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Recommendations

International Telecommunication Union
Standardization Sector

Supplement

ITU-T Y Suppl. 72 (11/2022)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

ITU-T Y.3000-series – Artificial intelligence standardization roadmap

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For further details, please refer to the list of ITU-T Recommendations.

Supplement 72 to ITU-T Y-series Recommendations

ITU-T Y.3000-series – Artificial intelligence standardization roadmap

Summary

Supplement 72 to ITU-T Y-series Recommendations provides the standardization roadmap for artificial intelligence (AI) in the field of information and communication technology (ICT). This AI standardization roadmap has been developed to assist in the development of AI related standards in the ICT field by providing information on existing standards and standards under development in key standards development organizations (SDOs). In addition, it provides overviews of AI and AI related technical areas from the standards perspective, AI related activities in SDOs, and gap analysis.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y Suppl. 72	2022-11-25	13	11.1002/1000/15249

Keywords

AI, artificial intelligence, standardization roadmap.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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Supplement 72 to ITU-T Y-series Recommendations

ITU-T Y.3000-series – Artificial intelligence standardization roadmap

1 Scope

This Supplement provides the standardization roadmap for artificial intelligence (AI) in the field of information and communication technology. It addresses the following subjects:

- overview of AI from the perspective of standards development;
- AI related activities in standards development organizations (SDOs);
- existing standards, and standards under-development;
- standardization gap analysis.

2 References

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.

[ITU-T Y.3600] Recommendation ITU-T Y.3600 (2015), *Big data – Cloud computing based requirements and capabilities*.

[ITU-T Y Sup.40] Supplement 40 to ITU-T Y-series Recommendations (2016), *ITU-T Y.3600 – Big data standardization roadmap*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 artificial intelligence (AI) [b-ISO/IEC 22989]: <discipline> research and development of mechanisms and applications of AI systems.

NOTE 1 – Research and development can take place across any number of fields such as computer science, data science, natural sciences, humanities, mathematics and natural sciences.

NOTE 2 – [b-ISO/IEC 22989] defines AI system as "engineered system that generates outputs such as content, forecasts, recommendations or decisions for a given set of human-defined objectives".

NOTE 3 – [b-ISO/IEC 2382] defines AI as "An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning".

NOTE 4 – [b-ETSI GR ENI 004] defines AI as "computerized system that uses cognition to understand information and solve problems".

3.1.2 machine learning (ML) [ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AAP Alternative Approval Process

AI Artificial Intelligence
API Application Programming Interface
ICT Information and Communication Technology
IEC International Engineering Consortium
IEEE Institute of Electrical and Electronics Engineers
ISO International Organization for Standardization
JTC 1 Joint Technical Committee 1
ML Machine Learning
NNEF Neural Network Exchange Format
SC Subcommittee
SDO Standards Development Organization
SG Study Group
TC Technical Committee
URI Uniform Resource Identifier
W3C World Wide Web Consortium
WG Working Group

5 Conventions

None.

6 Overview of artificial intelligence standards development roadmap

Artificial intelligence (AI) is the ability of machines or systems to acquire and apply knowledge to carry out intelligent behaviour. Defining the intelligence or knowledge is a philosophical and paradoxical question to which it is hard to find the answers with technical approaches [b-George F L.]. There are several AI definitions from SDOs. Table 6-1 shows various definitions of AI found in the standardization work.

Table 6-1 – The definitions of AI in the standardization

Source	Definition
[b-ISO/IEC 2382]	An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning.
[b-ETSI GR ENI 004]	Computerized system that uses cognition to understand information and solve problems. NOTE 1 – [b-ISO/IEC 2382] defines AI as "an interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning". NOTE 2 – In computer science, AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions to achieve its goals. NOTE 3 – This includes pattern recognition, the application of machine learning and related techniques.

Table 6-1 – The definitions of AI in the standardization

Source	Definition
	NOTE 4 – Artificial intelligence is the whole idea and concept of machines being able to carry out tasks in a way that mimics human intelligence and would be considered "smart".
[b-ISO/IEC 22989]	3.1.3 artificial intelligence AI <discipline> research and development of mechanisms and applications of AI systems (3.1.4) Note 1 to entry: Research and development can take place across any number of fields such as computer science, data science, natural sciences, humanities, mathematics and natural sciences. 3.1.4 artificial intelligence system AI system engineered system that generates outputs such as content, forecasts, recommendations or decisions for a given set of human-defined objectives

Since the definition of AI limits its scope to information technologies (IT), the contents of this supplement only include AI techniques that are being applied in the field of computer science. In computer science, AI is operated with computing resources and implemented with data that represent knowledge, the algorithms for applying knowledge, and programming languages for implementing knowledge. The domain of AI includes technical topics such as computer vision, natural language processing, robotics, search engines, online advertising, etc.

Machine learning is the one of the programmable approaches to building AI systems in the real world. Machine learning achieves the goal by automatically improving its ability to solve problems using a learning algorithm. The learning algorithm is explicitly programmed to enable computers to learn through experience. An example of machine learning is 'deep learning', which utilizes a neural network algorithm. Machine learning shows higher performance in many tasks than rule-based programming algorithms. Therefore, machine learning algorithms are adopted in many of computer science fields such as speech recognition, natural language processing, customer relationship management, etc.

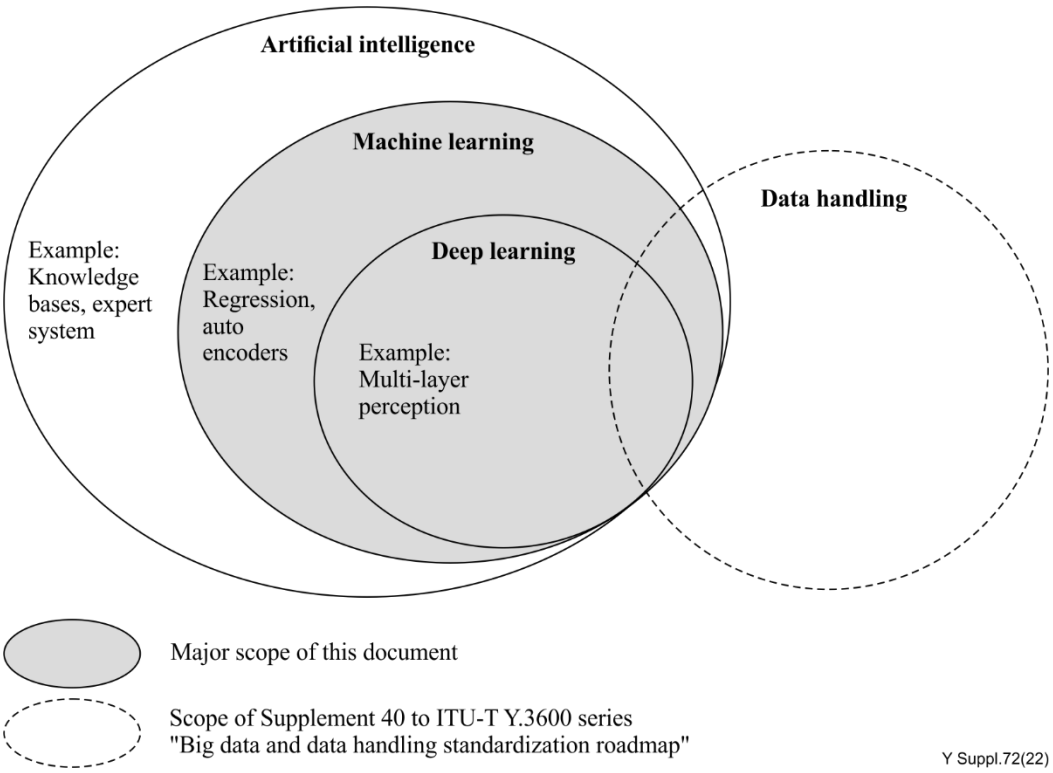

Figure 6-1 – AI technologies and the scope of this Supplement [b-Ian]

Figure 6-1 shows the scope of this Supplement in the fields of AI. This Supplement covers especially AI machine learning techniques, including machine learning, deep learning, neural network, etc. The standards related only with big data and data handling are covered in [ITU-T Y Sup.40].

7 SDOs developing standards on artificial intelligence

7.1 ITU-T SG13

ITU-T Study Group 13 (SG13) address the requirements, architectures, functional capabilities and application programming interfaces of converged future networks. Key areas of focus include network softwarization and orchestration, information-centric networking, content-centric networking, and the application of machine learning technologies.

Table 7-1 lists the ITU-T deliverables and work items related to artificial intelligence and machine learning.

Table 7-1 – ITU-T SG13 deliverables and work items

Study group	Reference	Title	Status
SG13	ITU-T Y.3170	Requirements for machine learning-based quality of service assurance for the IMT-2020 network	In force (Approved on 2018-09-29)
SG13	ITU-T Y.3175	Functional architecture of machine learning based quality of service assurance for the IMT-2020 network	In force (Approved on 2018-09-29)

Table 7-1 – ITU-T SG13 deliverables and work items

Study group	Reference	Title	Status
SG13	ITU-T Y.3180	Mechanism of traffic awareness for application-descriptor-agnostic traffic based on machine learning	In force (Approved on 2022-02-13)
SG13	ITU-T Y.3531	Cloud computing- functional requirements for machine learning as a service	In force (Approved in 2020-09-29)
SG13	ITU-T Y.3172	Architectural framework for machine learning in future networks including IMT-2020	In force (Approved on 2019-06-22)
SG13	ITU-T Y.3654	Big data driven networking – Machine learning mechanism	In force (Approved on 2022-02-13)
SG13	ITU-T Y.3174	Mechanism of traffic awareness for application-descriptor-agnostic traffic based on machine learning	In force (Approved on 2020-02-06)
SG13	ITU-T Y.Sup55	Machine learning in future networks including IMT-2020: use cases	In force (Agreed on 2019-10-25)
SG13	ITU-T Y.3156	Requirements for network slicing with AI-assisted analysis in IMT-2020 networks	In force (Approved on 2020-09-29)
SG13	ITU-T Y.3176	Machine learning marketplace integration in future networks including IMT-2020	In force (Approved on 2020-09-29)
SG13	ITU-T Y.3115	AI integrated cross-domain network architecture for future networks including IMT-2020	In force (Approved on 2022-02-13)
SG13	ITU-T Y.3177	Architectural framework of artificial intelligence-based network automation for resource and fault management in future networks including IMT-2020	In force (Approved on 2021-02-13)
SG13	ITU-T Y.3178	Functional framework of AI-based network service provisioning in future networks including IMT-2020	In force (Approved 2021-07-07)
SG13	ITU-T Y.3173	Framework for evaluating intelligence levels of future networks including IMT-2020	In force (Approved on 2020-02-06)
SG13	ITU-T Y.3812	Requirements of machine learning based QoS assurance for quantum key distribution networks	AAP (Approved on 2022-09-29)
SG13	ITU-T Y.Sup70	Quantum Key Distribution Networks – Applications of Machine Learning	In force (Agreed on 2021-07-16)
SG13	ITU-T Y.3814 (Y.QKDN-ml-fra)	Quantum Key Distribution Networks – Functional requirements and architecture for machine learning	AAP

Table 7-1 – ITU-T SG13 deliverables and work items

Study group	Reference	Title	Status
			(Consented on 2022-11-25)
SG13	ITU-T Y.IMT2020-DJLML	Requirements and framework for distributed joint learning to enable machine learning in future networks including IMT-2020	Under study (Timing: 2023-Q4)
SG13	ITU-T Y.ML-IMT2020-MLFO	Requirements and architecture for machine learning function orchestrator	Under study (Timing: TBR)
SG13	ITU-T Y.3181	Machine learning sandbox for future networks including IMT-2020: requirements and architecture framework	AAP (Approved on 2022-09-29)
SG13	ITU-T Y.3182	Machine learning based end-to-end multi-domain network slice management and orchestration	AAP (Approved on 2022-09-29)
SG13	ITU-T Y.3183 (Y.ML-IMT2020-VNS)	Framework for network slicing management enabled by machine learning including input from verticals	AAP (Consented on 2022-11-25)

- **ITU-T Y.3170**: This Recommendation specifies requirements of machine learning-based QoS assurance for the international mobile telecommunications 2020 (IMT-2020) network. It describes capabilities for QoS anomaly detection and prediction using machine learning. In addition, this Recommendation describes a functional model of machine learning-based QoS assurance which includes functional components such as QoS data collection, data pre-processing, data storage, modelling and training, QoS anomaly detection and prediction, QoS policy decision making, enforcement and reporting. Based on the capabilities and functionalities described in the functional model, this Recommendation specifies the high-level requirements and functional requirements of machine learning-based QoS assurance for IMT-2020 network.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14278

- **ITU-T Y.3175**: This Recommendation specifies architecture of machine learning based QoS assurance for the international mobile telecommunications 2020 (IMT-2020) network. It provides an overview of unified architecture for ML in 5G and future networks. In addition, it describes the architecture of machine learning based QoS assurance. Based on the architecture, this Recommendation specifies the procedures of machine learning based QoS assurance for IMT-2020 network.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15013

- **ITU-T Y.3180**: Application-descriptor-agnostic traffic is the traffic which cannot be identified by an application descriptor. On the one hand, traditional traffic awareness technologies such as deep packet inspection are not highly effective when they are applied to application-descriptor-agnostic traffic. On the other hand, with development of the artificial intelligence, many related technologies are emerging and applied in various areas. Compared to traditional traffic methods, traffic awareness method combining with machine learning based technologies will be more effective when it is used to process other application-descriptor-agnostic. Therefore, it is time to study mechanism and methods to implement application-descriptor-agnostic traffic awareness functions based on machine learning. This

Recommendation specifies the mechanism of traffic awareness for application-descriptor-agnostic traffic based on machine learning.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14619

- **ITU-T Y.3531**: This Recommendation provides cloud computing requirements for machine learning as a service, which addresses requirements from use cases. Machine learning as a service (MLaaS) is a cloud service category to support the development and applications of machine learning in the cloud computing environments. On the perspective of cloud computing service provisioning, this Recommendation defines the functional requirements for MLaaS to identify functionalities such as data gathering, machine learning modelling and computing resources, etc. Also, this Recommendation aligned with the cloud computing reference architecture of ITU-T Y.3502. Developments of machine learning algorithms and methodology are out of the scope on this Recommendation.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14484

- **ITU-T Y.3172**: This Recommendation specifies an architectural framework for machine learning (ML) in future networks including IMT-2020. A set of architectural requirements and specific architectural components needed to satisfy these requirements are presented. These components include, but are not limited to, ML pipeline and ML management and orchestration functionalities. The integration of such components into future networks including IMT-2020 and guidelines for applying this architectural framework in a variety of technology-specific underlying networks are also described.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15020

- **ITU-T Y.3654**: This Recommendation specifies the mechanisms of machine learning for big data driven networking, its scope includes the following aspects: studying the procedures of machine learning applied in bDDN; studying the general machine learning approach for bDDN; studying the interfaces related to machine learning for bDDN; studying the learning and control path based on machine learning for bDDN; studying other aspects related to machine learning for bDDN.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15183

- **ITU-T Y.3174**: A framework of data handling to enable machine learning in future networks including IMT 2020 is described in this Recommendation. The requirements for ML data collection and ML processing mechanisms in various usage scenarios for ML in future networks are identified along with the requirements of corresponding targets for ML output in the network. Based on this, a generic framework of data handling and examples of its realisation on specific underlying networks are described.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15177

- **ITU-T Y.Sup55**: This Supplement analyses the use cases for machine learning in future networks including IMT-2020 and presents them in a unified format. The Supplement provides use cases descriptions and indicates the basic set of possible requirements for each use case. The use cases are divided into categories.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15175

- **ITU-T Y.3156**: Based on the future operation and maintenance management of network slicing and the purpose of satisfying users' SLA requirements, the objective of this Recommendation is to describe the requirements, architecture and function design of network slicing based on intelligent network analysis.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15061

- **ITU-T Y.3176**: This Recommendation provides high-level requirements and the architecture for integrating ML marketplaces in future networks including IMT-2020. Based on these

requirements, the architecture for the integration of ML marketplaces is described taking into account the architectural framework in [ITU-T Y.3172] as a basis.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16345

- **ITU-T Y.3115**: This Recommendation specifies the design principles and architecture of AI (including machine learning) integrated cross-domain network for future networks including IMT-2020.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16347

- **ITU-T Y.3177**: This Recommendation specifies an architecture framework of artificial intelligence (AI)-based network automation for resource adaptation, failure detection and recovery for the purpose of improving network efficiency and maintaining QoS by continuously monitoring the network and promptly deciding about appropriate actions for resource adaptation and failure recovery with the help of AI including machine learning.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16343

- **ITU-T Y.3178**: This Recommendation specifies a functional framework of artificial intelligence (AI)-based network service provisioning in future networks, including IMT-2020. This Recommendation addresses the following aspects: Business role-based model for AI-based network service provisioning; High-level requirements for the roles and their interactions from an AI-based operational perspective; Functional components and their interactions for AI-based operations for network service provisioning.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16344

- **ITU-T Y.3173**: This Recommendation describes a framework for evaluating the intelligence levels of future networks including IMT-2020. This includes: development trend of network intelligence; methods for evaluating network intelligence levels; architectural view for evaluating network intelligence levels. The appendices describe the relationship between the framework described in this Recommendation and corresponding work in other standards or industry bodies, as well as the application of the method for evaluating network intelligence levels on representative use cases.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=15176

- **ITU-T Y.3812**: This Recommendation is to specify requirements of machine learning based QoS assurance for quantum key distribution networks as follows: Overview; Functional model of machine learning based QoS assurance for quantum key distribution networks; High-level requirements of machine learning based QoS assurance for quantum key distribution networks; Functional requirements of machine learning based QoS assurance for quantum key distribution networks.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18087

- **ITU-T Y. Sup.70**: For quantum key distribution networks (QKDN), the Supplement presents the applications of machine learning (ML) in the quantum layer, the key management layer and the management and control layers of QKDN including the use case background, issue, role of ML in QKDN, use case analysis and, benefits and impact.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16877

- **ITU-T Y.QKDN-ml-fra**: QKDN is expected to be able to maintain the stable operation and meet various cryptographic application requirements in an efficient way. Due to the advantages of machine learning (ML) related to autonomous learning, ML can help to overcome the challenges of QKDN in terms of quantum layer performance, key management layer performance and QKDN control and management efficiency. Based on the functional requirements and architecture of QKDN in [ITU-T Y.3801] and [ITU-T Y.3802], this

Recommendation is to specify the overview, functional requirements, and functional architecture model of ML in QKDN.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18146

- **ITU-T Y.IMT2020-DJLML**: This new Recommendation introduces distributed joint learning to enable machine learning into future networks including IMT-2020. With the help of distributed joint learning, it can be realized a highly automated, intelligent and multi-party collaborative network.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18129

- **ITU-T Y.ML-IMT2020-MLFO**: The overall architectural framework for ML in future networks including IMT-2020 is defined in [ITU-T Y.3172]. This draft Recommendation aims to study the detailed requirements and architecture for machine learning function orchestrator (MLFO) in future networks including IMT-2020. Firstly, high-level requirements of MLFO are provided based on the analysis of use cases described in [b-ITU-T Y.Sup55]. Secondly, the overall architecture is presented including the components of the MLFO architecture and its reference points. Finally, sequence diagrams which highlight the interactions between MLFO and other components in the network are described.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18090

- **ITU-T Y.3181**: This Recommendation defines the requirements and architecture framework for the ML Sandbox in future networks including IMT-2020. – Requirements and classifications – High level architecture and components of ML sandbox – Sequence diagrams and application programming interfaces (API).

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18091

- **ITU-T Y.3182**: This Recommendation provides the framework and requirements of machine learning based end-to-end network slice management and orchestration in multi-domain environments. The scope of this Recommendation includes: Overview; Use cases; Functional requirements; Framework of machine learning based multi-domain end-to-end network slice management and orchestration

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18092

- **ITU-T Y.ML-IMT2020-VNS**: This Recommendation provides a framework for network slice management enabled by machine learning including input from verticals, in order to ensure end-to-end quality of experience. The scope of this Recommendation includes: Framework for network slice management enabled by machine learning including input from verticals; Supporting APIs; Use cases.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18093

7.2 ITU-T SG16

ITU-T Study Group 16 (SG16) is responsible for studies relating to ubiquitous multimedia applications, multimedia capabilities for services and applications for existing and future networks, including the coordination of related studies across the various ITU-T SGs. It is the lead study group on multimedia coding, systems and applications; ubiquitous multimedia applications; telecommunication/ICT accessibility for persons with disabilities; human factors; intelligent transport system (ITS) communications; e-health; Internet Protocol television (IPTV) and digital signage; and e-services.

Table 7-2 lists the ITU-T SG16 deliverables and work items related to artificial intelligence and machine learning.

Table 7-2 – ITU-T SG16 deliverables and work items

Study group	Reference	Title	Status
SG16	ITU-T F.749.13	Framework and requirements for civilian unmanned aerial vehicle flight control using artificial intelligence	In force (Approved on 2021-06-13)
SG16	ITU-T F.749.4	Use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence	In force (Approved on 2021-06-13)
SG16	ITU-T H.862.5	Emotion enabled multimodal user interface based on artificial neural network	In force (Approved on 2021-06-13)
SG16	ITU-T F.748.13	Technical framework for shared machine learning system	In force (Approved on 2021-06-13)
SG16	ITU-T F.742.1	Requirements for smart class based on artificial intelligence	AAP (Consented on 2022-10-28)
SG16	ITU-T FSTP-ACC-AI	Guideline on the use of AI for ICT accessibility	Under study (Timing: 2023)
SG16	ITU-T F.CDN-AINW	Requirements and reference model for CDN services over AI network	Under study (Timing: 2023)
SG16	ITU-T F.748.11	Metrics and evaluation methods for deep neural network processor benchmark	In force (Approved on 2020-08-13)
SG16	ITU-T F.748.12	Deep Learning Software Framework Evaluation Methodology	In force (Approved on 2021-06-13)
SG16	ITU-T F.748.20	Technical framework for deep neural network model partition and collaborative execution	AAP (Consented on 2022-10-28)
SG16	ITU-T F.748.19	Framework for audio structuralizing based on deep neural network	AAP (Consented on 2022-10-28)
SG16	ITU-T F.746.16	Technical requirements and evaluation methods of intelligent levels of intelligent customer service system	AAP (Consented on 2022-10-28)
SG16	ITU-T F.AI-SCS	Use cases and requirements for speech interaction of intelligent customer service	Under study (Timing: 2023)
SG16	ITU-T F.746.13	Requirements for smart speaker based intelligent multimedia communication system	In force (Approved on 2022-03-16)
SG16	ITU-T F.Sup4	Overview of convergence of artificial intelligence and blockchain	In force (Agreed on 2021-04-30)

Table 7-2 – ITU-T SG16 deliverables and work items

Study group	Reference	Title	Status
SG16	ITU-T F.746.11	Interfaces for intelligent question answering system	In force (Approved on 2020-08-13)
SG16	ITU-T H.AI-SaMD-Req	Quality assessment requirements for artificial intelligence/machine learning-based software as a medical device	Under study (Timing: 2022)
SG16	ITU-T HSTP.Med-AI-CCTA	Guidelines on development and application of artificial intelligence in coronary computed tomography angiography	Under study (Timing: 2023)
SG16	ITU-T F.ADT4MM	Requirements and framework of AI-based detection technologies for 5G multimedia messages	Under study (Timing: 2023)
SG16	ITU-T F.AICP-GA	Technical specification for artificial intelligence cloud platform: General architecture	Under study (Timing: 2023)
SG16	ITU-T F.748.17	Technical specification for artificial intelligence cloud platform: Model development	AAP (Consented on 2022-10-28)
SG16	ITU-T F.AI-CPP	Technical specification for artificial intelligence cloud platform: Performance	Under study (Timing: 2024-04)
SG16	ITU-T F.747.11	Requirements for intelligent surface-defect detection service in industrial production line	AAP (Consented on 2022-10-28)
SG16	ITU-T F.AI-MKGDS	Requirements for the construction of multimedia knowledge graph database structure based on Artificial Intelligence	Under study (Timing: 2023)
SG16	ITU-T F.AI-RPAS	Technical requirements and evaluation methods for a robotic process automation	Under study (Timing: 2023)
SG16	ITU-T F.AI-RSRSreqs	Requirements for real-time super-resolution service based on artificial intelligence	Under study (Timing: 2023)
SG16	ITU-T F.748.21	Requirements and framework for feature-based distributed intelligent systems	AAP (Consented on 2022-10-28)
SG16	ITU-T F.REAIOCR	Requirements and evaluation methods for AI-based optical character recognition service	Under study (Timing: 2023)
SG16	ITU-T F.TCEF-FML	Trusted contribution evaluation framework on federated machine learning services	Under study (Timing: 2023)
SG16	ITU-T F.Med-Data-QC	General framework of quality control of medical images for machine learning applications	Under study (Timing: 2023)

Table 7-2 – ITU-T SG16 deliverables and work items

Study group	Reference	Title	Status
SG16	ITU-T F.747.12	Requirements for artificial intelligence based machine vision service in smart logistics warehouse system	AAP (Consented on 2022-10-28)
SG16	ITU-T F.AI-SF	Requirements for smart factory based on artificial intelligence	Under study (Timing: 2023)
SG16	ITU-T F.FML-TS-FR	Requirement and framework of trustworthy federated machine learning based service	Under study (Timing: 2023)

- **ITU-T F.749.13**: This Recommendation provides framework and requirements for civilian unmanned aerial vehicle (CUAV) flight control using artificial intelligence. Currently, the CUAV has been widely used in industry and consumption areas, there are also problems in the development of CUAVs. In addition to the policy and legal supervision, the other problem is how CUAVs avoid obstacles during the flight, and how the CUAVs applied in a specific industry can automatically navigate, track or fly along a specific area according to the mission requirements. This Recommendation provides a framework of civilian unmanned aerial vehicle flight control using Artificial Intelligence, including the flight navigation control of a CUAV itself (including avoiding obstacles, normal take-off and landing) and the specific flight control (including automatic navigation, tracking, or along a regular direction or specific area) based on the specific industry application requirements. This framework is not a specific implementation case, but it provides a framework and capability requirements for each specific implementation, and the product and system integrators can design and produce specific products and systems according to this framework.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14760

- **ITU-T F.749.4**: This Recommendation specifies use cases and requirements of artificial intelligence for ICT-enabled autonomous vehicle systems. This Recommendation covers the followings:
  - Use cases: to identify the use cases of artificial intelligence applied to the ICT-based autonomous vehicle systems, e.g., situational awareness, route planning, driving behaviour decision and human-computer interaction;
  - Requirements: to identify the service and network requirements, functional requirements and non-functional requirements of the ICT-based autonomous vehicle systems.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14767

- **ITU-T H.862.5**: Recommendation ITU-T H.862.5 provides functional entities and architecture for emotion enabled multimodal user interface based on artificial neural network. As emotion technology continues to make big improvements in human-computer interaction (HCI) areas, many companies and researchers have been studying emotion technology. Various applications using multimodality and emotion analysis are also introduced these days with artificial intelligence technology. However, many of the current systems do not yet infer human emotion properly because some systems are either too dependent on certain sources, or too weak for real circumstances. Therefore, the proposed system architecture is for multimodal user interface (UI) based on emotion analysis with some properties and illustrations, and data with an artificial neural network. The multimedia data for the input is composed of text, speech, and image. For the unimodal emotion analysis, the data is pre-

processed in the corresponding module. For example, the text data is pre-processed by data augmentation; person attributes recognition, topic cluster recognition, document summarization, named entity recognition, sentence splitter, keyword cluster, and sentence to graph functions.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15026

- **ITU-T F.748.13**: This Recommendation defines the roles, technical and security requirements of the shared machine learning system, and provides technical architectures, functional components and processing procedures of the shared machine learning system in the centralized and decentralized modes.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15262

- **ITU-T F.742.1**: Smart class is designed to improve lecture preparation, enhance interaction between teachers and students and promote teaching quality via educational data analytics and advanced teaching equipment. This document describes application scenarios and requirements for smart class based on artificial intelligence.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15294

- **ITU-T FSTP-ACC-AI**: This technical paper describes the use of AI for ICT accessibility. AI technologies such as automatic speech recognition for captioning are described, with their pros and cons. It also describes some parameters and criteria for objective, quantitative assessment and measurement the quality of service using these technologies.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17493

- **ITU-T F.CDN-AINW**: After the fifth-generation cellular network (5G) technology and network virtualization technology spread, it is expected that a huge amount of new services such as multimedia services (high resolution, AR, VR, et al.) and IoT services will be developed and used. The amount of the network traffic for those services will also be remarkably increasing. In order to satisfy the huge amount of network traffic of video related services, automatic network management supported by recent AI technologies, called AI network, will play an essential role for such era. In order to use AI network effectively, common data linkage regarding network status and service status between system of service providers over AI network and AI network is necessary. This Recommendation describes requirements for such data linkage and reference model including interface, metadata, and API about CDN services over AI network.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17512

- **ITU-T F.748.11**: This Recommendation provides the benchmarking framework, evaluation metrics and methods, and a guideline of technical testing for deep learning processor while doing training and inference task. The edge computing market, where AI computation is done on the device, is expected to represent more than three-quarters of the total market opportunity, with the balance being in cloud/data centre environments. Mobile phones will be a major driver of the edge market, and other prominent edge categories include automotive, smart cameras, robots, and drones.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15295

- **ITU-T F.748.12**: With great desire in AI applications, Deep Learning Framework provide an easy and fast way for manufacturers to develop their own applications. However, different frameworks show different performance under different scenarios. It is a necessity to formulate a recommendation to evaluate the performance of Deep Learning Frameworks in order to help manufacturers take full advantages of certain framework and avoid disadvantages of others.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15296

- **ITU-T F.748.20**: Deep neural network (DNN) model inference process usually requires a large amount of computing resources and memory. Therefore, it is difficult for end devices to perform DNN models independently. It is an effective way to implement end-edge collaborative DNN execution through DNN model partition, which can reduce latency and improve resource utilization at the same time. This recommendation aims to specify the technical framework of DNN model partition and collaborative execution. First, it is necessary to predict the overall inference latency under the current system state according to different DNN partition strategies in advance. Then, choose the appropriate partition locations and collaborative execution strategy based on the equipment computation capabilities, network status and DNN model properties. Finally, implement the model collaborative execution and optimize the resource allocation in the meanwhile.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17542
- **ITU-T F.748.19**: This Recommendation presents an overview of the framework for audio structuralizing based on deep neural network. It provides a high-level description of architecture, processing flows, data categories, audio processing tasks and requirements for data management.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17543
- **ITU-T F.746.16**: The intelligent customer service system can provide more convenient, efficient, and stable services for users through the application of AI technologies such as speech recognition, text to speech and natural language processing. Improving and evaluating the intelligence levels of the intelligent customer service system are valuable. This Recommendation specifies the requirements and evaluation methods for system intelligence of intelligence customer service system in four aspects, including the basic functions, the core technologies of AI, the maturation of system and the service experience.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17546
- **ITU-T F.AI-SCS**: This Recommendation describes the use cases and scenarios, high-layer architecture, functional requirements and performance requirements for speech interaction of intelligent customer service. Some detailed use cases and reference process for the creation of the knowledge base are described in appendix.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17531
- **ITU-T F.746.13**: This Recommendation defines the requirements of intelligent multimedia communication for varied types of smart speakers, including the reference architecture, requirements of smart devices, requirements of signalling and platform, as well as a few typical scenario examples. This Recommendation specifies the requirements to eliminate the difference in multimedia communication and access management of heterogeneous devices, to simplify the construction complexity of intelligent multimedia communication system, to improve the security and reliability of signalling and multimedia data transmission between smart speakers and the intelligent multimedia communication system, to finally guarantee high-qualified multimedia communication service.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17541
- **ITU-T F.Sup4**: Artificial intelligence (AI) is one of core essential driving forces of a new round of industrial reform, which can affect promoting the upgrading of the traditional industries. Blockchain presents opportunities for disruptive innovations, which enables global businesses to transact with less friction and more trust. AI and blockchain promote and influence each other, and the convergence of them could bring big driving forces for industries a great creativity across a wide range of business applications in many fields. There are many benefits and challenges to combine AI and blockchain together. This Supplement focuses on the research on the convergence of AI and blockchain, specifically analyses the mutual promotion between AI and blockchain, and provides a technical reference for the

application of AI and blockchain. Besides, this Supplement also provides application analysis of the convergence of AI and blockchain.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16631

- **ITU-T F.746.11**: This Recommendation describes interfaces for Intelligent Question Answering Service Framework [ITU-T F.746.3]. This Recommendation defines the interfaces among functional modules to support the intelligent Question Answering service, which provides advanced functions to generate answers for the user's question in a natural language. The scope of this Recommendation is focused on describing interfaces and functional features for natural language processing function, question analysis function, candidate answer generation function, and answer inference/generation function of intelligent question answering system.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15015

- **ITU-T H.AI-SaMD-Req**: The object of the Recommendation is to set up an initial requirement framework for the testing and evaluation on Artificial Intelligence/Machine Learning (AI/ML)-Based Software as a Medical Device (SaMD), including:
  - Testing requirements of network security capabilities;
  - Testing requirements of functionality and usability;
  - Testing requirements of performance of AI/ML-Based SaMD;

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17526

- **ITU-T HSTP.Med-AI-CCTA**: This guideline introduces expert consensus on database construction of CCTA, data specification and quality control, functions of image post-processing and assisted diagnosis and clinical evaluation. It may help to get consensus in medical imaging field, and facilitate the development and application of artificial intelligence assisted diagnostic technique in cardiovascular imaging.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17528

- **ITU-T F.ADT4MM**: The 5G standards encourages the implementation of a rich communication service (RCS) in 5G networks. 5G multimedia messages represent a kind of service that complies with GSMA RCS UP standard, which instructs operators to develop and deploy advanced communication services for customer messages and industry messages. Since 5G multimedia messages can support a variety of message types which are quite different from traditional ones, including text, image, audio, video, file and other potentially possible message types. On the one hand, it provides users and enterprises with more rich services. On the other side, it brings substantially more challenges and difficulties to message detection technologies. For example, message over 5G using Message as a Platform (MaaP) to implement industry messages, which is Application to Person (A2P) services, leads to much more complicated situation especially for message detection strategies. Thus, it is necessary to propose a new standard to clarify the requirements and framework for detecting 5G multimedia messages. This Recommendation specifies the requirements and framework of AI-based detection for multimedia messages in 5G era, including the overall requirements, the framework, detection strategy, detection procedure, as well as some additional considerations.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17618

- **ITU-T F.AICP-GA**: With the continuous development and integration of artificial intelligence and cloud computing, the processing of big data and the training of deep learning models have become core issues. Cloud service providers have launched various artificial intelligence cloud platforms, integrating the underlying resources with the upper-level deep learning framework, and providing users with common services such as training and

inference. There are many artificial intelligence platforms currently on the market, their functions are not uniform, and their quality is uneven, and their functions cannot fully meet the urgent needs of users. This proposal regulates the artificial intelligence cloud platforms capabilities provided by service providers from the following six aspects: resource management, model development, model deployment, high availability, performance, platform security. This proposal provides a reference for manufacturers to build artificial intelligence cloud platforms and user selection by regulating the capabilities of artificial intelligence cloud platforms, so as to promote the orderly development of industry standards.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17575

- **ITU-T F.748.17**: This Recommendation provides a framework for the cloud-based development of AI models. It covers the terminology, features, and reference design of an AI cloud platform to enable the development of AI models. It establishes the technical specifications of the platform's supporting functional modules, core functional modules, and auxiliary functional modules.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17576

- **ITU-T F.AI-CPP**: With the continuous development and integration of artificial intelligence and cloud computing, cloud service providers have launched a variety of artificial intelligence cloud platforms, integrating the underlying resources with the upper deep learning framework to provide users with training, inference and other public services. At present, there are many AI platforms in the market, but the performance of these platforms is uneven. Lacking of comprehensive and unified performance evaluation methods is not conducive to users to make the most appropriate choice. This recommendation specifies the performance of AI cloud platform from three levels of hardware level, platform level and service level. It aims to objectively measure the product performance of industry participants, thus providing direction for manufacturers to analyse and optimize the performance of AI cloud platform, and helping users choose an AI cloud platform that meets the performance requirements at the lowest possible cost, so as to promote the standardization and rapid development of the industry.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17616

- **ITU-T F.747.11**: Intelligent surface-defect detection service in industrial production line refers to accurate positioning of products defects, high-speed classification of defects types, real-time output and transmission of visual and auditory information to ensure the quality of industrial products. Compared with the inspection carried out manually by workers, the ISD service can improve the efficiency and consistency and reduce manual operations in dangerous areas. This work item specifies requirements for intelligent surface-defect detection service in industrial production line, including performance requirements, application requirements and functional requirements. To provide effective surface-defect detection service, it is required to fulfil three important parts. Firstly, it is important to ensure the accuracy of positioning and classification. Secondly, the inference efficiency of the service is also required to satisfy the real-time settings. Last but not the least, the service is required to adapt to the typical application scenarios in industrial production line inspection task. This Recommendation provides related requirements for intelligent surface-defect detection service in industrial production line.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17621

- **ITU-T F.AI-MKGDS**: This Recommendation defines the framework of the construction of knowledge graph based on Artificial Intelligence.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17570

- **ITU-T F.AI-RPAS**: As a kind of technology carrier, RPA realizes the interconnection of IT business parts and improves the efficiency of business execution. With the maturity of

artificial intelligence technology, RPA has just become a tool for the application of more AI technologies. However, the hot RPA industry has always been in a standard blank situation, and the development of the industry has been greatly hindered. This proposal intends to formulate technical standards for RPA products from five aspects, including RPA management monitoring, development testing, work execution, intelligence level and maturity. This standard will become an important reference for RPA manufacturers and users.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17574

- **ITU-T F.AI-RSRSreqs**: With the explosive growth development of video services, users' requirements for the resolution and quality of real-time image/video services is gradually improving. Taking the monitoring service as an example, the quality of service is reduced due to the insufficient acquisition capability of video monitoring terminal, image quality damage caused by network transmission and low resolution. For low resolution (LR) videos, the artificial intelligence based super-resolution (SR) technology can ensure the detail texture of the video and improve the video resolution to the greatest extent. The current SR technology is still limited to offline video repairing. Using the conventional neural network, one of the artificial intelligence algorithms, the LR images/videos can be reconstructed and the image and video quality improve practically. This document provides the requirements for real-time super-resolution service based on artificial intelligence.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17624

- **ITU-T F.748.21**: This Recommendation introduces the use cases, classification of features and framework for feature-based distributed intelligent systems relevant to intelligent scenarios, specifying the service requirement, functional requirements, and security requirements for feature-based distributed intelligent systems.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17620

- **ITU-T F.REAIOCR**: In this Recommendation, we make a reasonable standard for the technical requirements and evaluation methods for AI-based OCR service intelligence. We also hope to list some key indicators and aspects to help evaluate the service.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17571

- **ITU-T F.TCEF-FML**: Federated machine learning (FML) is an emerging distributed framework that enables collaborative machine learning (ML) and model construction across decentralized datasets on the basis of ensuring data security and private and legal compliance. In FML, where the computing for machine learning is where the data. FML allows participants to jointly training on the basis of not sharing data, which can technically break data islands and achieve collaborations. FML involves multiple participants, and each participant's contribution to the training results usually is different. Contribution degree on FML service is used to measure the contribution of different participant to the final FML result. Participant with high contribution degree deserve higher award. An effective and reliable evaluation mechanism for contribution degree on FML service is essential for the motivation of current and potential FML participants and can promote the sustainable development of FML services. This draft new Recommendation introduces an evaluation service for contribution degree on federated machine learning service, and provides its concept, characteristics, requirement, use cases, and specifies its reference framework and common capabilities.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17619

- **ITU-T F.Med-Data-QC**: This (draft) Recommendation gives a general frameworks of quality control of medical images for machine learning application. Application on chest volume CT and eye disease image are also described.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17527

- **ITU-T F.747.12**: The components of the part of requirements for artificial intelligence based vision detection service in smart logistics warehouse system:
  - Requirements for AI-enabled multimedia applications in intelligent collection of item information and status
  - Requirements for AI-enabled multimedia applications in inventory and quality inspection
  - Requirements for AGV vision system technology
  - Requirements for the overall environment vision system of logistics and warehousing

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17617
- **ITU-T F.AI-SF**: This Recommendation specifies high-level architecture, use cases and requirements for smart factory based on artificial intelligence.
  - This draft Recommendation covers the followings:
  - Requirements for smart factory based on artificial intelligence.
  - High-level architecture of smart factory based on artificial intelligence.
  - Use cases for smart factory based on artificial intelligence.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17569
- **ITU-T F.FML-TS-FR**: Federated machine learning (FML) is an emerging distributed machine learning paradigm that enables collaborative model training, learning, utilizing and construction from a large number of distributed datasets on the basis of ensuring data security and legal compliance. It performs where the computing is where the data, and data available is not visible and so is data computing. There are some challenges for FML-based services in aspects of trust for they work in distributed and/or decentralized environments, trusted or untrusted. All the challenges are often brought about by a lack of trust in the multiple participants of FML-based services, usually in the progresses of model training and utilizing, such as data indexing, data computing, parameter exchanging, etc. Additional functional components are needed to enhance the trustworthiness of FML-based services, such as to enhance dataset indexing, data computing, parameter communication, and model utilization. Decentralized ledger technology (DLT) system can be as one type of share data system to store the data of FML-based service as well. Convergence between FML and those components can make benefits for FML-based service, especially for helping for addressing the challenges for FML-based services in aspects of trust. This draft new Recommendation provides a trustworthy FML-based service, and specifies its concept, general characteristics and requirements, reference framework and common capabilities.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17652

7.3 ITU-T SG5

ITU-T Study Group 5 (SG5) is the lead study group on electromagnetic field (EMF), environment, climate action, sustainable digitalization, and the circular economy.

Table 7-3 lists the ITU-T SG5 deliverables and work items related to artificial intelligence and machine learning.

Table 7-3 – ITU-T SG5 deliverables and work items

Study group	Reference	Title	Status
SG5	ITU-T L.1305	Data centre infrastructure management system based on Big Data and artificial intelligence technology	In force (Approved on 2019-11-13)
SG5	ITU-T L.Sup41	Requirements on energy efficiency measurement models and the role of artificial intelligence and Big Data	In force (Agreed on 2021-05-20)
SG5	ITU-T L.Sup42	Guidelines on the environmental efficiency of machine learning processes in supply chain management	In force (Agreed on 2021-05-20)
SG5	ITU-T L.Sup43	Smart energy saving of 5G base station: Traffic forecasting and strategy optimization of 5G wireless network energy consumption based on artificial intelligence and other emerging technologies	In force (Agreed on 2021-05-20)
SG5	ITU-T L.Sup53	Guidelines on the Implementation of environmental efficiency Criteria for AI and Other Emerging Technologies Guidelines on the Implementation of environmental efficiency Criteria for AI and Other Emerging Technologies	In force (Agreed on 2022-10-27)
SG5	ITU-T L.Sup48	Data centre energy saving: Application of AI technology in improving energy efficiency of telecom equipment rooms and internet data centre infrastructure	In force (Agreed on 2022-07-01)

- **ITU-T L.1305**: This Recommendation contains technical specifications of data centre infrastructure management system (DCIM), following aspects are covered:– Principles – management objects – Management system scheme – data collection function requirements – operational function requirements – Energy saving management – Capacity management for ICT and facilities – Other operational Function requirements – Intelligent controlling on system to maximize the green energy uses. Other items – maintenance function requirements – Early Alarm and protection based on the big data analysis – Intelligent controlling on system to decrease the cost for maintenance are also considered.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14873

- **ITU-T L.Sup41**: Several assessment models have been introduced to calculate the urban energy system and to demonstrate the variants that calibrate the local energy efficiency. This Supplement focuses on the impact of Artificial Intelligence (AI) and big data on energy efficiency. More specifically, this Supplement identifies a model that can calculate the energy efficiency in an urban space, from an AI and Big Data perspective. A literature analysis is performed with regard to the identification of existing energy efficiency assessment models under the lens of AI and big data and a special focus on the urban system, which results to an AI taxonomy for energy efficiency and to corresponding jobs (process steps) where big data are involved. This Supplement aims to unveil the requirements for energy efficiency assessment, and the features that affect the energy demand. It attempts to define a unified assessment model for energy efficient cities.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17104

- **ITU-T L.Sup42**: This Supplement provides guidelines on the environmental efficiency of machine learning (ML) processes in supply chain management. This guidance document is intended to support machine learning researchers and operators to measure and improve the

environmental efficiency of ML, and other emerging technologies (e.g., Blockchain, Big Data, 5G, …) use in supply chain management.

URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17105

- **ITU-T L.Sup43**: This Supplement explores how network energy saving technologies that have emerged since the 4G era, such as carrier shutdown, channel shutdown, symbol shutdown etc., can be leveraged to mitigate 5G energy consumption. It also analyses how enhanced technologies like deep sleep, symbol aggregation shutdown etc., have been developing in the 5G era. This report aims to detail these fundamentals. However, it is far away from being enough, a revolutionized energy saving solution should be taken into consideration. In response to the requirement of an intelligent and self-adaptive energy saving solution, artificial intelligence (AI) and big data technology are introduced to form a more precise energy saving strategy based on specific site traffic and other site-related conditions, thus improving the efficiency and reducing the manpower required. More details about AI-driven smart energy saving solution will be elaborated.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17106

- **ITU-T L.Sup53**: This Supplement provides guidelines to policymakers, technologists, innovators, environmentalists and other stakeholders from the technology industry, environmental sciences, and policy arena, on the topic of eco-friendly criteria to assess the environmental impacts of artificial intelligence and other emerging technologies. These guidelines aim to serve as common factors, rather than a comprehensive list, for the above-mentioned stakeholders to consider while developing, deploying and promoting any piece of technology into the market and society. While "emerging technologies" is a broad term, this report identifies a few sample technologies through their accordant applications and areas of work in 16 applicable industry domains, which we hope our stakeholders can use as references to improve the environmental efficiency of their own technological products and/or services. When discussing environmental efficiency, this report approaches eco-friendly criteria from an adjusted model of Life Cycle Assessment of Product, with which three stages of environmental impacts – Materials, Use, and End of life – are examined. The core of this report – "Guidelines and Recommendations" – provides long-term and short-term strategies, which include not only specific examples for certain technologies addressing the three stages of environmental efficiency, but also an instrument to be used to localize such guidelines, as well as to allow global benchmarking.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17728

- **ITU-T L.Sup48**: Telecom Equipment Rooms and Internet Data Centre (IDC) Infrastructure is a data centre that contains a huge quantity of Information and Communication equipment. In order to keep the equipment running continuously and reliably, the room is equipped with air-conditioners to create an environment suitable for equipment operation. Nevertheless, it will cause a large amount of energy consumption and carbon emissions. This Supplement focuses on the application of AI technology and other emerging technologies such as digital twin technology, to improve the energy efficiency and reduce the carbon emissions of telecom equipment rooms and IDC infrastructures. Most of the existing equipment rooms do not have the full ability to identify indoor temperature distribution. Therefore, it is difficult to analyse the power consumption in real time and make timely appropriate adjustments. Consequently, this leads to the unnecessary consumption of energy. This Supplement will address how AI-based power management can achieve the following capabilities:
  - Data collections in telecom equipment rooms and IDC infrastructure;
  - Real-time analysis of the historical power consumption and parameters of the target equipment room;
  - The ability of training an intelligent model; and

- Making reasonable adjustments timely to the air-conditioning and temperature, so as to achieve energy saving in the equipment rooms and IDC infrastructure.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17749

7.4 ITU-T SG12

ITU-T Study Group 12 (SG12) is the expert group responsible for the development of international standards (ITU-T Recommendations) on performance, quality of service (QoS) and quality of experience (QoE). This work spans the full spectrum of terminals, networks and services, ranging from speech over fixed circuit-switched networks to multimedia applications over mobile and packet-based networks.

Table 7-4 lists the ITU-T SG12 deliverables and work items related to artificial intelligence and machine learning.

Table 7-4 – ITU-T SG12 deliverables and work items

Study group	Reference	Title	Status
SG12	ITU-T P.1402]	Guidance for the development of machine learning based solutions for QoS/QoE prediction and network performance management in telecommunication scenarios	In force (Approved on 2022-07-29)
SG12	ITU-T P.565	Framework for creation and performance testing of machine learning based models for the assessment of transmission network impact on speech quality for mobile packet-switched voice services	In force (Approved on 2021-11-29)
SG12	ITU-T P.565.1	Machine learning model for the assessment of transmission network impact on speech quality for mobile packet-switched voice services	In force (Approved on 2021-11-29)
SG12	ITU-T E.475	Guidelines for Intelligent Network Analytics and Diagnostics	In force (Approved on 2020-01-13)
SG12	ITU-T E.AIQ	Artificial Intelligence Quotient (AI-Q) for indexing and rating AI algorithms used in conversational AI systems employed for customer service management, service optimization and management as part of service quality assessment methodologies	Under study (Timing: 2023)
SG12	ITU-T P.SAMD	Single-ended perceptual approaches for multi-dimensional analysis	Under study (Timing: Not specified)
SG12	ITU-T P.Sup28	Considerations for the development of new QoS and QoE related objective models to be embedded in Recommendations prepared by ITU-T Study Group 12	In force (Agreed on 2020-09-11)

- **ITU-T P.1402**: This Recommendation introduces Machine Learning techniques and their application for QoS/QoE prediction and network performance management in telecommunication scenarios. Especially, the design of training and evaluation data is described and means to avoid overtraining for Machine Learning models. It is also discussed the relation to classical model or algorithm development and differences are described. This recommendation gives best practice guidance for the successful development and evaluation of models based on Machine Learning but does not describe concrete models or algorithms for a dedicated purpose.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17792

- **ITU-T P.565**: The output of the framework is a machine learning based speech quality prediction model, which predicts the impact on the speech quality from the IP transport and underlying transport, as well as the jitter buffer in the end client; thus providing a network centric view on the speech quality service delivered on mobile packet switched networks. This is expressed in terms of a MOS-LQO under the assumption of an otherwise clean transmission, without background noise, automatic gain control, voice enhancement devices, transcoding, bridging, frequency response, clock drift or any other impairment not caused by the IP transport and underlying transport. The models according to this framework use information on the temporal structure of the reference signal to identify the importance of individual sections of the bitstream with regard to speech quality. These models do not perform any perceptual analysis of the recorded speech signal. The framework specifies three modules required for the development of these kinds of metrics: the databases generator module, the machine learning module, and the validation module for the trained model. In addition, database content and the features used by the machine learning algorithm are described. The framework also provides a large set of test vectors, in the form of error (jitter and packet loss) patterns files for learning and validation. The recommendation specifies minimum required performance, as well as conditions and requirements for an independent additional validation for models developed based on the framework. The recommendation also specifies implementation requirements. The models developed based on the framework enable the assessment of transmission network impact on speech quality for mobile packet-switched voice services, and therefore benefit operators and regulators alike with a fast and easy speech quality trend monitoring / benchmarking and troubleshooting. In addition, if predictors according to this framework are used together with perceptual speech quality metrics like P.863, it is possible to identify if the source of problems resides inside or outside the transport network observed by the predictor according to this framework and thus a more detailed analysis of the situation can be achieved and consequently troubleshooting of less obvious degradations such as the ones occurring outside of the transport network (e.g., emerged from automatic gain control, voice enhancement devices, transcoding or analogue processing) is enabled.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16786

- **ITU-T P.565.1**: Recommendation ITU-T P.565.1 is based on the ITU-T P.565 framework. It provides a machine learning based model that predicts the impact on the speech quality from the Internet Protocol (IP) transport and underlying transport, as well as a standardized or pre-defined jitter buffer in the end client; thus, providing a network centric view on the speech quality service delivered on mobile packet switched networks. This is expressed in terms of a mean opinion score-listening quality objective (MOS-LQO) under the assumption of an otherwise clean transmission, without background noise, non-standard-conformant encoding on sending device, automatic gain control, voice enhancement devices, transcoding, bridging, frequency response, non-standard-conformant jitter-buffer (for IMS mobile calls) or decoding, clock drift or any other impairment not caused by the IP transport and underlying transport. The model supports the uses cases and applications defined in revised ITU-T P.565 for IMS mobile calls (VoLTE/VoNR with EVS, AMRWB codecs) and OTT/WhatsApp. In addition, it meets the minimum performance requirements for the provided test vectors (see ITU-T P.565, Annex D) and it also passed an independent validation on an additional unknown live recorded data set (see ITU-T P.565, Annex D). The model enables the assessment of transmission network impact on speech quality for mobile packet-switched voice services. In addition, if this predictor is used together with perceptual speech analysis or perceptual speech quality metrics like [ITU-T P.863], it is possible to identify if the source of problems resides inside or outside the transport network observed by the predictor.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16545

- **ITU-T E.475**: With the increased number of connected devices and the proliferation of web and multimedia services, cloud services and IoT applications, networks are subject to various network incidents and unregulated network changes which may be measured by network alerts and logs received from the underlying networks. Therefore, it is important for the networks to be aware of the services and applications they transport to optimize the operation and ensure that service quality meets user expectations. The absence of network alerts or network logs is generally interpreted as an indication of good network health, however this is not necessarily the case. Service quality problems may not be the result of network device failures, but instead due to issues that are not detected by traditional network monitoring tools such as configuration errors, insufficient network capacity, wireless access point issues (e.g., insufficient coverage, interference or overlapping channel), or third party network issues.

Typically, the manual network reconfiguration is time consuming and often error prone. In addition, service quality assessment methodologies need to further distinguish between network impairments and other causes of the performance degradation by considering application-specific factors (e.g., encoding/decoding, interaction between an application and a network) because the traditional assessment tools cannot provide accurate fault diagnosis, fault prediction, and root cause analysis. Furthermore, the reaction time of traditional assessment tools tends to be slow, responding after the service disruption occurs. In addition, the network performance metrics may contribute to QoS/QoE assessment, but many of existing network performance metrics may reflect only limited aspects of the network quality.

When the objectively-measured results indicate an unsatisfactory level of network performance or anomaly degree, it is desirable that the system performs necessary corrective actions automatically to resolve the identified quality problems.

This Recommendation specifies guidelines for intelligent network analytics and diagnostics for managing and troubleshooting networks. The Intelligent Network Analytics and Diagnostics (INAD) function is responsible for aggregating network data and setting up automatic tasks for network maintenance, providing the assurance of appropriate network performance, locating the service degradation area and service channels with poor performance, finding root causes of the detected network faults, probing network status, and predicting the possible network performance degradation at an early stage.

Specifically, this Recommendation describes the design considerations, functional architecture, network anomaly analysis models for network analytics and diagnostics. The network anomaly analysis model can be used to assess network anomaly degree, network performance, risk degree, to analyse the location and time of the network impairment and further to determine the root causes of the network impairments and to allow increased network visibility and network fault management automation.

This Recommendation also presents the concept of Network Health Indicator (NHI) which provides a numerical indication of the network anomaly degree based on Big Data Analytics. The NHI is not focused on specific multimedia application rating (e.g., rating of specific audio application, video conferencing application) and application layer monitoring. Instead, it aims at network monitoring and evaluation of specific networks (e.g., LAN, WAN, Storage Network, Data Centre Network) and further triggers Network Diagnosis using Big Data based fault diagnosis algorithms and determine the root causes of the network anomaly events.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14037

- **ITU-T E.AIQ**: Artificial Intelligence (AI) is advanced computing that enables a machine to interact with its environment in an intelligent way. With perpetual advancements in technologies pertaining to Neural Networks, Natural Language Processing, Facial Recognition and Sentiments and Gesture Analysis, AI is going to have potential uses of

serving as front desk support for consumer interfaces. AI assisted applications/virtual assistants can be used as conversational AI for customer service management, public grievance management, service optimization and quality of service management and can add tremendous value in customer service relations, quality of service and overall quality of experiences. AI systems will be used to better serve the human and their intelligence is mainly reflected in the process of serving. The higher the intelligence level is, the better service to the consumer will be offered by such system. Before putting such AI based systems in the network, if capabilities of AI algorithms are adjudged based on some predefined Key Performance Indicators (KPIs), it will help network managers in doing cost benefit analysis. The proposed Recommendation defines these Key Performance Indicators (KPIs) serving as basis for an A-IQ (Artificial Intelligence Quotient), which can be used for indexing and rating AI algorithms for their capabilities in quality of service and quality of experience improvement, as part of service quality assessment methodologies. This will be under mandate of SG12 for operational aspects of performance, QoS and QoE of such services and development of quality assessment methodologies, both subjective and objective.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17815

- **ITU-T P.SAMD**: The purpose of the model P.SAMD is to predict the overall speech quality, in narrowband, wide-band, super-wideband, and fullband telecommunication scenarios as it would be scored in a P.800 Absolute Category Rating (ACR) Listening Only Test (LOT) in a fullband context. In contrast to P.862 and P.863, the approach of P.SAMD is "single-ended" or "non-intrusive", which means that the quality prediction is based on the received speech signal only. In addition to the single-ended speech quality prediction, the model also provides more detailed information about the cause of quality degradation with an approach based on perceptual quality dimensions. The quality dimensions are assessed in a listening-only test.

  The model is based on a CNN (convolution neural network) with following self-attention layer for time-dependency modelling and a final pooling layer with attention mechanism. The model is trained end-to-end, exclusively with subjective ratings. The CNN and self-attention stages are shared between the overall quality and the speech quality dimension tasks, while there is a separate pooling block for each quality dimension and the overall quality.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17777

- **ITU-T P.Sup28**: This Supplement provides guidelines for Recommendations that describe or specify tools for the objective estimation of dimensions of quality of service (QoS) and quality of experience (QoE) with quality models, and which are planned to be approved by ITU-T Study Group 12 (SG12). This applies in particular for any quality model developed with machine learning techniques.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14956

7.5 ITU-T SG17

ITU-T Study Group 17 (SG17) work to build confidence and security in the use of information and communication technologies (ICTs) continues to intensify in order to facilitate more secure network infrastructure, services and applications. The ITU-T SG17 coordinates security-related work across all ITU-T Study Groups, often working in cooperation with other standards development organizations (SDOs) and various ICT industry consortia.

Table 7-5 lists the ITU-T SG17 deliverables and work items related to artificial intelligence and machine learning.

Table 7-5 – ITU-T SG17 deliverables and work items

Study group	Reference	Title	Status
SG17	ITU-T X.Sup37	Supplement to ITU-T X.1231: Countering spam based on machine learning	In force (Agreed on 2022-09-02)
SG17	ITU-T TR.sgfdm	Technical Report: FHE-based data collaboration in machine learning	Under study (Timing: 2023-09)
SG17	ITU-T XSTR-SEC-AI	Technical Report: Guidelines for security management of using artificial intelligence technology	Published (Agreed on 2022-05-20)
SG17	ITU-T X.gdsml	Guidelines for data security using machine learning in big data infrastructure	Under study (Timing: 2024-09)

- **ITU-T X.Sup37**: Supplement 37 to Recommendation ITU-T X.1231 defines a technical framework for countering spam based on machine learning (ML). It may help some relevant persons and companies in spam management, reduce the benefit loss of users and providers, improve user experience and promote the healthy development of telecommunication business. This Supplement to Recommendation ITU-T X.1231 provides some general scenarios, characteristics of spam, and defines general technical framework, work flows about countering spam based on ML.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17989

- **ITU-T TR.sgfdm**: This technical report analyses data leakage issues for data collaboration in machine learning described above, and provides a platform for secure inference and data aggregation in machine learning using fully homomorphic encryption (FHE) technology. The draft also describes definitions of FHE scheme and secure parameter selection.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17999

- **ITU-T XSTR-SEC-AI**: During the use of AI technology, AI security risk may run through the whole process of products, applications and services from design and development to retirement. It is very important to analyse the security risks of using AI technology from the perspective of the whole process. Organizations need to build security capabilities that can protect the whole process of AI products, applications and services they provide or use. Therefore, this proposal describes the process of using AI technology in products, applications and services, analyses the security risks in the process, and provides guidelines for security management of using AI technology in organizations

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18031

- **ITU-T X.gdsml**: In big data infrastructure, there are many security threats in the process of data storage, use, transmission and sharing. Current data security policy is usually static, because it does not change with the flow of data. How to dynamically and intelligently monitor, analyse, warn and respond to data security threats is a security problem to be solved in big data infrastructure. Using machine learning to enhance data security is not only helpful to improve security, but also becoming more and more urgent. It has become a necessary technology for data security protection in big data infrastructure. This Recommendation analyses the data security threats in big data infrastructure, develops a data security threat analysis framework based on machine learning, and specifies a reference model for data security threat monitoring, analysis, early warning and response using machine learning in

big data infrastructure. This Recommendation provides guidelines for data security using machine learning in big data.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18351

7.6 ITU-T SG20

ITU-T Study Group 20 (SG20) develops international standards (ITU-T Recommendations) providing commonly agreed guidance for implementing the Internet of Things (IoT) and its applications, as well as smart cities and communities. Its work supports digital transformation in both urban and rural areas enabled by solutions in fields such as IoT, digital twins, and artificial intelligence.

Table 7-6 lists the ITU-T SG20 deliverables and work items related to artificial intelligence and machine learning.

Table 7-6 – ITU-T SG20 deliverables and work items

Study group	Reference	Title	Status
SG20	ITU-T Y.4470	Reference architecture of artificial intelligence service exposure for smart sustainable cities	In force (Approved on 2020-08-29)
SG20	ITU-T Y.Sup63	Unlocking Internet of things with artificial intelligence	In force (Agreed on 2020-07-16)
SG20	ITU-T Y.CDML-arc	Reference architecture of collaborative decentralized machine learning for intelligent IoT services	Under study (Timing: 2023-Q1)
SG20	ITU-T Y.RA-FML	Requirements and reference architecture of IoT and smart city & community service based on federated machine learning	Under study (Timing: 2023-Q1)
SG20	ITU-T Y.AI-DECCS	Functional architecture of AI enabled device-edge-cloud collaborative services for IoT and smart city	Under study (Timing: 2023-Q3)

- **ITU-T Y.4470**: This Recommendation introduces the artificial intelligence service exposure (AISE) for smart sustainable cities (SSC), analyses common characteristics and high-level requirements of AISE, brings a reference architecture of AISE and relevant common capabilities. The AISE is one of the bases, supporting functional entities for smart sustainable cities, with which the SSC services can use the uniform interfaces (exposed by the AISE) to integrate and access the AI capabilities (functionalities) of AI services (e.g., machine learning services for video/audio/picture recognition, natural language processing services, traffic prediction services etc.). The AISE can leverage the AI capabilities developed and exposed by AI service providers for SSC services, and can support the SSC service providers to integrate and access the exposed AI capabilities. The AISE can provide security and privacy mechanism on the SSC data. The AISE can support the AI service providers to design and train AI capabilities with local SSC data on AISE in SSCs, and can support the SSC services to integrate and access AI capabilities.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14503

- **ITU-T Y.Sup63**: As the IoT system seeks to spread within the urban realm in keeping with smart and sustainable city aspirations, the need to manage the burgeoning big data and establishing a self-sustaining urban ecosystem is at the fore-front. Accordingly, this

Technical Report examines how artificial intelligence could step in as the saviour and bolster the intent of urban stakeholders to deploy IoT technologies and eventually transition to smart cities. This Technical Report includes:

- The various technologies from AI which will help cater to urbanization and facilitate smart city transformations;
- The role played by AI in managing the data generated within the IoT realm;
- The main benefits of adopting AI and delving into how this technology could be leveraged to attain the targets stipulated in the recently established Sustainable Development Goals (SDGs).

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14103

- **ITU-T Y.CDML-arc**: A collaborative decentralized machine learning (CDML) architecture can support ML model distributed training and inference across highly heterogeneous and resource-constrained IoT devices, which results in less latency, higher reliability, lower energy consumption, and saving bandwidth resources. With using CDML, spare resources across decentralized IoT devices can be fully used to perform computation-intensive ML tasks collaboratively with high performance. This draft Recommendation introduces collaborative decentralized machine learning (CDML) for intelligent IoT services, and provides the characteristics and reference architecture of CDML for intelligent IoT services.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17938

- **ITU-T Y.RA-FML**: The widespread popularity of data-driven services and application transforms the IoT and Smart City & Community (SC&C) system from a traditional data collecting and transportation network into a more holistic architecture with AI-native data processing and service delivery capability. One of the key challenges in designing an AI-based architecture for IoT and SC&C networking systems is to implement distributed data processing and learning across a large number of decentralized datasets that can be owned or managed by different entities such as cities, communities, buildings, devices, government and business entities. Federated machine learning (FML) is an emerging distributed AI framework that enables collaborative machine learning (ML) and model construction across decentralized datasets. It offers a viable solution for data-driven data learning and synthesis across a wide variety of entities across large SC&C networking systems. The main purpose of this recommendation is to provide a feasible and standardized solution for the IoT and SC&C relevant services and applications to use and deploy FML-enabled AI across distributed and decentralized data sources.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17924

- **ITU-T Y.AI-DECCS**: The maturity of Internet of things technology and the widespread deployment of network provide good infrastructure conditions to the application of AI at the device, edge and cloud for IoT and smart city. The requirements of AI models in IoT and smart city are dynamic, thus how to make AI system continuously and dynamically update, as well as infer and predict in real-time is essential to the application of AI in IoT and smart city. The device-edge-cloud collaborative service enables collaborative inference, and dynamic learning and updating of AI models on the device-edge-cloud architecture, so as to meet the needs of various current and future application scenarios. This recommendation specifies the Functional architecture of AI enabled device-edge-cloud collaborative services for IoT and smart city.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17929

7.7 ITU-T SG9

ITU-T Study Group 9 (SG9) carries out studies on the use of telecommunication systems in the distribution of television and sound programs supporting advanced capabilities such as ultra-high definition and 3D TV. This work also covers the use of cable and hybrid networks – primarily designed for the distribution of television and sound programs to the home – as integrated broadband networks to provide interactive voice, video and data services, including Internet access.

Table 7-7 lists the ITU-T SG9 deliverables and work items related to artificial intelligence and machine learning.

Table 7-7 – ITU-T SG9 deliverables and work items

Study group	Reference	Title	Status
SG9	ITU-T J.1600	Premium cable network platform – Framework	In force (Approved on 2019-10-07)
SG9	ITU-T J.pcnp-char	E2E network characteristics requirement for video services	Under Study (Timing: 2023)
SG9	ITU-T J.1611	Functional requirements for a Smart Home Gateway	In force (Approved on 2021-01-13)
SG9	ITU-T J.1302	Specification of a cloud-based converged media service to support Internet Protocol and Broadcast Cable TV – System Architecture"	In force (Approved on 2022-01-13)

- **ITU-T J.1600**: Recommendation ITU-T J.1600 specifies the framework of the premium cable network platform (PCNP) for cable TV and broadband network that exploit cloud based artificial intelligence (AI) and network data to optimize network and TV services, thus enabling the high satisfaction of user's experience of perceptual aspects of services.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14930

- **ITU-T J.pcnp-char**: Different video services (4K, 8K, VR, AR, etc.) have different requirements of the network performance which evaluated by network key performance indicators (KPI). Also different video services for user experience have different quality requirements to be evaluated by service key quality indicators (KQI). This recommendation will specify the E2E network characteristics (KPI and KQI) especially for their appropriate values or ranges for characterizing a very good delivery and user experience of advanced videos, includes TV and OTT videos (4K, 8K, VR, AR, etc.).

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17753

- **ITU-T J.1611**: Recommendation ITU-T J.1611 specifies functional requirements for a smart home gateway from both the hardware and software point of view to ensure secure interoperability among consumers, businesses and industries by delivering a standardized communications platform and allowing devices to communicate across operating systems, service providers, transport technologies or ecosystems. In a smart home solution, a gateway is incorporated to connect various appliances. In addition, a connection management platform based on the Internet of things (IoT) is required to enable various applications. These applicable solutions include home health, entertainment, security and home automation, which promote a safer, happier, as well as a more comfortable and convenient lifestyle.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14926

- **ITU-T J.1302**: Recommendation ITU-T J.1302 defines the high-level system architecture of a cloud-based converged media service to support Internet protocol (IP) and broadcast cable television (TV). With the cloud-native technology development, cloud-based converged media services can be quickly deployed by cable television operators. This Recommendation is part 2 of a multi-part deliverable.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17257

7.8 ITU-T SG11

ITU-T Study Group 11 (SG11) is responsible for signalling, producing international standards (ITU-T Recommendations) that define how telephone calls and other ICT services are handled in the network.

Table 7-8 lists the ITU-T SG11 deliverables and work items related to artificial intelligence and machine learning.

Table 7-8 – ITU-T SG11 deliverables and work items

Study group	Reference	Title	Status
SG11	ITU-T Q.5001	Signalling requirements and architecture of intelligent edge computing	In force (Approved on 2018-10-14)
SG11	ITU-T Q.5023	Protocol for managing Intelligent Network Slicing with AI-assisted analysis in IMT-2020 network	In force (Approved on 2021-08-29)
SG11	ITU-T Q.5024	Protocol for providing intelligent analysis services in IMT-2020 network	In force (Approved on 2022-02-13)
SG11	ITU-T Q.3646	Framework and protocols for signalling network analyses and optimization in VoLTE	In force (Approved on 2022-02-13)
SG11	ITU-T Q.5025	Protocol for managing User Plane function in IMT-2020 network	AAP (Approved on 2022-09-29)
SG11	ITU-T Q.IMT2020-SAO	Requirement, framework and protocols for signalling network analyses and optimization in IMT-2020	Under study (Timing: 2022-12)

- **ITU-T Q.5001**: A large volume of data have been generated from the use of various types of smart things. The related smart services have been working based on cloud systems. However, various issues have occurred as a result of the network bottleneck between terminals and a cloud system (e.g., data loss, network delay, etc.). An edge computing technology between the user equipment and a cloud server system is envisaged to solve these problems. In addition, applying the intelligent data processing functions by providing artificial intelligence (AI) technologies will provide enhanced networking capabilities for new emerging services and applications. Regarding these emerging environments, Recommendation ITU-T Q.5001 defines the intelligent edge computing (IEC). It is applicable to collect, store, and process data reliably in the intelligent edge computing, especially to support mission critical services. Thus, the main functionality of intelligent edge computing is collecting, processing, analysing the data and providing the values based on intelligent data processing. This Recommendation specifies use cases, signalling requirements and an architecture of intelligent edge computing.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14276

- **ITU-T Q.5023**: This Recommendation specifies APIs, API management, message format and procedures related of intelligent network slice with AI-assisted in IMT-2020 networks. Intelligent network slicing with AI-assisted functions is capable of allocating limited resources to meet the SLA of slicing users in real time dynamically. It is necessary to develop an intelligent network slicing API framework which makes the IMT-2020 network more efficient and flexible. The framework includes common aspects and some signalling flows which describe the data collecting, data analysis, MOS (Mean Opinion Score) training and QoE (Quality of Experience) calculation.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=15152

- **ITU-T Q.5024**: This Recommendation specifies architecture for supporting intelligent analysis services in IMT-2020 network, and intelligent analysis services offered by Data Analysis Function (DAF) including load balancing, network functions fault location and advance warning, device on/off analysis, mobility analysis, etc. It includes signalling flows for network functions (NFs) event exposure to DAF and DAF analytics exposure to NFs, message format, and security considerations. Data analysis function (DAF) is defined in ITU-T Q.INS-PM, and DAF introduced in IMT-2020 network [ITU-T Y.3104] can provide intelligent analysis services. Intelligent analysis services offered by DAF include load balancing, NF fault location and warning, device on/off analysis, mobility analysis, energy saving, etc. It is necessary to enable network automation and intelligence.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16387

- **ITU-T Q.3646**: This Recommendation defines the framework of signalling network analyses and optimization for VoLTE network, specifies the interfaces and protocols between signalling network analyses and optimization system and VoLTE network, specifies the service procedures of signalling network analyses and optimization, and specifies the AI-assisted functions and security issues of the proposed system. The proposed signalling network analyses and optimization system is a network management system with the characteristics of high efficiency, real time reaction, reliability and intelligence, designed for VoLTE network.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16385

- **ITU-T Q.5025**: This Recommendation specifies on protocol for managing user plane function (UPF) in IMT-2020 network. It describes the communication mechanism inside UPF. It also describes API management, procedure, signalling flow and message format between UPF and other core network functions or third party application.

  Native function/services of UPF includes traffic routing and forwarding, PDU session tunnel management, policy control, anchor point, event exposure and other customized functions, like packet inspection and collection of UPF traffic for lawful intercept and interworking functionalities among different network segments, e.g., interworking between IP-based core network and non-IP based access network. Data analysis function (DAF) can subscribe UPF information for data analysis and resource dispatch.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17848

- **ITU-T Q.IMT2020-SAO:** This draft Recommendation specifies the requirements, framework and protocols for signalling network analyses and optimization in IMT-2020 network. The signalling network in IMT-2020 refers to the network entities and corresponding signalling exchange which are related to IMT-2020 service procedures. The IMT-2020 signalling network analyses and optimization system is a network management system which consists of signalling collecting component, signalling network analyses component, signalling network optimization component, and AI/ML assistance component. The IMT-2020 signalling network analyses and optimization system is designed with the

characteristics of high efficiency, real time reaction, reliability and intelligence, aiming to be applied in IMT-2020 network.

URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17852

7.9 ITU-T SG2

ITU-T Study Group 2 (SG2) is home to Recommendation ITU-T E.164, the numbering standard which has played a central role in shaping the telecom networks of today. ITU-T E.164 provides the structure and functionality of telephone numbers, and without it we would not be able to communicate internationally. In recent years SG2 has worked on ENUM, an Internet Engineering Task Force (IETF) protocol for entering E.164 numbers into the Internet domain name system (DNS).

Table 7-9 lists the ITU T SG2 deliverables and work items related to artificial intelligence and machine learning.

Table 7-9 – ITU-T SG2 deliverables and work items

Study group	Reference	Title	Status
SG2	ITU-T M.3381	Requirements for energy saving management of 5G RAN system with AI	In force (Approved on 2022-01-13)
SG2	ITU-T M.3080	Framework of AI enhanced Telecom Operation and Management (AITOM)	In force (Approved on 2021-02-13)
SG2	ITU-T M.3382	Requirements for work orders processing in telecom management with AI	In force (Approved on 2022-06-29)
SG2	ITU-T M.rla-AI	Requirements for Log Analysis with AI-enhanced Management System	Under study (Timing: 2024-12)
SG2	ITU-T M.rmnoc-AI	Requirements for the management of network operation cost within AITOM in telecom operational aspects	Under study (Timing: 2024-12)
SG2	ITU-T M.rfmls	Management Requirements for Federated Machine Learning Systems	Under study (Timing: 2023-12)
SG2	ITU-T M.il-AITOM	Intelligence Levels of AI enhanced Telecom Operation and Management	Under study (Timing: 2023-12)
SG2	ITU-T M.rsca	Requirements for smart comprehensive analysis with AITOM	Under study (Timing: 2024-12)
SG2	ITU-T M.rsmca	Requirements for smart maintenance of cell antenna	Under study (Timing: 2024-12)
SG2	ITU-T M.rODFos	Requirements for Optical Distribution Frame (ODF) On-Site Smart Maintenance	Under study (Timing: 2024-12)
SG2	ITU-T M.ilef-AITOM	Intelligence levels evaluation framework of AI enhanced Telecom Operation and Management	Under study (Timing: 2024-12)

Table 7-9 – ITU-T SG2 deliverables and work items

Study group	Reference	Title	Status
SG2	ITU-T M.tsm-rest	REST-based interface design for on-site generic telecommunication smart maintenance	Under study (Timing: 2024-12)
SG2	ITU-T M.la-AI-ia	Protocol neutral interface analysis for log analysis in telecom management with AI	Under study (Timing: 2024-12)

- **ITU-T M.3381**: This Recommendation provides requirements for energy saving management of 5G RAN system with AI. This Recommendation targets for proving requirement of energy saving management for communication units and virtualized hardware resources of base station via OMC and open interfaces provided by vendors, from OSS perspective. As a necessary technology, AI is applied to the energy saving management of 5G RAN system across vendors and communication systems, such as 4G and 5G. In addition, this Recommendation includes sending intelligent energy saving strategies from OSS to OMC and then to wireless equipment.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16435

- **ITU-T M.3080**: This Recommendation provides framework of Artificial Intelligence (AI) enhanced Telecom Operation and Management (AITOM). It describes functional architecture of AITOM to support telecom operation management for efficiency improvement, quality assurance, cost management, and security assurance. It also describes AI pipeline and information model on how to enable AITOM using AI technology.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=16432

- **ITU-T M.3382**: This Recommendation focuses on work orders processing in telecom management with AI. This Recommendation provides the function requirement, typical scenario and feature extraction process of work orders.

  URI: https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17423

- **ITU-T M.rla-AI**: This Recommendation describes requirements for log analysis with AI-enhanced management system. As a new technology, AI can be used in log analysis of management system to realize real-time monitoring and fault prediction. This draft Recommendation is to explain the way of using AI to analyse log in management system, which specifically describes the function framework, function requirements and process, and typical scenarios of log analysis with AI-enhanced management system. This draft Recommendation is applicable to the design, development and application of log analysis with AI-enhanced management system.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17425

- **ITU-T M.rmnoc-AI**: This Draft Recommendation will focus on the application scenarios and business processes of AI technology in network operation cost management in telecom network operation and maintenance, and put forward the functional requirements and artificial intelligence (AI) pipelines under the AITOM standard.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17426

- **ITU-T M.rfmls**: In order to promote the construction and use of federated machine learning models and enhance the privacy protection and security performance of federated machine learning, this Draft Recommendation will this document specifies the structure and functional requirements for management of the federated machine learning system.

URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17427

- **ITU-T M.il-AITOM**: This Draft Recommendation will focus a method for evaluating the intelligence levels of AI enhanced Telecom Operation and Management. Applications for evaluating the levels on several representative use cases are introduced as well. Architecture scenarios for integrating this evaluation method into the unified architecture defined in [ITU-T M.3080] are also described.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=17428

- **ITU-T M.rsca**: This draft Recommendation describes the requirements for smart comprehensive analysis with AITOM. The goal of the draft is to explain the requirements of using AI technology to achieve smart comprehensive analysis, focus on service quality assurance, from the OSS level. This draft Recommendation considers the comprehensive application and typical use cases of AI technologies in smart comprehensive analysis.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18324

- **ITU-T M.rsmca**: This draft Recommendation describes the requirements for smart maintenance of cell antenna. The base station account data includes antenna longitude and latitude of location, azimuth, downtilt angle, power and other core working parameters. Since the antenna location (or site) and azimuth are key parameters for locating network users, it is important to keep them in good maintenance. The goal of the draft is to explain the requirements of using AI technology to process the big data from network side and calculate cell site and azimuth, and then provide recommendations for correction based on the comparison with current network configuration.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18325

- **ITU-T M.rODFos**: This document specifies the general structure and functional requirements for ODF on-site smart maintenance to promote the construction and use of ODF on-site smart maintenance and improve the capability of smart maintenance for optical communication network. The following aspects are within the scope of this draft Recommendation: Overall structure of ODF on-site smart maintenance, functional requirements of smart handover unit (SHU), functional requirements of ODF smart maintenance system (OSMS) and functional requirements of interface between SHU and OSMS.The document is applicable to the architecture design, R&D and O&M for the ODF on-site smart maintenance.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18326

- **ITU-T M.ilef-AITOM**: The draft Recommendation proposes the intelligence levels evaluation framework of AI enhanced Telecom Operation and Management, including four-layer evaluation framework, definition of each layer, evaluation method, and evaluation process, which can help to determine intelligence levels and identify the telecom operation and management shortcomings.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18327

- **ITU-T M.tsm-rest**: This draft document provides the REST-based interface design for on-site generic telecommunication smart maintenance (TSM). It describes the interface position for on-site TSM, and specifies the managed entities and their relationships for the on-site TSM interface at a REST technology-specific level (protocol-specific), and it also provides detailed attribute definitions of each managed entities, and the interactive control information exchanged through this TSM interface using the YAML/JSON language. This draft document applies to the design, development, inter-connection and inter-operation of on-site generic telecommunication smart maintenance.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18328

- **ITU-T M.la-AI-ia**: This draft Recommendation propose generic interface analysis model (information model) required to implement the management requirements about log analysis with AI-enhanced management system. The main contents of this recommendation include interface positions, the definition and description of general information model object classes and attributes, the relationship between general information model object classes. This draft Recommendation is applicable to the design, development and application of log analysis with AI-enhanced management system.

  URI: https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=18329

7.10 ITU-R SG6

ITU-R Study Group 6 (SG6) work for Radiocommunication broadcasting, including vision, sound, multimedia and data services principally intended for delivery to the general public.

Table 7-10 lists the ITU-R SG6 deliverables and work items related to artificial intelligence and machine learning.

Table 7-10 – ITU-R SG6 deliverables and work items

Study group	Reference	Title	Status
SG 6	ITU-R Question 144/6	Use of Artificial Intelligence (AI) for broadcasting	In force (Approved in 2019-01)
SG 6	ITU-R BT.2447-2	Artificial intelligence systems for programme production and exchange	In force (Approved in 2021-11)

- **ITU-R Question 144/6**: Question 144/6 acknowledges that Artificial Intelligence technologies are increasingly used in many areas of society including broadcasting and asks what is the impact of AI technology and how can it be deployed to increase efficiency in the areas of programme production, quality evaluation, programme assembly (including content scheduling and archive mining) and for broadcast emission.

  URI: https://www.itu.int/pub/R-QUE-SG06.144

- **ITU-R BT.2447-2**: Report ITU-R Report ITU-R BT. 2447 "Artificial intelligence systems for programme production and exchange", discusses current applications and efforts underway and evaluated that are relevant to the near-term broadcast programme and production pathway. Relevant applications and efforts are categorized into the following topical descriptions for areas of technological benefit: Workflow Optimization, Bandwidth Optimization, Automated Content Creation, Content Creation from Legacy Archives, Content Selection for Targeting Audience Demographics, Optimization of Asset Selection – Metadata Creation, Dynamic Product Placement and Advertising for Broadcast and Content Personalization.

  URI: https://www.itu.int/pub/R-REP-BT.2447

7.11 ISO/IEC JTC 1/SC 42

ISO/IEC JTC 1 is a joint technical committee (JTC) of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Its purpose is to develop, maintain and promote standards in the fields of information and communications technology (ICT). JTC 1/SC 42, which is specialized to focus on the area of "Artificial Intelligence", is developing AI standards. This group serve as the focus and proponent for JTC 1's standardization program on Artificial Intelligence, and provide guidance to JTC 1, IEC, and ISO committees

developing Artificial Intelligence applications. Table 7-11 lists the JTC 1 deliverables and work items related to artificial intelligence.

Table 7-11 – JTC 1/SC 42 deliverables and work items

WG	Reference	Name/Title	Status
WG1	ISO/IEC 22989	Artificial intelligence – Concepts and terminology	FDIS
WG1	ISO/IEC 23053	Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)	FDIS
WG1	ISO/IEC 42001	Artificial intelligence – Management System	CD2
WG2	ISO/IEC 24668	Information technology – Artificial intelligence –Process management framework for Big data analytics	FDIS
WG2	ISO/IEC 5259-1	Data quality for analytics and ML – Part 1: Overview, terminology, and examples	CD
WG2	ISO/IEC 5259-2	Data quality for analytics and ML – Part 2: Data quality measures	CD
WG2	ISO/IEC 5259-3	Data quality for analytics and ML – Part 3: Data Quality Management Requirements and Guidelines	CD
WG2	ISO/IEC 5259-4	Data quality for analytics and ML – Part 4: Data quality process framework	CD
WG2	ISO/IEC 5259-5	Data quality for analytics and ML – Part 5: Data quality governance	WD
WG2	ISO/IEC 8183	Artificial intelligence – Data life cycle framework	DIS
WG3	ISO/IEC 23894	Information Technology – Artificial Intelligence – Risk Management	DIS
WG3	ISO/IEC TR 24027:2021	Information technology – Artificial Intelligence (AI) – Bias in AI systems and AI aided decision making	Published
WG3	ISO/IEC TR 24028:2020	Information technology – Artificial Intelligence (AI) – Overview of trustworthiness in Artificial Intelligence	Published
WG3	ISO/IEC TR 24029-1:2021	Artificial Intelligence (AI) – Assessment of the robustness of neural networks – Part 1: Overview	Published
WG3	ISO/IEC 24029-2	Artificial Intelligence (AI) – Assessment of the robustness of neural networks – Part 2: Methodology for the use of formal methods	DIS
WG3	ISO/IEC TR 24368	Information technology – Artificial intelligence – Overview of ethical and societal concerns	DTR
WG3	ISO/IEC 25059	Software engineering – Systems and software Quality Requirements and Evaluation (SQuaRE) – Quality Model for AI systems	DIS
WG3	ISO/IEC TR 5469	Artificial intelligence – Functional safety and AI systems	WD
WG3	ISO/IEC TS 5471	Artificial intelligence – Quality evaluation guidelines for AI systems	WD
WG3	ISO/IEC TS 6254	Information technology – Artificial intelligence – Objectives and methods for explainability of ML models and AI systems	WD

Table 7-11 – JTC 1/SC 42 deliverables and work items

WG	Reference	Name/Title	Status
WG3	ISO/IEC TS 8200	Artificial intelligence – Controllability of automated artificial intelligence systems	WD
WG3	ISO/IEC TS 12791	Artificial intelligence – Treatment of unwanted bias in classification and regression machine learning tasks	WD
WG3	ISO/IEC 12792	Artificial intelligence – Transparency taxonomy of AI systems	WD
WG4	ISO/IEC TR 24030:2021	Information technology – Artificial Intelligence (AI) – Use cases	Published
WG4	ISO/IEC TR 24030 2nd Edition	Information technology – Artificial Intelligence (AI) – Use cases	WD
WG4	ISO/IEC 5338	Information technology – Artificial intelligence – AI system life cycle processes	CD
WG4	ISO/IEC 5339	Information Technology – Artificial Intelligence – Guidelines for AI applications	CD
WG5	ISO/IEC TR 24372:2022	Information technology – Artificial intelligence (AI) – Overview of computational approaches for AI systems	Published
WG5	ISO/IEC TS 4213	Information technology – Artificial Intelligence – Assessment of machine learning classification performance	DTS2
WG5	ISO/IEC 5392	Information technology – Artificial intelligence – Reference architecture of knowledge engineering	CD
WG5	ISO/IEC 17903	Information technology – Artificial intelligence – Overview of machine learning computing devices	AWI
JWG1	ISO/IEC 38507:2022	Information technology – Governance of IT – Governance implications of the use of artificial intelligence by organizations	Published
JWG2	ISO/IEC TS 29119-11	Artificial intelligence – Testing for AI systems – Part 11:	WD

- **ISO/IEC 22989**: This document establishes terminology for Artificial Intelligence (AI) and describes concepts in the field of AI. This document can be used in the development of other standards and in support of communications among diverse, interested parties/stakeholders. This document is applicable to all types of organizations (e.g., commercial enterprises, government agencies, not-for-profit organizations).

  URI: https://www.iso.org/standard/74296.html

- **ISO/IEC 23053**: This document establishes an Artificial Intelligence (AI) and Machine Learning (ML) framework for describing a generic AI system using ML technology. The framework describes the system components and their functions in the AI ecosystem. This document is applicable to all types and sizes of organizations, including public and private companies, government entities, and not-for-profit organizations, that are implementing or using AI systems.

  URI: https://www.iso.org/standard/74438.html

- **ISO/IEC 42001**: This document specifies the requirements and provides guidance for establishing, implementing, maintaining and continually improving an AI management

system within the context of an organization. This document is intended for use by an organization providing or using products or services that utilize AI systems. This document helps the organization develop or use AI systems responsibly in pursuing its objectives and meet applicable regulatory requirements, obligations related to interested parties and expectations from them. This document is applicable to any organization, regardless of size, type and nature, that provides or uses products or services that utilize AI systems.

URI: https://www.iso.org/standard/81230.html

- **ISO/IEC 24668**: The standard provides a framework for developing processes to effectively leverage big data analytics across the organization irrespective of the industries/sectors. This standard specifies process management for big data analytics with its various process groups taken into account along with their interconnectivities. These process groups are: Organization Stakeholder Processes, Competency Development Processes, Data Management Processes, Analytics Development Processes and Technology Integration Processes. This standard describes processes to acquire, describe, store and process data at an organization level which provides Big Data analytics services.

  URI: https://www.iso.org/standard/78368.html

- **ISO/IEC 5259-1**: The purpose of this document is to help organizations achieve effective data quality management using a standardized data quality process. This document is part of the ISO/IEC 5259 series. The aim of the ISO/IEC 5259 series is to provide tools and methods to assess and improve the quality of data used for analytics and ML.

  URI: https://www.iso.org/standard/81088.html

- **ISO/IEC 5259-2**: ISO/IEC 5259-2 provides a data quality model, data quality measures, and guidance on reporting data quality in the context of analytics and ML. ISO/IEC 5259-2 builds on the ISO 8000 series, ISO/IEC 25012 and ISO/IEC 25024. The aim of ISO/IEC 5259-2 is to enable organizations to achieve their data quality. Objectives and is applicable to all types of organizations.

  URI: https://www.iso.org/standard/81860.html

- **ISO/IEC 5259-3**: ISO/IEC 5259-3 specifies requirements and provides guidance for establishing, implementing, maintaining and continually improving the quality for data used in the areas of analytics and ML. ISO/IEC 5259-3 does not define a detailed process, methods or metrics. Rather it defines the requirements and guidance for a quality management process along with a reference process and methods that can be tailored to meet the requirements in this document. The requirements and recommendations set out in ISO/IEC 5259-3 are generic and are intended to be applicable to all organizations, regardless of type, size or nature.

  URI: https://www.iso.org/standard/81092.html

- **ISO/IEC 5259-4**: ISO/IEC 5259-4 provides general common organizational approaches, regardless of type, size or nature of the applying organization, to ensure data quality for training and evaluation in analytics and ML. It includes guidelines for: supervised ML, unsupervised ML, semi-supervised ML, and reinforcement ML. ISO/IEC 5259-4 is applicable to training and evaluation data that comes from different sources, including data acquisition and data composition, data pre-processing, data labelling, evaluation, and data use. ISO/IEC 5259-4 does not define specific services, platforms or tools.

  URI: https://www.iso.org/standard/81093.html

- **ISO/IEC 5259-5**: This document provides a data quality governance framework for analytics and machine learning to enable governing bodies of organizations to direct and oversee the implementation and operation of data quality measures, management, and related processes with adequate controls throughout the data life cycle. This document can be applied to any

analytics and machine learning. This document does not define specific management requirements or process requirements specified in 5259-3 and 5259-4 respectively.

URI: https://www.iso.org/standard/84150.html

- **ISO/IEC 8183**: This document provides an overarching data life cycle framework that is instantiable for any AI system from data ideation to decommission. This document is applicable to the data processing throughout the AI system life cycle including the acquisition, creation, development, deployment, maintenance and decommissioning. This document does not define specific services, platforms or tools. This document is applicable to all organizations, regardless of type, sizes and nature, that use data in the development and use of AI systems.

  URI: https://www.iso.org/standard/83002.html

- **ISO/IEC 23894**: This document provides guidelines on managing risk faced by organizations during the development and application of Artificial Intelligence (AI) techniques and systems. The guidelines also aim to assist organizations to integrate risk management into their AI-related activities and functions. It moreover describes processes for the effective implementation and integration of AI risk management. The application of these guidelines can be customized to any organization and its context. This document uses the guidelines described in the International Standard ISO 31000 (Risk management – Guidelines) and in addition provides additional guidance that arises by the application of AI to existing processes in any organization or when an organization provides an AI system for use by others.

  URI: https://www.iso.org/standard/77304.html

- **ISO/IEC 24027:2021**: This document addresses bias in relation to AI systems, especially with regards to AI aided decision making. Measurement techniques and methods for assessing bias are described, with the aim to address bias related vulnerabilities, and mitigation thereof. All AI system lifecycle phases are in scope, including but not limited to data collection, training, continual learning, design, testing, evaluation, and use.

  URI: https://www.iso.org/standard/77607.html

- **ISO/IEC 24028:2020**: This document surveys topics related to trustworthiness in AI systems, including the following:
  - approaches to establish trust in AI systems through transparency, explainability, controllability, etc.;
  - engineering pitfalls and typical associated threats and risks to AI systems, along with possible mitigation techniques and methods; and
  - approaches to assess and achieve availability, resiliency, reliability, accuracy, safety, security, privacy, maintainability, and durability of AI systems.

  URI: https://www.iso.org/standard/77608.html

- **ISO/IEC 24029-1:2021**: The present document provides background about the existing methods to assess the robustness of neural networks.

  URI: https://www.iso.org/standard/77609.html

- **ISO/IEC 24029-2**: This document provides methodology for the use of formal methods to assess robustness properties of neural networks. The document focuses on how to select, apply and manage formal methods to prove robustness properties.

  URI: https://www.iso.org/standard/79804.html

- **ISO/IEC 24368**: This document provides a high-level overview of the programme of work in SC 42 in the area of ethics and societal concerns relative to Artificial Intelligence (AI)

systems and applications. This document provides information in relation to principles, processes and methods in this area. This document is intended for technologists, regulators, interest groups, and the society at large. This document is not intended to advocate for any specific set of values (value systems).

URI: https://www.iso.org/standard/78507.html

- **ISO/IEC 25059**: This document outlines a quality model for AI systems and is an application-specific extension to the SQuaRE series. The characteristics and sub-characteristics detailed in the model provide consistent terminology for specifying, measuring and evaluating AI system quality. The characteristics and sub-characteristics detailed in the model also provide a set of quality characteristics against which stated quality requirements can be compared for completeness.

  URI: https://www.iso.org/standard/80655.html

- **ISO/IEC TR 5469**: This document describes the properties, related risk factors, available methods and processes relating to:
  - Use of AI inside a safety related function to realize the functionality;
  - Use of non-AI safety related functions to ensure safety for an AI controlled equipment;
  - Use of AI systems to design and develop safety related functions.

  URI: https://www.iso.org/standard/81283.html

- **ISO/IEC TS 5471**: This document provides guidance for evaluation of AI systems using an AI system quality model. The document is applicable to all types of organizations engaged in the development and the use of artificial intelligence.

  URI: https://www.iso.org/standard/82570.html

- **ISO/IEC TS 6254**: This document describes approaches and methods that can be used to achieve explainability objectives of stakeholders with regards to ML models and AI systems' behaviours, outputs, and results. Stakeholders include but are not limited to, academia, industry, policy makers, and end users. It provides guidance concerning the applicability of the described approaches and methods to the identified objectives throughout the AI system's life cycle, as defined in ISO/IEC 22989.

  URI: https://www.iso.org/standard/82148.html

- **ISO/IEC TS 8200**: This document defines a basic framework with principles, characteristics and approaches for the realization and enhancement for automated artificial intelligence (AI) systems' controllability. The following areas are covered:
  - State observability and state transition
  - Control transfer process and cost
  - Reaction to uncertainty during control transfer
  - Verification and validation approaches

  This document is applicable to all types of organizations (e.g., commercial enterprises, government agencies, not-for-profit organizations) developing and using AI systems during their whole life cycle.

  URI: https://www.iso.org/standard/83012.html

- **ISO/IEC TS 12791**: This document provides mitigation techniques that can be applied throughout the AI system life cycle in order to treat unwanted bias. This document describes how to address unwanted bias in AI systems that use machine learning to conduct classification and regression tasks. This document is applicable to all types and sizes of organization.

URI: https://www.iso.org/standard/84110.html

- **ISO/IEC 12792**: This document defines a taxonomy of information elements to assist AI stakeholders with identifying and addressing the needs for transparency of AI systems. The document describes the semantics of the information elements and their relevance to the various objectives of different AI stakeholders. This document uses a horizontal approach and is applicable to any kind of organization and application involving AI.

  URI: https://www.iso.org/standard/84111.html
- **ISO/IEC TR 24030:2021**: This document provides a collection of representative use cases of AI applications in a variety of domains.

  URI: https://www.iso.org/standard/77610.html
- **ISO/IEC TR 24030 2nd Edition**: This document provides a collection of representative use cases of AI applications in a variety of domains.

  URI: https://www.iso.org/standard/84144.html
- **ISO/IEC 5338**: This document defines a set of processes and associated concepts for describing the life cycle of AI systems based on machine learning and heuristic systems. It is based on ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017 with modifications and additions of AI-specific processes from ISO/IEC 22989 and ISO/IEC 23053:2022. This document provides processes that support the definition, control, management, execution and improvement of the AI system in its life cycle stages. These processes can also be used within an organization or a project when developing or acquiring AI systems. When an element of an AI system is traditional software or a traditional system, the software life cycle processes in ISO/IEC/IEEE 12207:2017 and the system life cycle processes in ISO/IEC/IEEE 15288:2015 can be used to implement that element.

  URI: https://www.iso.org/standard/81118.html
- **ISO/IEC 5339**: This document provides a set of guidelines for identifying the context, opportunities and processes for developing and applying AI applications. It can be used by ISO, IEC, and JTC 1 Technical Committees and Sub-Committees to build on these guidelines when developing standards for AI applications in their areas of interest. The guidelines provide a macro-level view of the AI application context, the stakeholders and their roles, relationship to the lifecycle of the system, and common AI application characteristics, properties and considerations. The guidelines reference, but do not duplicate or overlap, other AI-related standards.

  URI: https://www.iso.org/standard/81120.html
- **ISO/IEC TR 24372:2022**: This document provides an overview of the state of the art of computational approaches for AI systems, by describing: a) main computational characteristics of AI systems; b) main algorithms and approaches used in AI systems, referencing use cases contained in ISO/IEC TR 24030.

  URI: https://www.iso.org/standard/78508.html
- **ISO/IEC TS 4213**: This document specifies methodologies for measuring classification performance of machine learning models, systems and algorithms.

  URI: https://www.iso.org/standard/79799.html
- **ISO/IEC 5392**: This document defines a reference architecture of Knowledge Engineering (KE) in Artificial Intelligence (AI). The reference architecture describes KE roles, activities, constructional layers, components and their relationships amongst themselves and other systems from systemic user and functional views. This document also provides a common KE vocabulary by defining KE terms.

URI: https://www.iso.org/standard/81228.html

- **ISO/IEC TR 17903**: This document surveys machine learning (ML) computing devices, including the ML computing device terminology and characteristics, and existing approaches to the setting and use of characteristics for optimizing ML computing device performance. The information provided in this document is relevant for organizations of all types and sizes.

  URI: https://www.iso.org/standard/85078.html

- **ISO/IEC 38507:2022**: Governance, as an organisation-wide discipline and responsibility, is generally more stable than the systems subject to their direction, accountability, and oversight. Technologies and their related processes constantly change and evolve. Governance processes do not. This document gives only a summary overview of artificial intelligence (AI) and AI technologies. It does not describe or offer any guidance on technical implementation details. This document provides guidance for members of the governing bodies of organizations (which can comprise owners, directors, partners, executive managers, or similar) to ask the right questions regarding AI and thus determine the effective, efficient, and acceptable uses of AI technologies within their organizations.

  URI: https://www.iso.org/standard/56641.html

- **ISO/IEC TS 29119-11**: This document describes testing techniques (including those described in ISO/IEC/IEEE 29119-4) applicable for AI systems in the context of the AI system life cycle model stages defined in ISO/IEC 22989. It describes how AI and ML assessment metrics can be used in the context of those testing techniques. It also maps testing processes, including those described in ISO/IEC/IEEE 29119-2, to the verification and validation stages in the AI system life cycle.

  URI: https://www.iso.org/standard/84127.html

7.12 ISO/IEC JTC 1/SC 29

JTC 1/SC 29 focuses on utilization of AI/ML in multimedia information compression, compressed representations of neural networks for efficient storage and distribution, video coding for computer vision tasks and AI/ML based media processing aspects and systems via network-based media processing.

Table 7-12 – JTC 1/SC 29 deliverables and work items

WG	Reference	Name/Title	Status
WG1	ISO/IEC 6048	JPEG AI Learning based Image Coding system	AWI
WG4	ISO/IEC 15938-13	Information technology – Multimedia content description interface – Part 13: Compact descriptors for visual search	Published 2015
WG4	ISO/IEC 15938-15	Information technology – Multimedia content description interface – Part 15: Compact descriptors for video analysis	Published 2019
WG4	ISO/IEC 15938-17	Information technology – Multimedia content description interface – Part 17: Compression of neural networks for multimedia content description and analysis	FDIS
WG4	ISO/IEC 23090-8	Information technology – Coded representation of immersive media – Part 8: Network based media processing	Published 2020

- **ISO/IEC 6048**: The scope of JPEG AI is the creation of a learning-based image coding standard offering a single-stream, compact compressed domain representation, targeting both

human visualization, with significant compression efficiency improvement over image coding standards in common use at equivalent subjective quality, and effective performance for image processing and computer vision tasks, with the goal of supporting a royalty-free baseline.

URI: https://www.iso.org/standard/81984.html

- **ISO/IEC 15938-13**: This standard specifies an image description tool designed to enable efficient and interoperable visual search applications, allowing visual content matching in images. Visual content matching includes matching of views of objects, landmarks, and printed documents, while being robust to partial occlusions as well as changes in viewpoint, camera parameters, and lighting conditions.

  URI: https://www.iso.org/standard/65393.html

- **ISO/IEC 15938-15**: This standard specifies descriptor technology for search and retrieval applications, i.e., for visual content matching in video. Visual content matching includes matching of views of large and small objects and scenes, with robustness to partial occlusions as well as changes in vantage point, camera parameters and lighting conditions. The objects of interest comprise planar or non-planar, rigid or partially rigid, textured or partially textured objects, but exclude the identification of people and faces. The databases can be large, for example broadcast archives or videos available on the internet. Such applications thus require video descriptors that enable matching with smaller descriptor sizes and shorter runtimes as compared to application enabled by single-frame (still image) descriptors (e.g., CVDS, ISO/IEC 15938-13) in the video domain.

  URI: https://www.iso.org/standard/75399.html

- **ISO/IEC 15938-17**: This standard specifies compressed representation of the parameters/weights of a trained neural network, complementing the description of the network topology in existing (exchange) formats for neural networks. The standard is specified as a toolbox of compression methods, specifying (where applicable) the resulting elements of the compressed bitstream. This standard does not aim to define a custom exchange format, but to propose compressed representations that can be added to existing exchange formats. Hence, the standard also defines a high-level syntax that specifies required metadata elements and the semantics of components of the file. The compression tools described in this standard have been selected and evaluated for neural networks used in applications for multimedia description, analysis and processing. However, they may be useful for the compression of neural networks used in other applications and applied to other types of data.

  URI: https://www.iso.org/standard/78480.html

- **ISO/IEC 23090-8**: The Network-Based Media Processing specification defines the interfaces including both data formats and APIs among the entities connected through the digital networks for media processing. Media processing may refer to AI/ML based media analysis and information extraction, computer vision for media augmentation or any other media processing algorithm and functionality which is deployable at a processing system and having well-defined input/output interfaces. Users can access and configure their operations remotely for efficient processing. The framework describes and manages workflows to be applied to the media data. This process includes uploading of media data to the network, instantiation of the media processing tasks, and configuration of the tasks. The framework enables dynamic creation of media processing pipelines, access of processed media data and metadata in real-time or in a deferred way. The media and metadata formats used between the Media Source, Workflow Manager and Media Processing Entities in a media processing pipeline are also within the scope.

  URI: https://www.iso.org/standard/77839.html

7.13 IEEE SA

IEEE Standards Association (IEEE SA) is a leading consensus building organization that nurtures, develops and advances global technologies, through IEEE. We bring together a broad range of individuals and organizations from a wide range of technical and geographic points of origin to facilitate standards development and standards related collaboration. With collaborative thought leaders in more than 160 countries, we promote innovation, enable the creation and expansion of international markets and help protect health and public safety. Collectively, our work drives the functionality, capabilities and interoperability of a wide range of products and services that transform the way people live, work, and communicate.

Table 7-13 – IEEE deliverables and work items related to AI and ML

Groups	Reference	Name/Title	Status
IEEE	IEEE P7006	Standard for Personal Data Artificial Intelligence (AI) Agent	PAR Approval 2017-03-23
IEEE	IEEE P7007	Ontological Standard for Ethically Driven Robotics and Automation Systems	PAR Approval 2017-03-23
IEEE	IEEE P7008	Standard for Ethically Driven Nudging for Robotic, Intelligent and Autonomous Systems	PAR Approval 2017-06-15
IEEE	IEEE P7009	Standard for Fail-Safe Design of Autonomous and Semi-Autonomous Systems	PAR Approval 2017-06-15
IEEE	IEEE P7010	Wellbeing Metrics Standard for Ethical Artificial Intelligence and Autonomous Systems	PAR Approval 2017-06-15
IEEE	IEEE P7012	Standard for Machine Readable Personal Privacy Terms	PAR Approval 2017-12-06
IEEE	IEEE P7013	Inclusion and Application Standards for Automated Facial Analysis Technology	PAR Approval 2018-05-14
IEEE	IEEE P7014	Standard for Ethical considerations in Emulated Empathy in Autonomous and Intelligent Systems	PAR Approval 2019-06-13
IEEE	IEEE P2755.2	Recommended Practice for Implementation and Management Methodology for Software Based Intelligent Process Automation (SBIPA)	PAR Approval 2019-05-21
IEEE	IEEE P2801	Recommended Practice for the Quality Management of Datasets for Medical Artificial Intelligence	PAR Approval 2018-12-05
IEEE	IEEE P2802	Standard for the Performance and Safety Evaluation of Artificial Intelligence Based Medical Device: Terminology	PAR Approval 2018-12-05
IEEE	IEEE P2807	Framework of Knowledge Graphs	PAR Approval 2017-03-23

Table 7-13 – IEEE deliverables and work items related to AI and ML

Groups	Reference	Name/Title	Status
IEEE	IEEE P2841	Framework and Process for Deep Learning Evaluation	PAR Approval 2019-09-05
IEEE	IEEE P2805.3	Cloud-Edge Collaboration Protocols for Machine Learning	PAR Approval 2019-02-08
IEEE	IEEE P3333.1.3	Standard for the Deep Learning-Based Assessment of Visual Experience Based on Human Factors	PAR Approval 2017-09-28
IEEE	IEEE P3652.1	Guide for Architectural Framework and Application of Federated Machine Learning	PAR Approval 2018-12-05

- **IEEE P7006**: This standard describes the technical elements required to create and grant access to a personalized Artificial Intelligence (AI) that will comprise inputs, learning, ethics, rules and values controlled by individuals.

  URI: https://standards.ieee.org/project/7006.html
- **IEEE P7007**: The standard establishes a set of ontologies with different abstraction levels that contain concepts, definitions and axioms which are necessary to establish ethically driven methodologies for the design of Robots and Automation Systems.

  URI: https://standards.ieee.org/project/7007.html
- **IEEE P7008**: "Nudges" as exhibited by robotic, intelligent or autonomous systems are defined as overt or hidden suggestions or manipulations designed to influence the behaviour or emotions of a user. This standard establishes a delineation of typical nudges (currently in use or that could be created). It contains concepts, functions and benefits necessary to establish and ensure ethically driven methodologies for the design of the robotic, intelligent and autonomous systems that incorporate them.

  URI: https://standards.ieee.org/project/7008.html
- **IEEE P7009**: This standard establishes a practical, technical baseline of specific methodologies and tools for the development, implementation, and use of effective fail-safe mechanisms in autonomous and semi-autonomous systems. The standard includes (but is not limited to): clear procedures for measuring, testing, and certifying a system's ability to fail safely on a scale from weak to strong, and instructions for improvement in the case of unsatisfactory performance. The standard serves as the basis for developers, as well as users and regulators, to design fail-safe mechanisms in a robust, transparent, and accountable manner.

  URI: https://standards.ieee.org/project/7009.html
- **IEEE P7010**: IEEE Project 7010 Well-being Metrics for Autonomous and intelligent Systems is a standard for measuring the impact of artificial intelligence or autonomous and intelligent systems (A/IS) on humans. The overall intent of IEEE P7010 is to supports the outcome of A/IS having positive impacts on human well-being. It is the tenth of a series of standards in the P70xx series, all of which emerged from the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems. The standard is grounded in scientifically valid well-being indices currently in use and based on a stakeholder engagement process. The intent of the standard is to guide product development, identify areas for improvement, manage risks,

assess performance and identify intended and unintended users, uses and impacts on human well-being of A/IS products, services, and systems.

URI: https://standards.ieee.org/project/7010.html

- **IEEE P7012**: The standard identifies/addresses the manner in which personal privacy terms are proffered and how they can be read and agreed to by machines.

  URI: https://standards.ieee.org/project/7012.html

- **IEEE P7013**: The standard provides phenotypic and demographic definitions that technologists and auditors can use to assess the diversity of face data used for training and benchmarking algorithmic performance, establishes accuracy reporting and data diversity protocols/rubrics for automated facial analysis, and outlines a rating system to determine contexts in which automated facial analysis technology should not be used.

  URI: https://standards.ieee.org/project/7013.html

- **IEEE P7014**: This standard defines a model for ethical considerations and practices in the design, creation and use of empathic technology, incorporating systems that have the capacity to identify, quantify, respond to, or simulate affective states, such as emotions and cognitive states. This includes coverage of 'affective computing', 'emotion Artificial Intelligence' and related fields.

  URI: https://standards.ieee.org/project/7014.html

- **IEEE P2755.2**: This recommended practice describes implementation and management approaches and methods for enterprise implementation of Software Based Intelligent Process Automation (SBIPA) technologies. The recommended practice includes the exploration of technology capabilities, development of strategy, product evaluation, platform implementation, management and governance for service providers and end users.

  URI: https://standards.ieee.org/project/2755_2.html

- **IEEE P2801**: The recommended practice identifies best practices for establishing a quality management system for datasets used for artificial intelligence medical device. The recommended practice covers a full cycle of dataset management, including items such as but not limited to data collection, transfer, utilization, storage, maintenance and update. The recommended practice recommends a list of critical factors that impact the quality of datasets, such as but not limited to data sources, data quality, annotation, privacy protection, personnel qualification/training/evaluation, tools, equipment, environment, process control and documentation.

  URI: https://standards.ieee.org/project/2801.html

- **IEEE P2802**: The standard establishes terminology used in artificial intelligence medical device, including definitions of fundamental concepts and methodology that describe the safety, effectiveness, risks and quality management of artificial intelligence medical device. The standard provides definitions using the following forms, such as but not limited to literal description, equations, tables, figures and legends. The standard also establishes a vocabulary for the development of future standards for artificial intelligence medical device.

  URI: https://standards.ieee.org/project/2802.html

- **IEEE P2807**: This standard defines the framework of knowledge graphs (KGs). The framework describes the input requirement of KG, construction process of KG, i.e., extraction, storage, fusion and understanding, performance metrics, applications of KG, verticals, KG related artificial intelligence (AI) technologies and other required digital infrastructure.

  URI: https://standards.ieee.org/project/2807.html

- **IEEE P2841**: This document defines best practices for developing and implementing deep learning algorithms and defines a framework and criteria for evaluating algorithm reliability and quality of the resulting software systems.

  URI: https://standards.ieee.org/project/2841.html

- **IEEE P2805.3**: This standard specifies the collaboration protocols of enabling machine learning on the edge computing node with support from industrial clouds. This standard provides implementation reference of machine learning upon lower powered, cheaper, embedded devices, a specific hardware-based method of accepting the introduced machine learning models and then online optimization, i.e., comparing the models with incoming live data.

  URI: https://standards.ieee.org/project/2805_3.html

- **IEEE P3333.1.3**: This standard defines deep learning-based metrics of content analysis and quality of experience (QoE) assessment for visual contents, which is an extension of Standard for the Quality of Experience (QoE) and Visual-Comfort Assessments of Three-Dimensional (3D) Contents Based on Psychophysical Studies (IEEE STD 3333.1.1)) and Standard for the Perceptual Quality Assessment of Three Dimensional (3D) and Ultra High Definition (UHD) Contents (IEEE 3333.1.2). The scope covers the following. Deep learning models for QoE assessment (multilayer perceptrons, convolutional neural networks, deep generative models); Deep metrics of visual experience from High Definition (HD), UHD, 3D, High Dynamic Range (HDR), Virtual Reality (VR) and Mixed Reality (MR) contents; Deep analysis of clinical (electroencephalogram (EEG), electrocardiogram (ECG), electrooculography (EOG), and so on) and psychophysical (subjective test and simulator sickness questionnaire (SSQ)) data for QoE assessment; Deep personalized preference assessment of visual contents; Building image and video databases for performance benchmarking purpose if necessary

  URI: https://standards.ieee.org/project/3333_1_3.html

- **IEEE P3652.1**: Federated learning defines a machine learning framework that allows a collective model to be constructed from data that is distributed across data owners. This guide provides a blueprint for data usage and model building across organizations while meeting applicable privacy, security and regulatory requirements. It defines the architectural framework and application guidelines for federated machine learning, including: 1) description and definition of federated learning, 2) the types of federated learning and the application scenarios to which each type applies, 3) performance evaluation of federated learning, and 4) associated regulatory requirements.

  URI: https://standards.ieee.org/project/3652_1.html

7.14 Khronos Group

The Khronos group is the organization that develops open standards for software and hardware in areas of graphics, parallel computing, and etc. In December 2017, the Khronos Group announced the Neural Network Exchange Format (NNEF) standard for artificial intelligence. Currently, the NNEF 1.0.5 standard document is available on the Khronos website with providing open source tools related to NNEF.

NOTE – Khronos members page URI: https://www.khronos.org/members/list.

Table 7-14 – Khronous Group deliverables and work items related to AI and ML

WG	Reference	Title	Status
NNEF	NNEF 1.0.5	Neural Network Exchange Format (NNEF)	Published 2022-02

- **NNEF 1.0.5**: NNEF is a data format for exchanging information about (trained) neural networks. Exchanging such information in a standardized format has become inevitable with the spreading of deep learning, as neural networks found their way from academic research to real-world industrial applications. With the proliferation of open-source deep learning frameworks and hardware support emerging for the acceleration of neural networks, the field faces the problem of fragmentation, as different accelerators are compatible with different frameworks. The goal of NNEF is to provide a standard platform for connecting accelerated neural network execution engines and available deep learning tools. Ideally, neural networks trained in deep learning frameworks would be exported to NNEF, and neural network accelerator libraries could consume it without worrying about compatibility with all deep learning frameworks.

  URI: https://registry.khronos.org/NNEF/

7.15 W3C

The mission of the World Wide Web Consortium (W3C) is to lead the Web to its full potential by creating technical standards and guidelines to ensure that the Web remains open, accessible, and interoperable for everyone around the globe. W3C well-known standards HTML and CSS are the foundational technologies upon which websites are built. W3C works on ensuring that all foundational Web technologies meet the needs of civil society, in areas such as accessibility, internationalization, security, and privacy. W3C also provides the standards that undergird the infrastructure for modern businesses leveraging the Web, in areas such as entertainment, communications, digital publishing, and financial services.

NOTE – W3C information page URI: https://www.w3.org/.

Table 7-15 – W3C deliverables and work items related to AI and ML

WG	Reference	Title	Status
WebML WG	WebNN API	Web Neural Network API	Working Draft

- **WebNN API**: The Web Neural Network API describes a dedicated low-level API for neural network inference hardware acceleration. It defines a web-friendly hardware-agnostic abstraction layer that makes use of Machine Learning capabilities of operating systems and underlying hardware platforms without being tied to platform-specific capabilities. The abstraction layer addresses the requirements of key Machine Learning JavaScript frameworks and also allows web developers familiar with the ML domain to write custom code without the help of libraries. A complementary Model Loader API defines a higher-level abstraction targeting primarily web developers.

  URI: https://www.w3.org/TR/webnn/

8 Gap analysis in artificial intelligence standardization

This clause provides a matrix for gap analysis and the related standardization activities with artificial intelligence in order to identify standardization gaps.

The matrix is composed of two axes. The horizontal axis describes document categories which cover the subject of applications as follows:

- **General, definition**: the standard which provides general descriptions or terms and definitions of the technology;
- **Requirements, use cases**: the standard which provides use cases and derived general/functional requirements;

- **Architecture**: the standard which provides reference architecture;
- **API, interface, profile**: the standard which provides common interface, API and/or its profile;
- **Data model, format, schema**: the standard which provides data model or protocol including scheme and/or its encoding format;
- **Others** (e.g., guidelines, technical reports).

The vertical axis describes the related technologies for supporting artificial intelligence as follows:

- **Foundational**: the common concept and terms of artificial intelligence and machine learning;
- **Data**: data handling and management for artificial intelligence including quality and life cycle;
- **Trustworthiness**: approaches to establish the trustworthiness in artificial intelligence through transparency, explainability, robustness, safety, and etc.;
- **Ethical/Societal Concerns**: considerations for the impact of artificial intelligence to human autonomy, society, and regulation;
- **Computational characteristics**: methods and approaches to develop and measure the computational characteristics in artificial intelligence including cost, performance, and etc.;
- **Governance**: process and guidance for using or applying the artificial intelligence to organizations, and community;
- **AI Applications:** a technical and industrial scope of artificial intelligence application;
  - Computing: computing methods and applications in the computing environment including cloud computing, edge computing, and etc.;
  - Network & Telecommunications (5G/6G): applications and service for/in the network and telecommunications;
  - Smart City & IoT: applications and service for/in the smart city & IoT;
  - Healthcare: applications and service for/in the healthcare;
  - Autonomation: applications and service for/in the automation including robots, automated vehicle, factory, and etc.;
  - Multimedia: applications and service for/in the multimedia;
  - Others: applications and service for/in technical domains other than the above domains.

NOTE 1 – The items on the horizontal axis are not subordinated to the different technologies.

NOTE 2 – The items on the vertical axis can be modified with technology change.

NOTE 3 – A standard has more than one location on the matrix. In the case that one standard is included in multiple document categories (horizontal axis) or related technologies (vertical axis), it can be mapped several times.

Table 8-1 shows the standardization matrix related to artificial intelligence.

Table 8-1 – Standardization matrix of artificial intelligence

	General/ Definition	**Requirement/ Use case**	**Architecture**	**API, Interface and its profile**	**Data model, format, schema**	**Others (e.g., guideline)**
Foundational	ISO/IEC 22989 ISO/IEC 23053 ISO/IEC 5338	ISO/IEC TR 24030:2021	ISO/IEC 23053	W3C WebNN API	NNEF 1.0.3	ISO/IEC 42001 ISO/IEC 5339, IEEE P2841

Table 8-1 – Standardization matrix of artificial intelligence

		General/ Definition	Requirement/ Use case	Architecture	API, Interface and its profile	Data model, format, schema	Others (e.g., guideline)
Data		ISO/IEC 5259-1	ISO/IEC 5259-2, ISO/IEC 5259-3			ISO/IEC 5259-4	L.1305, TR.sgfdm, X.gdsml, ISO/IEC 24668, ISO/IEC 5259-5, ISO/IEC 8183
Trustworthiness		ISO/IEC 23894, ISO/IEC TR 24027:2021, ISO/IEC TR 24028:2020, ISO/IEC TR 24029-1:2021, ISO/IEC TR 5469, ISO/IEC TS 6254 ISO/IEC 5471 ISO/IEC TS 8200 ISO/IEC TS 12791 ISO/IEC 12792 ISO/IEC TS 29119-11	ISO/IEC AWI 24029-2 ISO/IEC 25059	ISO/IEC AWI TR 5469			XSTR-SEC-AI, ISO/IEC 25059
Ethical/Societal Concerns		ISO/IEC TR 24368	E.AIQ	IEEE P7006,	IEEE P7012	IEEE P7013	X.Sup37, IEEE P7010, IEEE P7014
Computational characteristics		ISO/IEC TR 24372:2022, ISO/IEC 17903, IEEE P2807		ISO/IEC 5392			ISO/IEC TS 4213
Governance		ISO/IEC 38507:2022					
AI Applications	**Computing**	F.748.13	Y.3531, F.748.13, F.AICP-GA, F.748.21, F.FML-TS-FR, Q.5001, M.rfmls	F.748.13, F.748.20	F.748.12	IEEE P2805.3	F.748.11, F.748.17, F.AI-CPP, IEEE P3652.1
	Network & Telecommunications (5G/6G)	Y.3180, Y.3654, Y.3174, Y.3176, Y.3182, M.3080	Y.3170, Y.QKDN-ml-fra, Y.IMT2020-DJLML, Y.ML-IMT2020-MLFO, Y.3181, Q.IMT2020-SAO, M.3381, M.3382, M.rla-AI, M.rmnoc-AI, M.rsca, M.rsmca, M.rODFos	Y.3172, Y.3175, Y.3115, Y.3177, Y.3178, Y.3173, Y.3181, Y.ML-IMT2020-VNS, F.CDN-AINW, J.1600, Q.3646, Q.IMT2020-SAO	E.475, Q.5023, Q.5024, Q.5025, Q.3646, Q.IMT2020-SAO, M.il-AITOM, M.ilef-AITOM, M.tsm-rest, M.la-AI-ia		Y.Sup55, Y.Sup70, L.Sup43, P.1402, M.il-AITOM, M.rsca, M.ilef-AITOM

Table 8-1 – Standardization matrix of artificial intelligence

		General/ Definition	Requirement/ Use case	Architecture	API, Interface and its profile	Data model, format, schema	Others (e.g., guideline)
	Smart City & IoT		Y.RA-FML, J.1611	Y.4470, Y.CDML-arc, Y.RA-FML, Y.AI-DECCS			L.Sup41, Y.Sup63
	Healthcare	F.Med-Data-QC, IEEE P2802	H.AI-SaMD-Req, IEEE P2801	HSTP.Med-AI-CCTA			IEEE P2801, IEEE P2802
	Autonomation	IEEE P7007, IEEE P7008	F.749.13, F.749.4, F.AI-RPAS		IEEE P7009		IEEE P2755.2
	Multimedia	ISO/IEC 6048	F.742.1, F.AI-SCS, F.746.13, F.ADT4MM, F.AI-MKGDS, F.AI-RSRSreqs, F.REAIOCR, P.SAMD, J.pcnp-char, ITU-R BT.2447-2	FSTP-ACC-AI, F.748.19, J.1302	F.746.11, H.862.5, ISO/IEC 15938-13, ISO/IEC 15938-15, ISO/IEC 15938-17, IEEE P7013, IEEE P3333.1.3	ISO/IEC 23090-8	P.565, P.565.1, P.Sup28, ITU-R Question 144/6
	Others (e.g, blockchain, customer service)	F.Sup4	F.746.16, F.747.11, F.747.12, F.AI-SF				L.Sup42, L.Sup53, L.Sup48, E.AIQ

Appendix I

ITU-T Focus Group activities in AI fields

In ITU-T, Focus Groups are created to work with an ITU-T Study Group as a parent body. Focus Groups provide stand-alone Focus Group deliverables (e.g., Technical Specifications or Technical Reports), which may be proposed to the Study Groups for progression into traditional ITU-T products (e.g., Recommendations and Supplements). The difference between Study Groups and Focus Groups is that Focus Groups can be created very quickly and are usually short-lived.

I.1 ITU-T FG-AI4AD (This Focus Group was terminated in 2022-09)

The FG-AI4AD (Focus Group on AI for autonomous and assisted driving) supports standardization activities for services and applications enabled by AI systems in autonomous and assisted driving. The parent group for FG-AI4AD is ITU-T SG16.

Table I.1 lists the ITU-T FG-AI4AD deliverables and work items related to artificial intelligence and machine learning.

Table I.1 – ITU-T FG-AI4AD deliverables and work items

Sub-group	Reference	Title	Status
–	TR01	Technical Report on automated driving safety data protocol – Specification	Published
–	FGAI4AD-02	Technical Report on "Automated driving safety data protocol – Ethical and legal considerations of continual monitoring"	Published
–	TR03	Technical Report on automated driving safety data protocol – Practical demonstrators	Published
	TR04	Draft Technical Report on "Automated driving safety data protocol – Public safety benefits of continual monitoring"	Draft

- **TR01**: In the context for FG-AI4AD, leading measures for behavioural evaluation are expected to require data which acts as input to metrics whose results can be compared against thresholds. The scope of this report is limited to the specification of the data required as input to the expected metrics and related thresholds. Specification of metrics and thresholds are out of scope but may be referenced to provide context for the value of, or requirement for, specified data. The real-time behavioural assessment is specifically targeted at monitoring, which takes place post-hoc (after the event). Adopting a post-hoc assessment of the automated or assisted driving software ensures the outcomes of decisions and actions taken with reference to the road traffic situation. The real-time behavioural assessment is not designed to be used by the automated or assisted driving software within the situational risk assessment or path-planning process e.g., the real-time behavioural assessment is not designed to prevent a near-miss event from occurring, its purpose is to ensure the near-miss event can be detected, recorded, investigated and used to improve safety in the future. However, any triggers, generated as metrics cross specified thresholds, are published in real-time and may be consumed by the automated or assisted driving software to enhance safety e.g., notification of a near-miss event may be considered within minimal risk manoeuvre decision-making which may consider it an appropriate response to the endangerment of other road users. The scope of the data specification within technical report is to define the minimum set of data required for making a meaningful safety assessment of driving

behaviour whilst acknowledging the need for the protection of privacy and intellectual property.

- **FGAI4AD-02**: The scope of this Technical Report will cover ethical and legal considerations of continual monitoring. It will describe the public's justified expectations of performance of these systems and the impact of the public's justified expectations in the context of product liability.
- **TR03**: The expectation is that ITU-T Recommendations generated by FG-AI4AD activities should be:
  - Globally applicable and globally comparable
  - Independent from AV software architecture
  - Flexible to implementation software and hardware
  - Flexible to hosting on-board the vehicle or off-board the vehicle at the edge or in the cloud
  - Provide a framework for assessment of performance but enable individual entities to set acceptance thresholds for performance
  - Policy agnostic – meaning the implementing entity may include; self-certification, enhanced telematics insurance, independent safety organisation, government regulator or other.
  - Applicable to both real-world and virtual-world environments
  - Sensitive to the cost of implementation.

  The practical demonstrations of the proposed behavioural evaluation showcase the benefits of standardised field monitoring of assisted and automated vehicles and the value of continual validation of safety performance to building public trust in the future of mobility.
- **TR04**: The scope of this Technical Report covers the public safety benefits of Automated Driving Safety Data Protocol and the specific approach to the continual monitoring of driving behaviour exhibited by autonomous and assisted driving systems in the real-world. It will describe the public's justified expectations of performance of these systems, the benefits of risk-based evaluation and the expected impact on public liability.

I.2 ITU-T FG-AI4EE

The FG-AI4EE (Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies) identifies the standardization needs to develop a sustainable approach to AI and other emerging technologies including automation, augmented reality, virtual reality, extended reality, smart manufacturing, industry 5.0, cloud/edge computing, nanotechnology, 5G, among others. The FG-AI4EE established by ITU-T SG5.

Table I.2 lists the ITU-T FG-AI4EE deliverables and work items related to artificial intelligence and machine learning.

Table I.2 – ITU-T FG-AI4AD deliverables and work items

Sub-group	Reference	Title	Status
WG1	D.WG1-01	Standardized Glossary of Terms	–
WG1	D.WG1-02	Scorecard to identify enhanced eco-friendly business processes	–
WG1	D.WG1-03	Solution scorecard on environmental behavioral influencers	–

Table I.2 – ITU-T FG-AI4AD deliverables and work items

Sub-group	Reference	Title	Status
WG1	D.WG1-04	List of KPIs/metrics	Agreed on 08 April 2021
WG1	D.WG1-05	Reporting templates on AI, AR and ML	–
WG1	D.WG1-06	High-Level Qualitative Impact Matrix of Artificial Intelligence and Blockchain on Sustainable Development Goals and on environmental efficiency	–
WG1	D.WG1-07	Visions of Best Practices on Artificial Intelligence and Blockchain in 2025	–
WG1	D.WG1-08	Connecting Environmental Efficiency of Digital Technologies to the Sustainable Development Goals (SDGs)	–
WG1	D.WG1-09	A method for Intuitive Human interaction with data model (ML & AI etc.)	Agreed on 08 April 2021
WG1	D.WG1-10	Guidelines on applying U4SSC KPIs in a digital twin city using ML, AR & AI for better climate mitigation solutions	–
WG1	D.WG1-11	Best Practices for Graphical Digital Twins of Smart Cities	–
WG2	D.WG2-01	Environmental Impact self-check assessment	–
WG2	D.WG2-02	Computer Processing, Data management and Energy perspective	–
WG2	D.WG2-03	Requirements on energy efficiency measurement models and the role of AI and big data	Agreed on 08 April 2021
WG2	D.WG2-04	Guidelines on Evaluating and Measuring the Impacts of Artificial Intelligence and Blockchain on Environmental Efficiency	–
WG2	D.WG2-05	Guidelines on Energy Efficient Blockchain Systems	Agreed on 08 April 2021
WG2	D.WG2-06	Assessment of Environmentally Efficient Data Centre and Cloud Computing in the framework of the UN Sustainable Development Goals (SDGs)	–
WG3	D.WG3-01	Guidelines on the implementation of eco-friendly criteria for AI and other emerging technologies	–
WG3	D.WG3-02	Smart Energy Saving of 5G Base Station: Based on AI and other emerging technologies to forecast and optimize the management of 5G wireless network energy consumption	Agreed on 08 April 2021
WG3	D.WG3-03	Application of AI technology in improving energy efficiency of telecom equipment rooms and Internet Data Centre infrastructure	–
WG3	D.WG3-04	Methodology for Supporting the Implementation of Artificial Intelligence and Blockchain Solutions at the Government Level	–
WG3	D.WG3-05	Best Practice Catalogue on Environmentally Efficient Artificial Intelligence and Blockchain Application	–

Table I.2 – ITU-T FG-AI4AD deliverables and work items

Sub-group	Reference	Title	Status
WG3	D.WG3-06	Guidelines on the Environmental Efficiency of 5G Usage in Smart Water Management	–
WG3	D.WG3-07	Guidelines on the Environmental Efficiency of Machine Learning Processes in Supply Chain Management	Agreed on 08 April 2021

- **D.WG1-01**: This document will contain a dictionary of common terms and phrases used in the Focus Group's deliverables that will help readers to have common definitions and frames of reference.
- **D.WG1-02**: This document will provide the following:
  - Impact assessment document to help organizations quantify their environmental impact on how they conduct work;
  - Rating system so that organizations can self-assess how much positive or negative impact they are creating;
  - Guidelines on finding more environmentally friendly practices as substitutes for a business process/function.
- **D.WG1-03**: This document will provide a scoring system for organizations to measure how much positive impact they have created (internally and/or externally) on individuals who have incorporated more eco-friendly behaviours and practices in their regular activities.
- **D.WG1-04**: The document will define how environmentally sensitive issues could benefit from Artificial Intelligence (AI), Machine Learning (ML), and other emerging technologies, by providing a set of standard measurements and definitions in the form of a list of Key Performance Indicators (KPIs)/metrics. This KPIs system will focus on finding indicators which are easy to measure and give a broad range of coverage. This system will be designed for easy and simple use by Small and Medium-Sized Businesses (SMBs) and other smaller organizations. Therefore, a set of maximum 50 indicators will be defined. Whenever possible, solutions will rely on existing best practices and globally respected sources.
- **D.WG1-05**: This document will generate a set of standard reporting templates/dashboards to visualize data produced from technology solutions such as AI, Augmented Reality (AR) and ML, that employ defined eco-friendly practices. This document will aim to display the results gained from D.WG1-04 in an instinctive way. The graphical interface will share a design language with D.WG1-09 and results may be used in D.WG1-10 and D.WG1-11.
- **D.WG1-06**: This document will contain a set of high-level impact matrix that supports policymakers, operators and other relevant stakeholders in assessing the implication of different AI and blockchain solutions. The objective of the matrix is to provide:
  - The necessary tools for relevant stakeholders to determine the AI and blockchain solutions with the highest impacts, allowing them to prioritize solutions and design possibilities that are aligned closest to the values of the Sustainable Development Goals;
  - The necessary tools for relevant stakeholders to determine the AI and blockchain solutions with the highest impacts, allowing them to prioritize solutions and design possibilities necessary to improve the environmental performance of AI and blockchain.
- **D.WG1-07**: This document will discuss the vision of best practices on artificial intelligence and blockchain in 2025. AI and blockchain are revolutionizing every aspects of society. The capability and performance of these technologies will substantially be improved and expanded in the next decades, from enhanced AI prediction, rising AI assistant and

automation in all aspects of operation, boosting transparency, further decentralized networks, further blending between physical and digital computing, further security concerns and more. It is crucial to anticipate the policy, procedure and environmental frameworks needed to ensure the sustainability and accessibility of these technologies.

- **D.WG1-08**: This document is intended to raise awareness on the growing concern over the environmental impacts of digital technologies. The double-edged sword nature of digital technologies on the one hand offer promising solutions to resolve the most pressing global issues from climate change, social equality, preserving biodiversity and more. Yet, more and more data centres are being built to process data. In order to achieve the SDGs, it is crucial to start reducing the carbon footprint of these technologies. This document will highlight the 5 ways environmental efficiency of digital technologies are directly connected to the SDGs and will consider the policy needs of environmental efficiency of digital technologies. This document will not consider the energy consumption of digital technologies.
- **D.WG1-09**: This document will demonstrate a method for elegantly connecting complex data, including (ML & AI) into a system level solution designed for humans, allowing communication between man and machine which cultivates mutual enhancement. Interfacing humans to data is key to using its power to accelerate the speed with which we can solve our environmental problems. Machines are very powerful at working with data including ML & AI. Humans need to interact effectively with this information. This means building it into an interface which is manageable and allows comparison between data sources. The aim is to create a system for adding many data sets and being able to compare these with one another in a way machines and humans can understand. This could have a measurement score system based on a "traffic light" concept covering environmental factors, for example:
  - Heating/cooling & energy consumption
  - Impact on plant and animal life
  - Carbon & other air-based emissions
  - Waste & water management

  Increasing amounts of the world's population live in cities. This is also the source of many of our environmental key pressures for climate change. This group will therefore use cities as a model for this report.
- **D.WG1-10**: This document will provide guidelines on how to use the United Nations "United for Smart Sustainable Cities" (U4SSC) Key Performance Indicator (KPI) system in a digital twin city, to identify high impact climate mitigation solutions. It will include a set of case studies showing examples of projects where emerging technology, such as ML, AR & AI, has or could have been used to reduce the negative impact of climate change in cities. It will contain a set of online video and testimonials to illustrate those examples.
- **D.WG1-11**: This report-based example will focus on how emerging technology solutions can have most impact on environmental issues within cities. The data used will be based on information gained from the United Nations "United for Smart Sustainable Cities" (U4SSC) reports. The focus will be on comparing results from different cities and looking at the areas where cities gained low results. What are the emerging technologies that could improve these results? How should the data be structured to improve results?
- **D.WG2-01**: This document will contain a scorecard for an organization to grade itself on how well they have built a product or service based upon environmental impacts. It will define a set of standard areas to be scored (e.g., power consumption, water consumption, etc.) as well as standardized scoring criteria so that scoring is measured the same across industries and products/services.

- **D.WG2-02**: We live in an era that is defined the "Cambrian explosion of data", and advanced data analytics (Deep and Machine Learning, mainly) is ready to drive us in this world. The volume of data produced hourly and daily is enormous and is intended to dramatically increase in the next years –just consider the IoT revolution. Data centres of the future will be data driven. A clear limiting factor is their energy consumption. Presently, data centres consume more power than several European Union Member States, producing a larger footprint than all aircrafts. For these reasons, innovative strategies and technological solutions are needed to allow a scalability that is essential to enable and support the AI revolution. The document aims at recognizing important areas of innovation addressing this issue and facilitating the AI uptake by our Society.
- **D.WG2-03**: This document will provide an overview of existing evaluation metrics and methodologies for energy efficiency and the role of Information and Communications Technologies (ICTs), based on a gap analysis of existing relative standards and on a detailed and systematic literature review on corresponding assessment models:
  - Resources: scientific databases (e.g., sciencedirect, scopus, etc.)
  - Keywords: "energy efficiency" AND "assessment" AND "model" AND "big data" AND "AI"
- **D.WG2-04**: This document will contain a framework for evaluating and measuring the impacts of AI and blockchain on environmental efficiency. The objective of the framework is to support operators and other related stakeholders in assessing the environmental impacts of AI and blockchain. The results aim to inform them to make better environmental decisions, improve the operational quality and efficiency of the two technologies, and identify a clear pathway for AI and blockchain stakeholders to align their values with the visions of the United Nations Sustainable Development Goals.
- **D.WG2-05**: This document will describe the rationale, principles on transitioning from Proof of Work to Proof of Stake in blockchain systems. In contrast to Proof of Work, the Proof of Stake model introduces 'validators' to add the next block, effectively eliminating the incentive to compete to be the first miner to solve the puzzle that is given to them in order to obtain the rewards. This document will consider also a comparison of traditional implementation of algorithm with respect to the new proposed implementation.
- **D.WG2-06**: This document will conduct a more comprehensive environmental sustainability assessment with a multi-impact and life cycle approach. It includes the following aspects:
  - An assessment of environmental impacts of data centre and cloud computing through a life cycle approach
  - An assessment of the current sustainability matrixes of data centre and cloud computing
  - An analysis on the links to the 17 SDGs with breakdown indicators being evaluated
  - A gap analysis of policies that facilitating the development of environmentally efficient data centre and cloud in support of the achievement of the Paris agreement and the UN SDGs
  - Policy recommendations
  - A section of a gap analysis on existing standards (e.g., [ITU-T L.1302] Assessment of energy efficiency on infrastructure in data centres and telecom centres, [ITU-T L.1351] Energy efficiency measurement methodology for base station sites, [ITU-T L.1502] Adapting information and communication technology infrastructure to the effects of climate change etc.) could be developed upon the availability of expertise, with potential adoption by ITU as sector standards.

- **D.WG3-01**: This document will define a set of guidelines for organizations to review their implementation and build process to assess the technological impact to environmental factors like:
  - Materials used;
  - Energy consumed;
  - Water consumed;
  - Waste generated.

  These guidelines will serve as common factors, not a comprehensive list, for technologists to consider as they design and build any piece of technology.
- **D.WG3-02**: The energy consumption of 5G base stations is three to four times that of 4G. With the help of AI, intelligent pattern recognition, deep learning prediction, and automatic hierarchical control of energy-saving scenarios could be achieved, the customer-oriented cross-network 5G base station intelligent energy-saving capability could be established. This document will establish model algorithms for intelligent identification of base station energy saving scenarios, business load forecasting, etc.; It will set up the basic framework scheme of perception-oriented hierarchical base station energy saving strategy; develop basic functions of 5G base station smart energy-saving experimental system.
- **D.WG3-03**: Most of the existing equipment rooms do not have the full ability to identify indoor temperature distribution. Therefore, they are unable to analyse power consumption in real-time and make appropriate and timely adjustments. As a result, it causes energy to be wasted. This document will cover how AI-based power management capabilities can:
  - Collect data in telecom equipment rooms and IDC infrastructure;
  - Analyse the historical power consumption and real-time parameters of the target equipment room;
  - Train an intelligent model; and
  - Make reasonable adjustments to the equipment room air- conditioning and temperature, so as to achieve energy saving in the equipment rooms and IDC infrastructure.
- **D.WG3-04**: This document will contain a four-step methodology for supporting policymakers and other government entities in implementing artificial intelligence and blockchain solutions. Policymakers play a decisive role in shaping the environment in which AI and blockchain applications operate in. This four-step methodology will contain a set of guidelines that allow governments to take the initiative in determining the environmental efficiency aspect of AI and blockchain application. It will consider the global market needs of these technologies in the coming decades, and in particular the way in which they can be aligned with visions and values of the Sustainable Development Goals (SDGs). The outcome will allow policymakers to foster the development of AI and blockchain related applications in a more sustainable and efficient manner. The results will also allow government entities to develop a strategic vision on their application, serving as the foundation for collaboration with other stakeholders.
- **D.WG3-05**: This document will contain a list of best practices on artificial intelligence and blockchain applications that have taken environmental efficiency into full consideration. The growing energy demands of AI and blockchain is directly contributing to carbon emissions. The best practices contained in this specification will support relevant stakeholders in making better environmental decisions and reduce the environmental footprint of these technologies. The best practices also act as benchmarking tools that allow operators and service providers to assess their own operation, improve process management and learn from the industry leaders.

- **D.WG3-06**: This guidance document is intended to support researchers and practitioners in measuring and improving the environmental efficiency of IoT technologies, in particular 5G connectivity in water management systems. The requirements, recommended processes, best practices and other considerations regarding the measurement and verification of environmental impact/efficiency contained in this document are developed based on inputs from leading academic experts and industry leaders. These requirements provide general guidelines applicable to the use of IoT connectivity of 5G. Other stakeholders may also utilize this guidance to gain new understanding on the environmental impacts from the use of IoT and 5G to connect and enable further networked sensors and applications to manage water supplies and reduce water loss.
- **D.WG3-07**: This guidance document is intended to support ML researchers and operators to measure and improve the environmental efficiency of ML use in supply chain management. The requirements, recommended processes, best practices and other considerations regarding the measurement and verification of environmental impact/efficiency contained in this document are developed based on inputs from leading academic experts and industry leaders. These requirements provide general guidelines applicable to the use of ML in supply chain management. Other stakeholders may also utilize this guidance to gain new understanding on the environmental impacts of ML use in supply chain management. Big data impact will also be considered as well Blockchain and the circular economy.

I.3 ITU-T FG-AI4H

The FG-AI4H (ITU/WHO Focus Group on Artificial Intelligence for Health) works in partnership with the World Health Organization (WHO) to establish a standardized assessment framework for the evaluation of AI-based methods for health, diagnosis, triage or treatment decisions. Participation in the FG-AI4H is free of charge and open to all. The group was established by ITU-T Study Group 16 at its meeting in Ljubljana, Slovenia, 9-20 July 2018.

Table I.3 lists the ITU-T FG-AI4H deliverables and work items related to artificial intelligence and machine learning. Figure I.1 demonstrates the structure and relationship of these deliverables.

Table I.3 – ITU-T FG-AI4H deliverables and work items

Study group	Reference	Title	Status
–	DEL0	Overview of the FG-AI4H deliverables	–
–	DEL0.1	Common unified terms in artificial intelligence for health	–
–	DEL01	AI4H ethics considerations	–
–	DEL02	AI4H regulatory best practices	–
–	DEL02.1	Mapping of IMDRF essential principles to AI for health software	–
–	DEL02.2	Good practices for health applications of machine learning: Considerations for manufacturers and regulators	–
–	DEL03	AI4H requirement specifications	–
–	DEL04	AI software life cycle specification	–
–	DEL05	Data specification	–
–	DEL05.1	Data requirements	–
–	DEL05.2	Data acquisition	–
–	DEL05.3	Data annotation specification	–

Table I.3 – ITU-T FG-AI4H deliverables and work items

Study group	Reference	Title	Status
–	DEL05.4	Training and test data specification	–
–	DEL05.5	Data handling	–
–	DEL05.6	Data sharing practices	–
–	DEL06	AI training best practices specification	–
–	DEL07	AI for health evaluation considerations	–
–	DEL07.1	AI4H evaluation process description	–
–	DEL07.2	AI technical test specification	–
–	DEL07.3	Data and artificial intelligence assessment methods (DAISAM) reference	–
–	DEL07.4	Clinical evaluation of AI for health	–
–	DEL07.5	Assessment platform	–
–	DEL09	AI4H applications and platforms	–
–	DEL09.1	Mobile Applications	–
–	DEL09.2	Cloud-based AI applications	–
–	DEL10.0	AI4H use cases: Topic Description Documents	

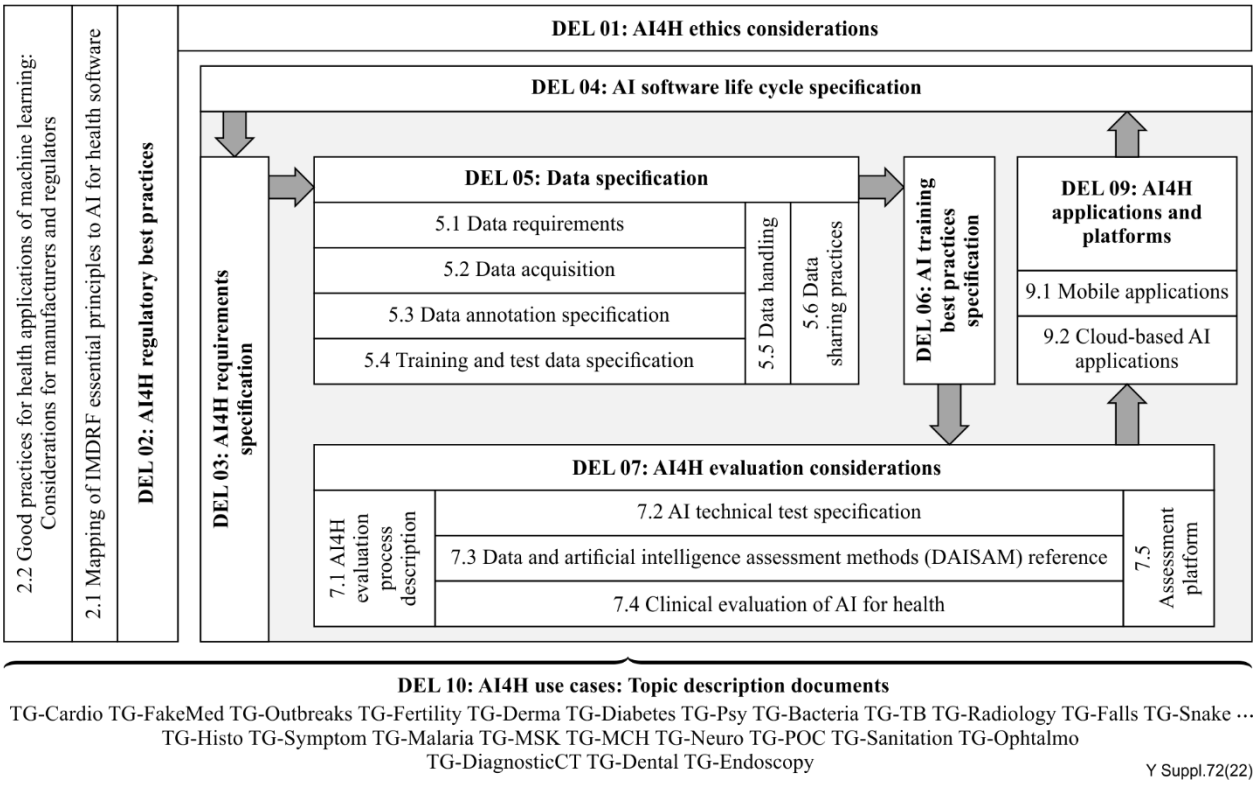

Figure I.1 – FG-A4H Deliverables structure

- **DEL0**: This deliverable provides an overview of the structure, relationship, progress, and corresponding collaborations of all FG-AI4H deliverables, including 9 generalized specifications on ethics, regulatory, requirement, data, training, evaluation, application, etc., and 20 topic description documents on specific use cases with corresponding AI/ML tasks, to establish a standardized assessment framework for the evaluation of AI-based methods for health.
- **DEL0.1**: This deliverable of the FG-AI4H contains a glossary with agreed terminology in artificial intelligence (AI) for health, in order to promote the consistent and harmonized use of important AI for health terms across the various deliverables as well as across the different disciplines involved in this cross-disciplinary field.
- **DEL01**: This document provides consideration on the ethical issues and challenges posed by AI, including ethical, legal and social concerns, e.g., regarding equitable access, privacy, appropriate uses and users, liability and bias and inclusiveness, to develop harmonised ethics guidance for the design and implementation of AI in global health.
- **DEL02**: This document is aimed as a general, high-level, and nonexclusive overview of key regulatory considerations' topic areas delivered by the WG-RC on AI for health. It highlights some of the key regulatory principles and concepts, such as risk/benefit assessments and considerations for the evaluation and monitoring of the performance of AI solutions.
- **DEL02.1**: This document contains a mapping of the International Medical Device Regulators Forum (IMDRF) Essential Principles to related aspects of AI for health software.
- **DEL02.2**: This document defines a set of guidelines intended to serve the AI solution developers/manufacturers on how to do conduct a comprehensive requirements analysis and streamline the conformity assessment procedures to ensure regulatory compliance for the AI-based Medical Devices (AI/ML-MD).
- **DEL03**: This document defines the System Requirement Specifications (SyRS) that explains the informational, functional, behavioural and operational aspects of a generic AI for health (AI4H) system to help identify, control and track various requirements and changes to those requirements during the AI4H system development lifecycle.
- **DEL04**: This document includes the identification of all standards and best practices that are relevant for the AI for health software life cycle. b) discussion of the existing limits/gaps and need for action. c) Identification of life cycle steps that are specific/characteristic for AI for health software. d) Specification of the AI for health software life cycle and definition of best practices for the different life cycle steps.
- **DEL05**: This document combines a set of four separate deliverables as an umbrella, which address six important aspects related to data specification when used for artificial intelligence (AI) and machine learning (ML) models/methods for health purposes.
- **DEL05.1**: This document lists acceptance criteria for data submitted to the FG-AI4H and states the governing principles and rules, which will facilitate the establishment of the undisclosed test dataset as the core of the benchmarking framework for AI for health methods and make sure that the test dataset will not be made accessible to the AI developers.
- **DEL05.2**: This document presents a framework for public healthcare data acquisition and management model based on standard protocol for its easy adoption by any country or international health organizations, to bridge the gap in developing an integrated and comprehensive framework that addresses the use of EHR in a standardized way.
- **DEL05.3**: This document provides general guidance on data annotation specification, including definitions, framework, standard operating procedure (SOP), inconsistency criteria, recommended metadata, etc. to improve the data annotation quality for machine learning.

- **DEL05.4**: This document explains the best practices of data quality assurance aimed at minimizing the data error risks during the training and test data preparation phase of the machine learning process lifecycle. The training and test data requirement specifications follow the data integrity, data security and data safety norms of the AI data governance lifecycle process.
- **DEL05.5**: This document outlines how data will be handled, once they are accepted. Two major issues are discussed in the data handling policy: (a) compliance with regulations dealing with the use of personal health data; and (b) non-disclosure of the undisclosed test data held by FG-AI4H for the purpose of model evaluation.
- **DEL05.6**: This document provides guidance for existing industry best practices for the sharing of health-related data. It outlines the roles of each party with respect to the data provider, processor, and receiver while exploring traditional and novel approaches leveraging distributed and federated methods for developing privacy-preserving AI/ML models.
- **DEL06**: This document provides a review of the different aspects of the AI model training pipeline, including aspects of data pre-processing and AI model training, to facilitate maximum performance and transparency.
- **DEL07**: This document combines a set of five separate deliverables as an umbrella with considerations on the evaluation of AI for health. It provides an overview of DEL7.1-5, preliminary considerations on the evaluation process, characteristics of validation and evaluation, the concept of standardized model benchmarking, requirements for a benchmarking platform and best practices for model assessment.
- **DEL07.1**: This document includes a review of existing evaluation principles and methods, evaluation needs and solutions specific to AI4H. It also looks into ethics and risks aspects to gain insights into the direction of how the current evaluation methods evolve toward the concept of real AI.
- **DEL07.2**: This document specifies how an AI can and should be tested in silico. Best practices for test procedures known from (but not exclusively) AI challenges is reviewed, including important testing paradigms that are not exclusively related to AI applications.
- **DEL07.3**: This document is the reference collection of WG-DAISAM for assessment methods of data and artificial intelligence quality evaluation, to provide a framework for technologists that build health-related AI-based products to investigate the presence of algorithmic bias.
- **DEL07.4**: This document outlines the current best practice, the principles and outstanding issues for further considerations related to clinical evaluation of AI models for health, to promote confidence among clinicians, patients, researchers and policymakers in the safety, efficacy, and cost-effectiveness of AI solutions in health requires a more comprehensive evaluation.
- **DEL07.5**: This document collects practical experiences and lessons learned to guide the implementation of assessment platforms using AI for health. Two options to explore the implementation of an assessment platform has resulted in two code bases: (a) custom assessment platform and (b) EvalAI-based assessment platform.
- **DEL09**: This document combines a set of two separate deliverables as an umbrella with the discussion on the development of AI tools for health using mobile applications and cloud-based AI applications.
- **DEL09.1**: This document contains a draft set of rules for the development of AI tools for Health using Mobile Applications, their testing and benchmarking. It also discusses the regulatory/ethical rules for Mobile Apps with AI for Healthcare.

- **DEL09.2**: This document contains a draft set of rules for the development of Cloud-based AI applications, their testing and benchmarking. It also discusses technology, security and legal issues related to cloud-based AI tools.
- **DEL10**: This document provides an overview and template documentation for AI4H use cases as a topic description document (TDD), to facilitate topic groups to establish a procedure to benchmark AI models developed for a special task within their health topic. The TDD contains information about the structure, operations, features, and considerations of each specific health topic.

I.4 ITU-T FG-AI4A

The FG-AI4A (Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture") addresses the core challenges and opportunities within the agricultural sector. The FG-AI4A will explore the potential of emerging technologies including AI and IoT in supporting data acquisition and handling, improving modelling from a growing volume of agricultural and geospatial data, and providing effective communication for interventions related to the optimization of agricultural production processes. The parent group for FG-AI4A is ITU-T SG20.

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