc.) to the end user
SONET (Synchronous Optical Networking)	A standardized protocol for transferring multiple digital bit streams synchronously over optical fibre. SONET is used in the US and Canada.

Span	A direct physical connection between two nodes.
Synchronous Digital Hierarchy (SDH)	A group of fiber optic transmission rates that transport digital signals with different capacities.
Tower	A self-supporting or cantilevered structure, while a mast is held up by stays or guys. A mast is a ground-based or rooftop structure that supports antennas at a height where they can satisfactorily send or receive radio waves.
Under construction	The span is in the process of being physically deployed.

Demand-side research

Taking account of the prior work on the data model by the technical working group[1], the objectives of the demand side research were to identify and document the use cases that informed the draft data model prepared by the technical working group and any additional use cases that should be considered. It included producing use cases, user stories, analyzing requirements and validating them.

Use cases are high-level narrative descriptions of how different stakeholders want to use and/or publish open fiber data. As part of the demand-side research nine stakeholder interviews were conducted to understand the needs of data users. Desk research was carried out to identify other users and use cases for open fiber data. Seven primary use cases and four cross-cutting use cases were identified detailing the characteristics and needs of users.

Primary use cases included:

1) Network investment, planning, and deployment;
2) Avoiding damage to existing network infrastructure;
3) Climate and disaster resilience;
4) Impact analysis, policy development, and decision making;
5) Advocacy;
6) Statistics and indicators;
7) Progress and investment monitoring.

Crosscutting uses cases included:

1) Mapping and GIS analysis;
2) Connecting to other datasets;
3) Combining data from different networks;
4) Non-fiber technologies.

[1] Technical working group constituted by the steering committee members included technical staff from infrastructure owners, international organizations, and mapping service providers.

Use cases are described in depth in the demand side research consultation document **(Annex 2).**

User stories are detailed and specific descriptions of the user needs identified for each use case. Based on the use cases, 47 user stories for open fiber data were documented (**Annex 3**).

Requirements are technical conditions that the standard should satisfy. Requirements may cover fields to be disclosed, publication formats or access methods. Based on the user stories, a list of requirements for OFDS were documented. They are included in **Table 2**. **Annex 4** includes an extended list.

Table 2. Requirements for the standard

Requirement	Example fields
The capacity of existing and planned fibre infrastructure	Capacity
The organisation that is responsible for the passive physical infrastructure	Owner,Owner,Physical infrastructure provider
The physical deployment of links in the network	Deployment
The physical route of fibre cables	Link route,Geometry (Multilinestring),Geometry (Linestring)
The endpoints of each link in the network	Endpoints,Link endpoints,Link endpoints
Operational status of the transmission network	Remark,Span status,Link status,Phase status,Status_of_N,Status,Link status
Node locations	Node locations,Node location,Geometry (Point)
Transmission network length (Route kilometers)	Optical length (km),Km
Network capacity (bit rate)	Capacity,Stm1,link capacity
Number of optical fibres within the cable	Number of cores
Node name	Endpoints,Node name,Node names,Node name,Transmissi,Town,Node name
Node type	Node type,Node type
Node region	Area
Node country	Country
Node city	City
Node address - structured data	Address,Address
Node status	Node status
Node international connections	International connections,International connections available at nodes,International connections
Link name	Section,link name
The country of the link	Country

The phase in which nodes and links will be deployed	Phase,Phase,Status
Phase date	Phase year
phase name	Phase name
Expected completion date for span	Remark,Planned phase commissioning date,Phase status
Whether the cable is deployed aerially or underground	Fiber type and installation method
Additional details about the deployment of the cable	Fiber type and installation method
The ITU standard of the fibre	Standard,fibre standard
Cable landing station	Submarine landing station with number of sea cables
Number of sea cables at cable landing stations	Submarine landing station with number of sea cables
Transmission medium	Transmission medium

Supply-side research

The objectives of the supply side research were to identify the practices that informed the draft data model prepared by the technical working group and any additional practices that should be considered.

In order to gain an understanding of current practice across countries of different sizes, languages, income groups and development levels, a representative sample of nine African countries was selected for desk research. For each country, the regulatory agency and key network providers were identified, and desk research was carried out to collect examples of data publication. Moreover, a wider scan of publication practices outside Africa was carried out during which publications from Chile, New Zealand, the United Kingdom, and the United States were identified. The full list of datasets, publications and publishers identified can be viewed in **Annex 5.**

The scope of the research was restricted to publications that include information on fiber optic network infrastructure. In particular, area-based maps of broadband coverage and availability were omitted from the scope.

The research was followed by the review of the structure, content, and format of the datasets identified in each publication and the fields present in each dataset. For each dataset, the recorded properties included: Publisher, Country, Reach (National backbone, middle mile, or access), Publication format(s), Access methods, Fields. For each field, example values, codelists, and a mapping to concepts in the glossary and properties in the draft data model were recorded. The fields in each dataset were then mapped to concepts in the glossary. The list of concepts identified is listed in **Table 3**. In total, 343 fields across 84 datasets from 41 publications were

reviewed. Extended list can be viewed in Supply side research: Common concepts and standardization **(Annex 6).**

Table 3. List of supply side research concepts

Concept	Parent concept
Node location	Node
Link route	Link
Node name	Node
Link status	Link
Node type	Node
Node address	Node
Link physical infrastructure provider	Link
Node international connections	Node
Phase name	Phase
Link length	Link
Link deployment	Link
Link name	Link
Node status	Node
Link capacity	Link
Link number of fibers	Link
Node identifier	Node
Node type: Point of Presence (PoP)	Node
Link network provider	Link
Link ownership	Link
Link installation date	Link
Network name	Network
Link technology	Link
Link fiber standard	Link
Link country	Link
Link identifier	Link
Link transmission medium	Link
Node type: Repeater site	
Data centre	
Node type: Cable landing	
Link go-live date	Link
Link dark fiber availability	Link

Prior art research

As part of prior art research phase, desk research was conducted to identify existing standards and initiatives to inform the development of the standard. 45 related standards and initiatives were identified and linked to concepts, classes and fields in the draft data model (**Annex 7**). Some of them are listed in **Table 4**.

Table 4. Related standards and projects

Name	URL	Relevance
Policy and Regulation Initiative for Digital Africa (PRIDA)	https://www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/PRIDA/Pages/default.aspx	Potential use of data
The World Bank Infrastructure Data	https://datacatalog.worldbank.org/infrastructure-data	Standardisation of infrastructure data
INSPIRE	https://inspire-geoportal.ec.europa.eu	Data sharing
AfterFibre	https://afterfibre.nsrc.org/	Standardisation
Submarine Cable Map	https://www.submarinecablemap.com/submarine-cable/zeus	Standardisation of submarine cable data
Liquid Intelligent Technologies - Africa Schools Open Data Broadband Project	https://liquidtelecom.maps.arcgis.com/apps/dashboards/306249435562435f98fba6f6927f4cab	Example of data use
Geospatial standards for UK authoritative data providers	https://www.ordnancesurvey.co.uk/documents/geospatial-standards-report.pdf	Recommendations on geospatial standards
SEDL	https://spec.socialeconomydatalab.org/en/latest/	Developing a draft data specification
Asset Management Data Standard	https://www.nzta.govt.nz/roads-and-rail/asset-management-data-standard/data-standard/	Example of data standard
Vetro FiberMap	https://vetrofibermap.com/products/fibermap/?#!	Fiber management platform
GeoJSON Text Sequences	https://www.rfc-editor.org/rfc/rfc8142	Incremental parsing of arbitrarily large GeoJSON datasets
Landonline accuracy classification	https://www.linz.govt.nz/regulatory/25006	Accuracy

Positional accuracy	https://marswiki.jrc.ec.europa.eu/wikicap/index.php/Positional_Accuracy	Accuracy
Horizontal accuracy standard	https://www.icsm.gov.au/sites/default/files/Spatial_Data_Horizontal_Accuracy.pdf	Accuracy
National Standard for Spatial Data Accuracy	https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3	Accuracy
GeolocationCoordinates.accuracy	https://developer.mozilla.org/en-US/docs/Web/API/GeolocationCoordinates/accuracy	Accuracy, API
ISO 19115, STAC, the WMO Core Metadata Profile, and the WIGOS Metadata Standard	https://www.youtube.com/watch?v=_t3glNMIV2Y	Metadata workflow
ETF Validator	https://etf-validator.net	Validation
ITU transmission map	https://www.itu.int/en/ITU-D/Technology/Pages/InteractiveTransmissionMaps.aspx	Standardisation
Study on Broadband and Infrastructure Mapping	https://op.europa.eu/en/publication-detail/-/publication/93e80f02-9acb-4279-97c7-10f614ea1799/language-en/format-PDF/source-237566232	Mapping methodology
ITU Broadband Maps	https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/Events2020/IPEC-20/Day3-RED-Ses3-3-Vladimir_InteractiveMaps.pdf	Examples of data use
Africa Bandwidth Maps	http://www.africabandwidthmaps.com/	Standardisation
Energydata.info	https://energydata.info/	Standardisation
Framework and Methodology for the ITU World Terrestrial Transmission Map Project	https://www.itu.int/en/ITU-D/Technology/Documents/InteractiveTransmissionMaps/Mi	General

	sc/MapFrameworkMethodology.pdf	
NTIA Broadband Availability Data, Data Submission Guidelines	https://broadbandusa.ntia.doc.gov/sites/default/files/2021-06/NBAM%20Data%20Submission%20Guidelines_0.pdf	Standardisation of broadband coverage
GLEIF state transition rules	https://www.gleif.org/media/pages/about-lei/common-data-file-format/current-versions/level-2-data-reporting-exceptions-2-1-format/42f6c37a86-1661956758/2022-04-01_state-transition-validation-rules_v2.6-final.pdf	Rules for updating, managing and publishing reference data according to common data file formats.
Report on data sharing systems for the protection of underground infrastructure	https://www.enisa.europa.eu/publications/protection-of-underground-infrastructure/@@download/fullReport	Data stewardship models, possible use case
INSPIRE Reference Validator	https://inspire.ec.europa.eu/validator/home/index.html	Validation
Versioning in 2021: when and how you should do it	https://www.youtube.com/watch?v=DNWmfQmrFTM	Versioning
Kart - Distributed version-control for geospatial and tabular data	https://kartproject.org/	Versioning
GLEIF - Level 2 data	https://www.gleif.org/en/lei-data/access-and-use-lei-data/level-2-data-who-owns-whom	Defining identifiers
Delivering next generation access through PPP	https://www.eib.org/attachments/epec/epec_broadband_en.pdf	Examples of different ownership, financing and business models
Construction of the National Fiber Optic Backbone	http://web.archive.org/web/20220407154022/https://mpten.gov.gn/construction-du-backbone/	Example of difference between funders and installers
ITU Broadband Transmission Capacity Indicators	https://www.itu.int/en/ITU-D/Technology/Documents/Int	Scope of fields

	eractiveTransmissionMaps/Misc/BroadbandTransmissionCapacityIndicators.pdf	
Connect2Recover - A methodology for identifying connectivity gaps and strengthening resilience in the new normal	https://www.itu.int/en/ITU-D/Pages/connect-2-recover.aspx	Potential use of data
Giga - Connecting Every School to the Internet	https://giga.global/	Potential use of data
Disaster Connectivity Maps	https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Pages/Disaster-Connectivity-Maps.aspx	Example of data use case
ITU Broadband Maps	https://www.itu.int/en/ITU-D/Technology/Pages/InteractiveTransmissionMaps.aspx	Potential use of data
G.652 : Characteristics of a single-mode optical fibre and cable	https://www.itu.int/rec/T-REC-G.652-201611-I/en	ITU Recommendations
Twinning project ALBANIA - SLOVENIA: BROADBAND INFRASTRUCTURE MAPPING	https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Publications/ALBANIA_404807_E_BAT5.pdf	Some prior standardisation, good examples of data analysis
Exchange of location point guidance	https://www.gov.uk/government/publications/open-standards-for-government/exchange-of-location-point	Summary of CRS used in UK government
OGC Standards	https://www.ogc.org/docs/is	
Spatial Data on the Web Best Practices	https://www.w3.org/TR/sdw-bp/#spatial-things-features-and-geometry	Defining spatial features
GoLab Impact Bonds	https://golab.bsg.ox.ac.uk/the-basics/impact-bonds/	Funding

Data modelling

To organize elements of data and standardize how they relate to one another and to the properties of real-world concepts a conceptual draft data model was prepared by the technical working group (**Figure 1**) and desk research was conducted to clarify the concepts and

relationships in the model. It was documented in a conceptual model working paper (**Annex 8**) and presented to the steering committee. **Table 5** lists some of those concepts.

Figure 1. Conceptual Draft Data Model

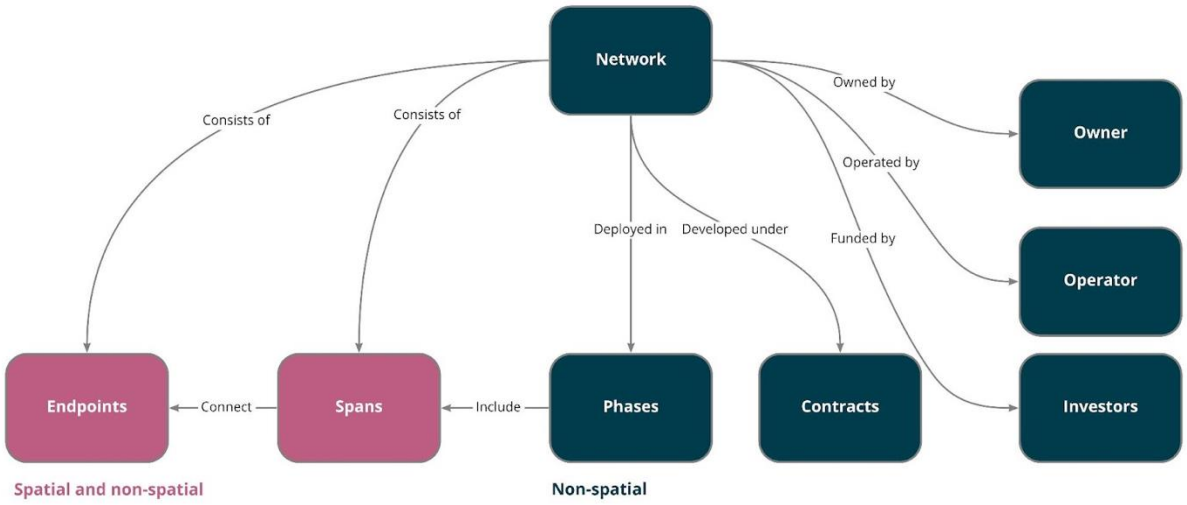

Table 5. Model concepts

Concept	Concept type	Definition	Relationships
Network	Spatial and non-spatial	See Network	A network is the top-level concept to which other concepts belong.
Endpoint	Spatial and non-spatial	See Endpoint	Endpoints are connected by **spans**.
Span	Spatial and non-spatial	See Span	Spans connect **endpoints**.
Phase	Non-spatial	See Phase	**Networks** can be deployed in phases.
Contract	Non-spatial	See Contract	**Networks** can be developed under contracts.
Owner	Non-spatial	See Owners and Operators	A **network** is owned by an owner.
Operator	Non-spatial	See Owners and Operators	A **network** is operated by an operator.
Investor	Non-spatial	See Investor	Investors finance the development of a **network**.

In addition to the data model, the development of an open data standard needs to account for how data will be collected and shared and what publication formats and access methods are required to meet user needs. Based on the inputs, requirements related to data stewardship, publication formats and access methods were documented (**Annex 9**). Some requirements include:

1. The standard should take into account the current approaches to data collection by supporting:
- Publication of data by both network providers and third parties.
- Publication of data collected by tracing and digitizing map images.
2. The standard should take into account the current approaches to data management by supporting publication from, and use in, common GIS systems.
3. The standard documentation should provide guidance on discoverability, publication formats and access methods. We will also develop a validation tool to support publishers in assessing and improving the quality of their data.
4. The standard documentation should strongly recommend that publishers publish data in JSON, GeoJSON and CSV format in order to meet the widest range of use cases.

Schema and documentation

A data standard is composed of the schema and documentation for a data model. A schema is a physical implementation of a data model in a specific language. A schema describes exactly how to structure and format data in accordance with a standard. It makes it possible to check that data conforms to a standard and to develop reusable tools and methodologies for working with data in a standardized format.

JSON Schema and CSV codelists were used to document the schema and codelists for OFDS. Alongside the schema and codelists, a documentation website was prepared with components listed in **Table 6.**

Table 6. OFDS Components

Component	Description	Example
Normative documentation	Normative documentation is the prescriptive part of a standard. It sets the rules to be followed in order to be evaluated as compliant with the standard, and from which no deviation is permitted.	The OFDS schema reference documentation.
Non-normative	Non-normative content is the non-prescriptive, or 'descriptive', part of	The OFDS primer and guidance.

Component	Description	Example
documentation	a standard. It can include analogies, synonyms, explanations, illustrations, context, and examples.	
Example data	Examples of data that conforms to a standard.	The OFDS example network package.

In order to validate the schema and documentation, the 0.1-alpha release was shared with stakeholders and sought feedback via the following channels:

- A presentation to and discussion with the technical working group.
- A consultation form for structured feedback.
- The OFDS discussion forum for general feedback, questions and suggestions.
- The OFDS issue tracker for bug reports or feedback on specific elements of the data model and documentation.
- Email.

The alpha standard was well received by the technical working group. Two specific points of feedback were received: Network Value Chain and Fibre sub-types. The above issues were addressed in the 0.1-beta release.

Pilots and testing

As part of the project, Open Data Standards team undertook pilot field trips in Ghana and Kenya in November 2022, with the objectives to introduce the standard to key stakeholders and encourage adoption by government and industry; and further develop the understanding of publisher and user needs. Further details of these pilot workshops will be included under separate deliverable under this activity.

The key lessons learned for standard development from the workshops and pilot experience include:

1) The user stories generated from demand side research came through very strongly from conversations with governments, regulators and network providers. In particular:
- Network providers wanted to identify the organizations responsible for existing and planned fiber infrastructure to avoid overbuild and identify opportunities for co-usage and co-deployment of infrastructure. They also expressed interest in information on the availability of dark fiber to identify fiber to lease and avoid overbuild.

- Regulators and digital economy agencies expressed interest in combining data from different networks providers and technologies to get a country level view of broadband access.
- Physical infrastructure providers expressed interest in sharing granular data on the physical location of fiber infrastructure with trusted authorities so that infrastructure is not damaged by construction works.

2) A number of areas for iterative improvement in the schema and documentation were identified:

- Discussions with providers and industry associations revealed complex leasing arrangements between physical infrastructure providers and network providers. Based on this, a need for a change to the schema in regards to how network providers are associated with spans and nodes was identified.
- Discussions with government, regulators, and network providers revealed a need for clearer guidance on how to combine network location data with other data sources.
- A need for guidance and tooling to assist publishers with converting data from existing formats into OFDS compliant data was discovered.

Engagement with stakeholders in Ghana and Kenya show their strong commitment but more advocacy and engagement efforts are needed to engage bigger players and get their buy-in.

Tooling development

Alongside the development of the standard, data validation and conversion tooling was developed to support implementers and users of the standard. Users can use the form to submit their data and check that it conforms to the Open Fiber Data Standard. Moreover, it allows to convert OFDS data between different formats, to validate data against the schema, and to explore the data through visualisation on a map.

Next Steps

OFDS version 0.2.0 was released recently, which incorporates learnings from the pilots in Kenya and Ghana. The documentation site for the Standard includes a primer on open fiber data and OFDS; guidance on how to publish and use OFDS data; and comprehensive reference documentation for the schema, codelists and publication formats. Moreover, Open Data Standards team developed a version of CoVE, a tool for converting, validating and exploring data, for OFDS: https://ofds.cove.opendataservices.coop/.

Open Data Standards team will continue supporting the pilots by running capacity building workshops in Kenya and Ghana and by providing remote support until June 2023. They also continue to refine the Standard and its documentation as they learn more about implementers and users' needs, and will be working with partners on community building, advocacy and

governance for the standard. Additionally, the team plans to create and release version v0.3 of OFDS, based on feedback from this virtual review, workshops and other implementation support work.

Annexes

Annex 1. Glossary for the standard
Annex 2. Demand side research: Use cases
Annex 3. User stories for open fiber data
Annex 4. Requirements for OFDS
Annex 5. List of datasets, publications and publishers
Annex 6. Supply side research: Common concepts and standardization
Annex 7. Prior Art Research: Related standards and initiatives
Annex 8. Conceptual model working paper
Annex 9. Data stewardship, publication formats and access methods consultation document