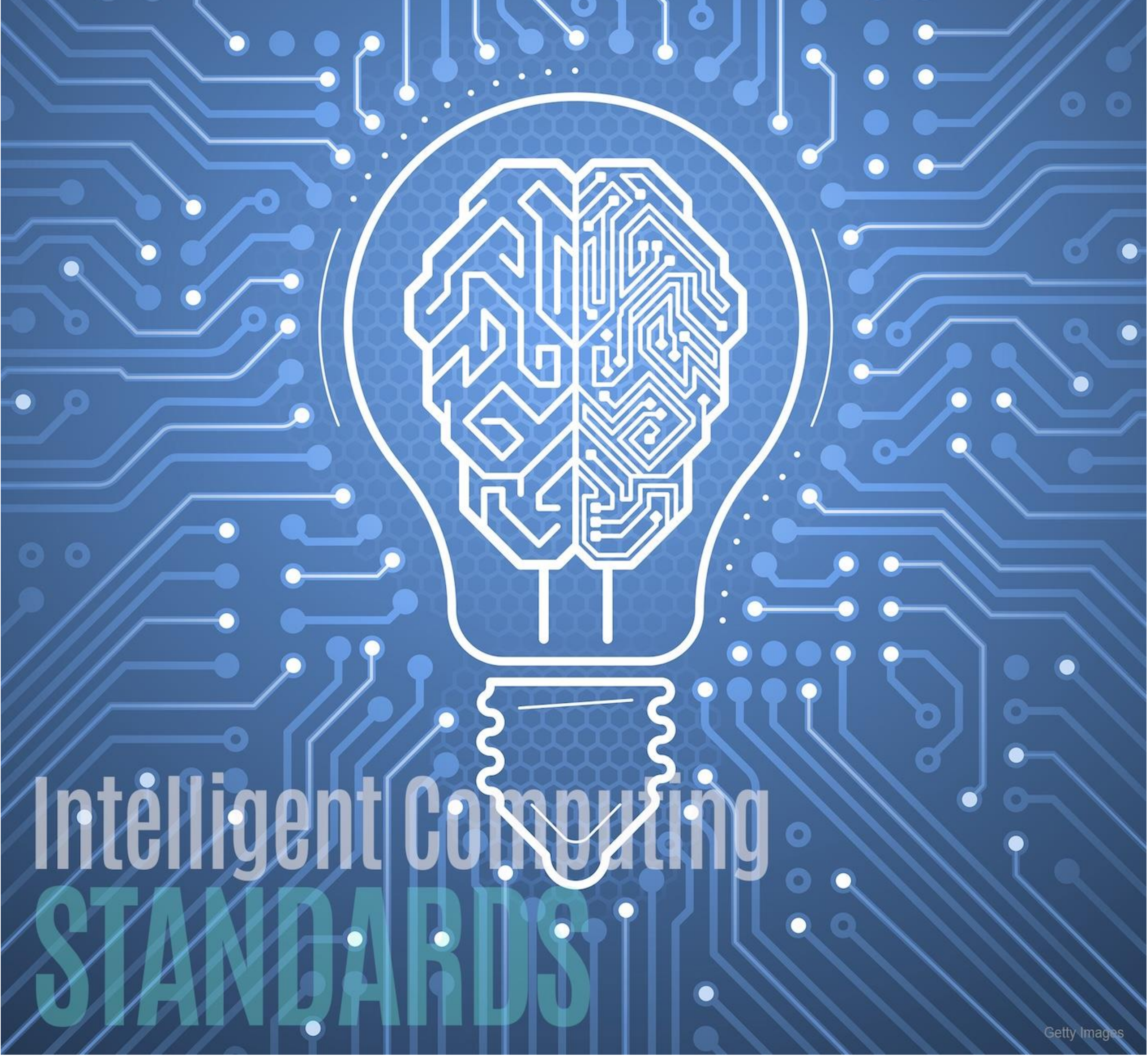


ISO JTC1 IEC
INFORMATION TECHNOLOGY STANDARDS

**JTC 1 Technology Trend Report**

# Intelligent Computing

# Executive Summary

Intelligent computing is a broad field of computing technology that encompasses various approaches and techniques. It uses innovative architectures, AI algorithms, network, and new hardware, etc. for enhancing and optimizing the performance of computing systems, in which, AI could be considered one of the enabler technologies, but it is not essential nor synonymous for intelligent computing.

This report explores the current status of intelligent computing including technologies, markets and standardization. This report includes:

- Intelligent Computing: Overview, concepts, related technologies, reference architectures, use cases
- Related standardization activities in ISO/IEC JTC 1, ISO/IEC committees and other international standardization organizations
- Challenges to JTC 1

**About ISO/IEC JTC 1**

ISO/IEC JTC 1, entitled "Information technology", is a joint technical committee of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). ISO/IEC JTC 1 develops Standards that support the advancement of information and communications technology (ICT) across multiple industry sectors.

**About JTC 1 JETI**

ISO/IEC JTC 1 Advisory Group 2 on JTC 1 Emerging Technology and Innovation (JETI) has been mandated to seek opportunities to facilitate JTC 1 Standards development for future emerging and innovative technologies as a technology watch group in JTC 1.

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# Section 1

## Introduction

In the ever-evolving landscape of technology, the concept of "Intelligent Computing" has emerged as a transformative force driving innovation across various domains. This multifaceted field encompasses a wide spectrum of techniques, algorithms, and systems that aim to replicate and enhance human-like intelligence in machines. Intelligent Computing leverages the power of data, advanced algorithms, and computational resources to enable machines to reason, learn, and make decisions autonomously, thereby revolutionizing industries ranging from healthcare and finance to transportation and entertainment.

This report explores the current status of Intelligence Computing including general concepts, characteristics, related technologies, market status, and standardization activities, and discusses challenges to JTC 1 in addressing this topic from a JTC 1's standardization perspective.

# Section 2

## Terms and Definitions

We do not re-define terms or include new definitions. We use the following terms in the context of this report as described below:

- Servers: A system of hardware and software providing processing capabilities
- Storage: A system of hardware and software enabling to store of data and information
- Network: A system of hardware and software providing allowing the exchange of data, information, and related services
- Application: A software package combining servers, storage, and networks to the intelligent computing infrastructure
- Use Case: Specific software to fulfill a specific sectoral intended purpose using the intelligent computing infrastructure

# Section 3

## General Concepts and Characteristics

### 3.1 General Concepts

Intelligent computing is an enhancement of computing technology by intelligent approaches, which includes theoretical revolutions, AI methods, emerging computing technologies, advanced system architectures, new hardware, universal development of network, big data, etc., where emerging computing technologies refer to quantum computing, neuromorphic computing, optoelectronic computing, computing in memory, biological computing, etc. All together, these intelligent approaches greatly boost computing capability and efficiency. Henceforth, intelligent computing further enables the rapid growth of intelligence applications and the leverage of its benefits.

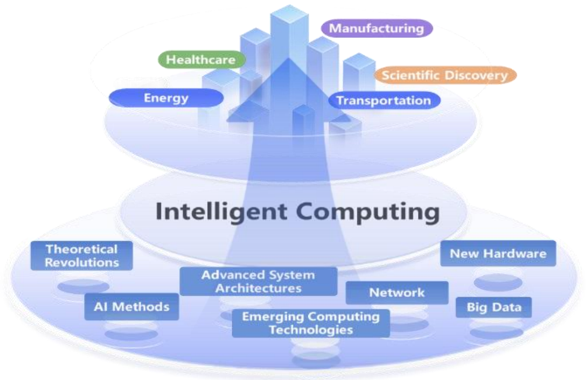


Figure 1. General concept of intelligent computing

Intelligent computing leverages all possible resources including compute power, data, and network connectivity to collect, process, and analyze input data, and act based on this data in an intelligent and automated way:

- Compute: The availability of high-performance computing resources, such as CPUs and GPUs, is essential for intelligent computing. This allows for the efficient processing of large amounts of data and the execution of complex algorithms. The use of specialized hardware, such as field-programmable gate arrays (FPGAs) and application-specific integrated circuits (ASICs), can further enhance the performance and efficiency of intelligent computing systems.
- Data: Intelligent computing relies on the availability of large and diverse datasets to train and improve algorithms. This can include structured data, such as numerical and categorical data, as well as unstructured data, such as text, images, and videos. The quality and quantity of data are critical for the success of intelligent computing, and data preprocessing and cleaning are often necessary to ensure the data is accurate and usable.
- Network: Intelligent computing requires the ability to share and transfer data and computational resources across networks. This includes both local and wide area networks, as well as cloud-based infrastructure. The use of distributed computing and parallel processing techniques can also enhance the efficiency and scalability of intelligent computing systems.

Each subfield of intelligent computing utilizes AI techniques and algorithms to enhance computing systems with specific capabilities, such as the ability to recognize speech, identify objects in images, make predictions based on data patterns, etc.

Intelligent computing is particularly useful in the context of huge amounts of specific data as collected nowadays also by the Internet of Things (IoT). With intelligent computing, this data can be processed and analyzed quickly and efficiently, allowing for more informed decision-making and automated responses to changing input.

Intelligent computing is a powerful technology that has also applications in fields like drones, autonomous vehicles, healthcare, manufacturing, transportation, smart homes and many more. It has the potential to revolutionize the way we live and work, and to create new opportunities for innovation and growth. By utilizing intelligent techniques to optimize the performance of computing systems, it can help organizations improve efficiency, reduce costs, and achieve better outcomes. However, there are also important ethical and social considerations associated with intelligent computing, such as privacy, security, bias, and job displacement. As such, the development and implementation of intelligent computing systems require careful consideration of these issues, as well as a commitment to transparency, accountability, and fairness.

The concept of intelligent computing as an umbrella term is constantly evolving as new technologies and applications are developed. This report describes the general concepts of intelligent computing from JTC 1/SC 38, JTC 1/SC 41, and JTC 1/SC 42 as follows:

General concept in JTC 1/SC 38

Intelligent computing plays a crucial role in cloud computing and distributed platforms, which are the main focus of JTC 1/SC 38. The general concept of intelligent computing in this subcommittee is to develop standards and best practices related to the use of intelligent computing technologies in cloud computing and distributed platforms.

Intelligent computing provides the algorithms and techniques necessary to process and analyze the vast amounts of data generated by cloud-based applications and services. This includes techniques such as machine learning, natural language processing, and data analytics. By using intelligent computing, cloud-based applications can provide more accurate and personalized services to users and can improve their overall performance and efficiency.

JTC 1/SC 38 is focused on developing standards related to various aspects of cloud computing, including security, interoperability, and management of cloud services. Intelligent computing can play a key role in each of these areas. For example, intelligent computing can be used to detect and respond to security threats in real time, to ensure the interoperability of different cloud-based applications and services, and to optimize the allocation of computing resources in a cloud-based environment.

Another important aspect of intelligent computing in JTC 1/SC 38 is the development of standards related to the use of edge computing. Edge computing involves the use of intelligent computing technologies to process data closer to where it is generated, such as on a mobile device or a sensor. By processing data locally, edge computing can reduce the latency and bandwidth requirements of cloud-based applications and can improve their overall performance and efficiency.

The general concept of intelligent computing in JTC 1/SC 38 is to promote the safe and effective use of intelligent computing technologies in cloud computing and distributed platforms. This includes developing standards related to security, interoperability, management of cloud services, and the use of edge computing. By establishing standards in these areas, JTC 1/SC 38 aims to facilitate the adoption of intelligent computing technologies in cloud-based applications and services, and to ensure their interoperability and security.

General concept in JTC 1/SC 41

The general concept of intelligent computing in JTC 1/SC 41 is to develop standards and guidelines for the use of intelligent computing technologies in IoT applications and systems. Intelligent computing plays a key role in IoT, as it enables IoT devices to process and analyze data in real-time, and to make intelligent decisions based on that data. This includes techniques such as machine learning, natural language processing, and data analytics, which are used to extract insights from the massive amounts of data generated by IoT devices.

JTC 1/SC 41 is focused on developing standards related to various aspects of IoT, including interoperability, security, and privacy. Intelligent computing can play a key role in each of these areas. For example, intelligent computing can be used to ensure the interoperability of different IoT devices and systems, by providing common protocols and data formats. It can also be used to detect and respond to security threats in real-time, and to protect the privacy of user data.

Another important aspect of intelligent computing in JTC 1/SC 41 is the development of standards related to the use of edge computing in IoT. Edge computing involves the use of intelligent computing technologies to process data closer to where it is generated, such as on an IoT device or a gateway. By processing data locally, edge computing can reduce the latency and bandwidth requirements of cloud-based IoT applications, and can improve their overall performance and efficiency.

The general concept of intelligent computing in JTC 1/SC 41 is to promote the safe and effective use of intelligent computing technologies in IoT applications and systems. This includes developing standards related to interoperability, security, privacy, and the use of edge computing. By establishing standards in these areas, JTC 1/SC 41 aims to facilitate the adoption of intelligent computing technologies in IoT, and to ensure their interoperability, security, and privacy.

<u>General concept in JTC 1/SC 42</u>

The general concept of intelligent computing in JTC 1/SC 42 is to develop standards and guidelines for the development, deployment, and use of AI systems. AI plays a key role in intelligent computing, while intelligent computing enables the rapid growth of AI applications, as it encompasses the range of computing technologies and techniques used to enable machines to perform tasks that typically require human intelligence. This includes techniques such as machine learning, natural language processing, computer vision, and data analytics.

JTC 1/SC 42 is focused on developing standards related to various aspects of AI, including ethics, transparency, interoperability, and governance. One important aspect of intelligent computing in JTC 1/SC 42 is the development of standards related to the responsible use of AI. This includes establishing ethical guidelines for the development and deployment of AI systems, ensuring transparency in the use of AI, and promoting the use of AI for the benefit of society.

Another important aspect of intelligent computing in JTC 1/SC 42 is the development of standards related to the interoperability of AI systems. Interoperability is critical for the development of AI systems that can work together seamlessly and efficiently and can share data and knowledge effectively.

JTC 1/SC 42 is also focused on developing standards related to the governance of AI. This includes establishing guidelines for the responsible use of AI, promoting the development of ethical and transparent AI systems, and ensuring that AI is used in ways that benefit society.

The general concept of intelligent computing in JTC 1/SC 42 is to promote the development, deployment, and use of AI systems in a responsible, ethical, and transparent manner. This includes developing standards related to ethics, transparency, interoperability, and governance, and ensuring that AI is used to benefit society as a whole. By establishing these standards, JTC 1/SC 42 aims to promote the responsible and sustainable development of AI, and to ensure that AI systems are developed and used in ways that are safe, ethical, and beneficial to society.

## 3.2 Characteristics

### 3.2.1 Compute resource

Compute resource can be considered into HW aspect and SW aspect. In the aspect of HW, storage (collecting data), server (processing/analyzing data), and all computing node connected by network can be included and these can be classified in three-tiers model (which is basic) depicted in the figure 2.

There are different conceptual models how the infrastructure for intelligent computing can be structured in addition to a traditional client-server model. All models are illustrative rather than definitive – in reality, the number of tiers, the type of node in each tier, and the networks connecting them, are variable, depending on the nature of the system involved.

The three-tier model can also be refined by using different layers (User, Access, Service and Resource layers) and different planes (Data plane, Control plane, Management plane), which add additional dimensions to the model. The task and challenge for intelligent computing are to find the best approach to perform the tasks at the right place and at the right time depending on the conceptual model chosen, the implementation, the concrete task and the available infrastructure restriction.

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- Storage

A hybrid cloud world means a massive amount of data is being generated all the time. This data can be incredibly useful, but only if it can be accessed, organized, and analyzed. Traditional data storage systems were not designed to effectively handle this task, meaning valuable data is hidden or overlooked and enterprise and IT resources are strained. Intelligent storage systems remove the barriers that keep customers from taking advantage of their data by understanding what workloads need, adapting to changes in real-time, and simplifying management and support.

Intelligent storage is a storage system that uses advanced indexing, sharing, replication, and AI techniques to better manage and serve data in the hybrid cloud environment. It can be deployed as hardware on-premises, as a virtual appliance, or as a cloud service. Intelligent storage can move data where it needs to be and proactively optimize data through its life cycle. It provides data protection and encryption to eliminate potential security threats.

Intelligent storage delivers a solution that prevents most failures before they occur by self-adaptive adjustment. It also provides fast and efficient recovery in case of system crashes.

- Server

Information flows constantly, propelled by an insatiable appetite for all things digital, which puts increasing demands on server infrastructure. All of that data has to be stored, protected, analyzed, and shared to create business insight. For today's data centers, small advances in technology won't solve the issues that come with handling such large volumes of data and the real-time or low-latency acquisition, perception, processing and intelligent data analysis. To solve these issues, accessible and easy-to-use intelligent servers are required.

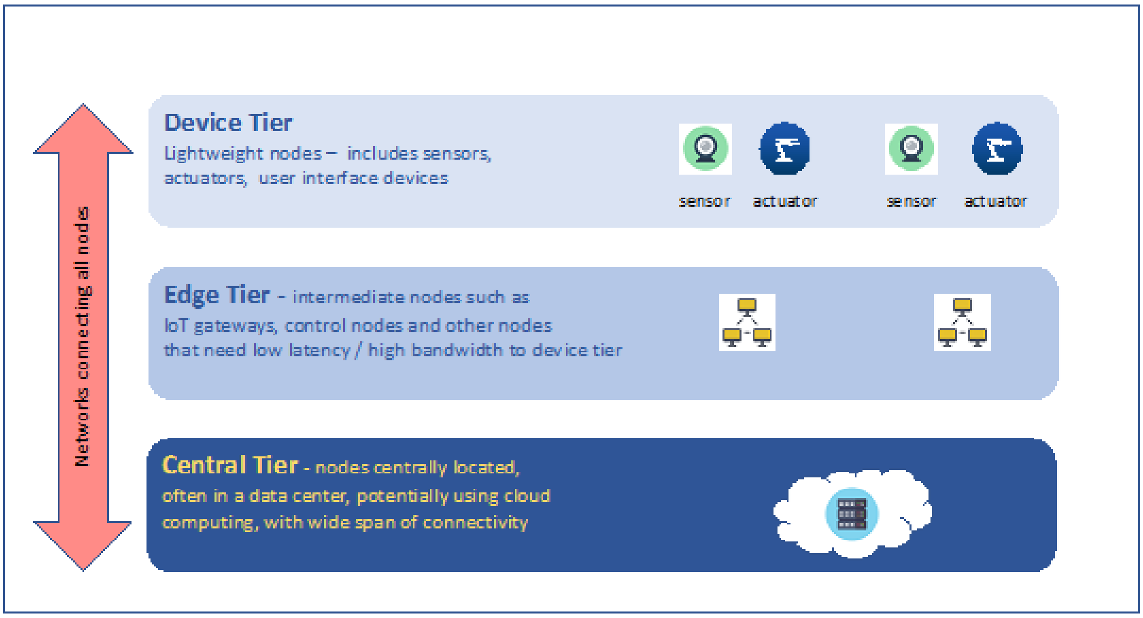


Figure 2. Computing nodes in three-tier model [5]

To respond effectively to the explosion of applications, data, and digital content, the intelligent server is needed to build for the challenges of the cloud computing era.

An intelligent server helps you gain a competitive edge by delivering maximum performance and reliability while simplifying day-to-day management as well as providing self-managing. It also continuously analyzes thousands of system parameters and resolves potential issues before they turn into problems. An intelligent server is built with these capabilities—providing the foundation for an intelligent, responsive, and converged infrastructure.

[Benefits of Intelligent server]

- Eliminate tedious tasks with integrated life cycle automation
- Turbo-charge performance with dynamic workload acceleration
- Fine-tune space, power, and cooling demands with automated energy optimization
- Resolve issues quickly with the intelligent server insight experience
- Decomposition of demand-side diversified tasks based on supply-side resource
- Automatic resource management and scheduling

Most of the "intelligence" is at the end software. The data is not per se part of the software, but in case of machine learning approaches necessary for the training and continuous learning and therefore to be considered as well. This includes the collection of the data in a way, which respects agreed ethical principles and avoids negative bias where possible. In the aspect of SW, we can think of collecting, processing, and analyzing the data. Theses can be aligned with HW like storage for collecting data, server for processing/analyzing data. Therefore, the "Intelligence" takes place in choosing the right node in the right tier at the right time.

Applications relying on an intelligent infrastructure do no longer care

- where the computing is done or
- where the data is stored.

Similar to a user today, who doesn't care if the computing is done by the CPU or on the chip on the graphic card. On the other side, limiting factors are given due to reliability, security and privacy. Some of the data can by different reasons only be processes at a certain place or in case of an unavailable network or computing resource not be distributed to the usual location. This has to be considered when developing the application. New applications shall be available to allow the human control in a suitable way.

### 3.2.2 Data resource

Data intelligence refers to the practice of using artificial intelligence (AI) and machine learning (ML) tools to analyze and transform different data from computing resources into intelligent data insights/decisions depending on its degree of autonomy, which can then be used to improve services and investments. Intelligent computing data tools and techniques can optimize the usage of the resources provided by decision makers to achieve his goals.

### 3.2.3 Network resource

An intelligent network is a type of network that uses advanced technologies in access, routing, and scheduling, such as artificial intelligence, data analytics, computing aware networking, segment routing over IPv6, to provide more efficient and effective services to users. Intelligent networks are designed to be flexible and adaptable, allowing them to respond to changing network conditions and user demands.

Intelligent networks typically consist of a set of interconnected nodes, such as switches, routers, and servers, that can communicate with each other and exchange data. The nodes in an intelligent network are usually equipped with sensors and other monitoring devices that allow them to collect data on network conditions and user behavior.

By analyzing this data using machine learning and other techniques, an intelligent network can automatically adjust its configuration and routing to optimize performance, improve network security, and reduce downtime. Intelligent networks can also be used to provide advanced services such as virtual assistants, personalized recommendations, and real-time analytics.

Intelligent network allows functionality to be distributed flexibly at a variety of nodes on and off the network and allows the architecture to be modified to control the services.

Intelligent Network technology consists of remotely manageable and automatically adjusting broadband nodes and amplifiers, as well as their management software.

Since the rapidly increasing number of IoT devices cannot be accommodated by manpower, a fundamental change in the network is inevitable to prepare for the future digital era.

The intelligent network not only solves the challenges facing companies through the integration of new technologies such as machine learning, analytics, and automation, but ultimately supports business. Intelligent networking is a technology that continuously learns, adapts, automates, and protects itself, and is expected to play a role in optimizing network operations and protecting networks from evolving threats.

Until now, wireless networks have been limited to technologies that connect humans, but with advances in communication technology, intelligent networking combined with other technologies such as sensing, visual information expression, display, and AI will enable hyper-connection between humans and things.

 

# Section 4

## Related Technologies

This section provides an overview of the technology trends for compute, data, and network resources that are relevant to the development of intelligent computing. As the field of intelligent computing continues to evolve, it is important to keep up with the latest trends and advancements in these areas to ensure that related technologies are being developed in a way that promotes intelligent computing.

The intelligent computing is highly related to cloud deployments, especially in hybrid clouds and edge cloud scenarios.

The computing resources shall be available where they are needed at a certain time and in a certain amount, without the active interference of a human administrator

This is connected to privacy and security techniques since the possibilities of data protection are related to the specific platform used.

It is also related to environmental concerns, especially the energy consumption of the computing infrastructure, since using the right kind and amount of computing infrastructure can decrease the energy consumption significantly

### 4.1 Compute resource

Intelligent computing relies heavily on compute resources, as they are essential for processing large amounts of data and running complex algorithms and models that enable machines to learn, reason, and make decisions based on data.

Compute resources include the hardware and software components that enable machines to perform computational tasks, such as servers, processors, memory, storage, and software frameworks. These components are essential for running AI and machine learning algorithms, which are the backbone of intelligent computing.

As the field of intelligent computing continues to evolve, there is a growing demand for more powerful and specialized compute resources, such as GPUs and TPUs, to support the increasing complexity of AI and machine learning workloads. Additionally, there is a growing trend towards distributed computing and edge computing, which enable compute resources to be deployed closer to the source of data, reducing latency and improving efficiency.

Quantum Computing:

Quantum computing is an emerging technology that has the potential to solve complex problems that are currently intractable for classical computers. In recent years, significant progress has been made in the development of quantum hardware, such as qubits and quantum processors, and quantum algorithms. One trend in quantum computing is the commercialization of quantum computers by companies such as IBM, Google, and Microsoft, making the technology more accessible to researchers and businesses. Another trend is the increasing focus on improving the stability and reliability of qubits, which are the building blocks of quantum computers. As the technology matures, quantum computing is expected to have a significant impact on fields such as cryptography, drug discovery, and materials science.

Neuromorphic Computing:

Neuromorphic computing is a type of computing that aims to mimic the structure and function of the human brain using artificial neural networks. One trend in neuromorphic computing is the development of hardware and software that can support more complex and sophisticated neural networks. Another trend is the integration of neuromorphic computing with other technologies, such as robotics and computer vision, to enable new applications and use cases. Neuromorphic computing is expected to have a significant impact on fields such as artificial intelligence, machine learning, and robotics.

### High-Performance Computing (HPC):

High-performance computing involves the use of supercomputers and parallel processing to perform computationally intensive tasks. One trend in HPC is the growth of cloud-based HPC services, which provide on-demand access to high-performance computing resources without the need for significant capital investment. Another trend is the use of HPC for AI and ML workloads, such as deep learning and natural language processing, which require large amounts of computational power. As data volumes continue to grow, HPC is expected to play an increasingly important role in data processing, simulation, and modeling.

### Cloud Computing:

Cloud computing is a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand [2]. Resources include servers, operating systems, networks, software, applications, storage equipment, etc. Cloud providers are offering specialized hardware, such as GPUs, TPUs, and AI accelerators, to speed up machine learning and AI workloads. This trend enables faster model training and inference, enhancing the capabilities of intelligent computing solutions. Serverless computing is another trend in which cloud providers manage the underlying infrastructure, allowing developers to focus solely on writing code. This simplifies the deployment of intelligent computing applications, making it easier to implement and scale services without managing servers directly.

### Edge Computing:

Edge computing is form of distributed computing in which significant processing and data storage takes place on nodes which are at the edge of the network [5]. One trend in edge computing is the increasing adoption of edge computing in IoT and other applications, which enables faster and more efficient processing of data at the edge. Another trend is the development of edge AI and ML technologies, which enable intelligent computing to be performed locally on edge devices, reducing latency and improving privacy and security.

### Optoelectronic computing:

Optoelectronic computing is a computing technology that uses photons produced by laser/ diodes for data transmission, data exchange, and data logical operations. Optoelectronic computing can significantly improve computing speed and energy efficiency by overcoming the inherent limits of electrons. Compared with electronic computing, optoelectronic computing fully combines the unique advantages of multi-dimensional multiplexing, high bandwidth, and low energy consumption of optics, which is a more practical and competitive solution for accelerating computation. Optoelectronic computing naturally has significant advantages in the application scenarios such as automatic driving and drones which require high bandwidth and real-time response, as well as in high-concurrent, high-throughput, and compute-intensive supercomputing platforms and data centers.

### Computing in memory:

Computing in memory (CIM) is an emerging computing paradigm where data processing and storage are integrated into the same unit. This approach differs from the traditional von Neumann architecture where the processor and memory are separated units, and data must be transferred between these units for processing. CIM reduces data movement by processing data directly in the memory unit where it is stored, thus significantly decreasing processing time and energy consumption. CIM is particularly useful for applications that involve large amounts of data and has the potential to revolutionize the way computers are designed and operated in the future.

### Biological computing:

Biological computing is a new computing technology developed using the inherent information processing mechanism of biological systems. In short, it is used to solve computational problems with biological methods.

 

Biological computers mainly include protein computers, RNA computers, and DNA computers. The protein computer takes the law of protein motion as the basic prototype of computer operation. RNA and DNA computers use the specific hybridization between nucleic acid molecules as the basic model. Biology-empowered intelligent computing has unique advantages compared to traditional computing, which can be summarized as the strong parallel and distributed computing ability and low power consumption. It consumes molecular energy to solve large-scale and complex computing problems.

## 4.2 Data resource

Intelligent computing and data resources have a close and interdependent relationship. Data resources are essential for intelligent computing, as they provide the raw material from which machines can learn, reason, and make decisions.

Data resources include structured and unstructured data, such as text, images, audio, and video, that are collected from various sources, such as sensors, social media, and customer interactions. These data resources are then processed and analyzed using AI and machine learning algorithms to extract insights and patterns that enable intelligent decision-making and automation.

Intelligent computing relies heavily on data resources to train and develop models that can be used to make predictions, automate processes, and generate insights. Without sufficient and relevant data resources, machines cannot learn or improve, and intelligent computing cannot be achieved.

In turn, intelligent computing can also improve data resources by enabling businesses to automate data processing tasks, such as data cleansing and preparation, and identify patterns and insights that may not be visible to the naked eye. This can lead to more efficient and accurate data analysis and decision-making, as well as improved business outcomes.

Big Data:

Big data is extensive datasets primarily in the data characteristics of volume, variety, velocity, and/or variability that require a scalable technology for efficient storage, manipulation, management, and analysis [16]. One trend in big data is the development of tools and platforms that can handle larger and more diverse datasets, such as data lakes and distributed databases. Another trend is the increasing use of machine learning and AI algorithms to extract insights from big data. Big data is expected to have a significant impact on fields such as business intelligence, healthcare, and scientific research.

Data Mining:

Data mining is the process of discovering patterns and relationships in large datasets using statistical and machine learning techniques. These techniques can be applied to various types of data, including tabular data, text data, time series data, and graph-structured data. One trend in data mining is the integration of data mining with other technologies, such as AI and ML, to enable more sophisticated and accurate analysis. Another trend is the development of techniques for mining unstructured data, such as text and multimedia, which are becoming increasingly important in many fields. Graph processing is a typical data mining method used to discover complex patterns and connections within objects, making it easier to draw insights from big data. Graph can also be used to analyze and visualize data, allowing analysts to uncover hidden knowledge, rules and connections that may be difficult to see with other data mining tools. Data mining is expected to have a significant impact on fields such as marketing, finance, and healthcare.

Data Warehousing:

Data warehousing involves the collection, storage, and management of large datasets from various sources for analysis and decision-making. One trend in data warehousing is the use of cloud-based data warehousing solutions, which provide scalable and cost-effective storage and processing of large datasets. Another trend is the integration of real-time data processing and analytics, which enable businesses to make faster and more informed decisions. Data warehousing is expected to have a significant impact on fields such as finance, marketing, and supply chain management.

Machine Learning:

Machine learning is a key component of data resources in intelligent computing. It heavily relies on data for model training, development, and predictions. The process involves data collection, cleaning, preprocessing, and integration from various sources. Machine learning also requires efficient data storage, labeling, and privacy and security measures. The quality and accessibility of data directly affect the success of machine learning applications. Federated learning is a trend that focuses on decentralized machine learning, where models are trained across multiple decentralized edge devices or servers, without exchanging raw data. It's ideal for privacy-sensitive applications and IoT, allowing collaborative model training while keeping data localized and secure.

Cloud computing:

Cloud computing has a significant impact on how data resources are managed and utilized. Cloud platforms are evolving to support data lakes and data warehouses, offering highly scalable and cost-effective solutions for storing and managing large volumes of data. This trend is essential for intelligent computing, as it enables efficient data storage and retrieval for machine learning and analytics. Cloud platforms offer services for data processing and analysis, enabling users to extract valuable insights from data efficiently. This is particularly important for data-driven machine learning and AI applications.

### 4.3 Network resource

Intelligent computing and network resources are closely related, as network resources are essential for facilitating the exchange and processing of data, which is at the heart of intelligent computing.

Network resources include the hardware and software components that enable data to be transmitted and processed across a network, such as routers, switches, firewalls, and software-defined networks. These resources are essential for enabling data to be transmitted quickly and securely between different parts of a network, which is necessary for intelligent computing applications that rely on real-time data analysis and decision-making.

Intelligent computing applications, such as machine learning algorithms and AI-based decision-making systems, require large amounts of data to be processed and transmitted quickly and efficiently. Network resources play a critical role in ensuring that data is transmitted and processed quickly and accurately, and that the network is secure from potential threats.

Additionally, network resources can also be optimized to improve the performance of intelligent computing applications. For example, edge computing resources can be deployed closer to the source of data, reducing latency and improving the speed and efficiency of data processing. Software-defined networks can also be used to allocate network resources dynamically, based on the demands of intelligent computing applications.

5G Networks:

5G is the latest generation of wireless network technology that provides high-speed connectivity and low latency, enabling new applications and use cases. One trend in 5G networks is the deployment and expansion of 5G networks, which is expected to accelerate as more countries and mobile operators roll out 5G infrastructure. Another trend is the development of new applications and services that take advantage of 5G's speed, low latency, and high bandwidth, such as autonomous vehicles, remote surgery, and virtual and augmented reality. As intelligent computing becomes more pervasive, 5G networks are expected to play an increasingly important role in enabling these applications and services.

Network Function Virtualization (NFV):

NFV is a key technology for enabling intelligent networks. It allows network functions to be implemented as software that can be run on standard hardware, rather than relying on dedicated hardware appliances. This allows network operators to more easily deploy and scale network functions, and it enables the creation of more flexible and dynamic networks.

Network Slicing:

Network slicing is another technology that is essential for intelligent networks. It allows network operators to create multiple virtual networks on a shared physical infrastructure, each with its own set of resources and capabilities. This enables more efficient use of network resources and allows network operators to offer customized services to different types of users.

### Cloud Computing:

Cloud computing, with its global network infrastructure, scalability, security, and integration of edge computing, is fundamental to the network aspect of intelligent computing. It provides the necessary tools and resources to ensure low-latency, high-performance data transmission and processing, supporting applications that rely on real-time analytics, AI, and machine learning for decision-making and automation.

### Edge Computing:

Edge computing is another important technology for intelligent networks. It involves moving computing resources closer to the network edge, where they can be used to process data in real-time and reduce latency. This can be used to enable new types of applications and services, such as augmented and virtual reality, that require low-latency and high-bandwidth connectivity.

### Computing Aware Networking:

Computing Aware Networking (CAN), also known as Computing First Networking (CFN) or Computing Power Networking (CPN), is a network system that takes into account the distribution and status of computing resources within a network. It aims to interconnect these distributed computing resources to achieve seamless collaboration between the network and computing resources. Unlike the management of distributed cloud systems, CAN focuses on the network status between computing sites as well as the status of individual computing nodes. By leveraging CAN, service requests can be efficiently dispatched to the most suitable site, ensuring the fulfillment of computing requirements for various services. Ultimately, this enables comprehensive collaboration among all computing resources within the network.

### IPv6+:

IPv6+ is an upgrade of IPv6 and an intelligent IP network for the 5G and cloud era. It requires three major features: intelligent ultra-wide, intelligent connection, and intelligent operation and maintenance [20].

The following key technologies of IPv6+ enable intelligent networks:

- Segment Routing over IPv6 (SRv6): SRv6 is a next-generation IP bearer protocol that combines Segment Routing and IPv6. Utilizing existing IPv6 forwarding technology, SRv6 implements network programming through flexible IPv6 extension headers. SRv6 reduces the number of required protocol types, offers great extensibility and programmability, and meets the diversified requirements of more new services. It also provides high reliability and offers exciting cloud service application potential.
- In-situ Flow Information Telemetry (IFIT): IFIT is a new data plane telemetry technique. Different from the active and passive OAM schemes, IFIT will not generate additional test traffic, but to insert the telemetry instruction into the user traffic, and measure the real user traffic. IFIT can provide fine grained flow SLA monitoring, measure the real user traffic and monitor packet behavior in the network.
- Application-aware IPv6 Networking (APN6): APN6 conveys APN attributes (including APN IDs and parameters for identifying applications and for identifying network performance requirements, respectively) to a network by leveraging the extension header space in IPv6 packets, enhancing the network's ability to perceive business and enabling service providers to provide fine-grained network services and achieve precise network operations and maintenance.

# Section 5

## Use cases

When existing problems are solved by products and services that also use AI methods and approaches, these solutions become use cases for intelligent computing. From the user's point of view, the AI is subordinate to the main function and not the main characteristic. E.g., even the most intelligent self driving car, is for the person still a mean of transportation and the most intelligent fridge has to cool the food. This section provides an overview of the technology trends for compute, data, and network resources that are relevant to the development of intelligent computing. As the field of intelligent computing continues to evolve, it is important to keep up with the latest trends and advancements in these areas to ensure that related technologies are being developed in a way that promotes intelligent computing.

### 5.1 Use cases from IEC whitepapers

Even though intensive research is currently being conducted in many areas, most of the problems described in the referenced documents are far from being fully solved in everyday life. This section adds therefore to the many details and applications which can be found in the IEC whitepaper regarding AI across the industries [14] and the IEC whitepaper on Edge Intelligence [15]. Please be aware that they were at time of publication of the white papers not referred to as "intelligent computing" but as "artificial intelligence deployment" [14] and "edge intelligence" [15].

#### 5.1.1 Smart homes

Intelligent computing in smart homes involves creating a comprehensive ecosystem that connects individual devices in a home through a control center. This ecosystem, built upon the IoT, integrates various hardware, software systems, and cloud-based platforms, and utilizes AI technologies such as speech and visual recognition, deep learning models, and user profiling to understand user needs.

The goal of smart homes is to achieve device interoperability and self-learning, enabling personalized services for safer, more comfortable, and energy-efficient living. These systems also improve the efficiency of home appliances, reduce energy consumption, and promote a sustainable and healthier lifestyle.

The smart home industry is actively developing solutions, including smart refrigerators, air conditioners, washing machines, kitchen appliances, and more, reflecting the concept of interconnected devices. Companies gather large amounts of data for prediction and analysis tasks, and consumers have embraced internet-based capabilities.

The continuous development of intelligent computing with AI, machine learning, and IoT technology has made smart homes more interactive and user-friendly. Products are evolving to focus on innovative human-machine interaction. Looking ahead, intelligent computing technology may enable smart homes to become even more intelligent and take on decision-making tasks. The integration of AI is expected to open broader opportunities in the smart home market.

#### 5.1.2 Smart manufacturing

Intelligent computing use case in smart manufacturing involves integrating Information and Communication Technology (ICT) with advanced manufacturing techniques to create smart factories. These factories are highly integrated and networked, connecting data from supply chains, design teams, production lines, and quality control.

The manufacturing sector relies on automation, machine learning, and other AI fields to address challenges and achieve flexibility in diverse production domains. Machine learning allows systems to continuously improve, resulting in faster, more flexible, and scalable manufacturing processes. It provides predictive insights to manage plant effectiveness, supplier selection, and pricing based on demand.

AI in manufacturing also supports economic growth by managing capital efficiency, labor requirements, machinery schedules, enabling on-demand production, improving operating efficiency, shortening product cycles, increasing production capacity, reducing downtime, and achieving cost savings.

Some key applications of AI in manufacturing include optimizing production processes, predictive maintenance, quality control, and supply chain management. These advancements in intelligent computing revolutionize the manufacturing industry and redefine the future of production lines.

### 5.1.3 Smart transportation

Intelligent computing in the context of smart transportation revolutionizes the way we move and transport goods, offering a broad range of applications with significant market potential. From private vehicles and public transportation to parking, logistics, and emergency services, various aspects of the transportation sector benefit from AI technologies.

The exponential growth in the number of vehicles, particularly in densely populated cities, has led to pressing challenges in traffic management and congestion control. To address these issues, AI solutions come into play. Image analysis enables real-time monitoring of traffic flow and identifies congestion points, while route optimization algorithms help in efficiently navigating through complex urban networks.

A notable advancement in smart transportation is the development of self-driving vehicles. These autonomous cars rely heavily on AI technologies, utilizing object identification to recognize pedestrians, vehicles, and other objects on the road, ensuring safe navigation and driving.

Intelligent computing capabilities are deployed at multiple levels within the transportation ecosystem. End devices, such as mobile phones, provide personalized transportation services to users, offering real-time traffic updates and alternate routes. Edge devices, like the AI systems integrated into vehicles, enable autonomous driving and immediate decision-making based on sensor data.

Moreover, the cloud plays a crucial role in managing and processing vast amounts of transportation-related data. Data centers use AI algorithms to analyze traffic patterns, predict demand, and optimize transportation networks on a larger scale, leading to more efficient and sustainable mobility solutions.

As intelligent computing becomes more ingrained in smart transportation, we can expect to see a safer, more efficient, and eco-friendly transportation ecosystem. By leveraging intelligent computing technologies, smart transportation will continue to enhance the overall travel experience for individuals and businesses alike, addressing the ever-growing challenges faced in modern urban environments.

### 5.1.4 Smart energy

Intelligent computing plays a crucial role as a use case in the smart energy sector, addressing challenges related to primary energy (oil, gas, coal) and secondary energy (electricity). The increasing depletion of natural resources and the urgent need to combat climate change have prompted countries worldwide to adopt counterstrategies, focusing on optimizing energy supply and demand management.

The goal of smart energy is twofold: to enhance the efficiency of energy production, transmission, and consumption while enabling effective energy management. The emphasis has been on minimizing energy losses through the convergence of Information and Communication Technology (ICT), including IoT, big data, and AI. This convergence acts as a driving force for technological innovation in the energy sector.

With the integration of ICT technologies, smart energy solutions offer improved estimation of energy supply and demand during production and consumption phases. It also facilitates energy transactions between different buildings and equipment. AI, combined with communication technologies, enables the analysis of vast amounts of information, leading to unprecedented levels of energy savings and optimization.

By leveraging intelligent computing, the smart energy sector can pave the way for a more sustainable and efficient energy ecosystem, contributing significantly to global efforts in achieving a greener and cleaner future.

## 5.2 Other use cases

### 5.2.1 Healthcare provision

Healthcare provision planning and administration:

The planning of national healthcare provision (aka public health) as well the planning of the hospital operation (e.g., medical stuff, logistics, wards, building, costly environment use) relies on data from health system monitoring, operational monitoring, population trends and other sorts of reports.

The joint project of JTC 1/SC 42 and ISO/TC 215 JWG 3 (first project "Technical Report - Application of AI technologies in health informatics") has made a start in this field.

However, the data sources for reports are partly outside health informatics. In hardware monitoring, in supply chain data, in data provided by other stakeholders (e.g., government population-centric databases, smart cities, emergency response systems, liability costs, billing-related documentation optimization).

Such amount of data and complex questions need intelligent computing.

Remote and off-site support:

COVID taught us, that provision of pharmaceutics in Europe and the vaccination rate for preventable disease (e.g., measles, DPT-3) in middle- and low-income countries are related, on the other side it increased the acceptance by all stakeholders of possibilities to provide remote health support.

Remote support can be provided by the intelligent IoT devices the home (smart speakers, home appliances, etc.) or on the body of the patient (watches, clothing etc.). It can be sending consulting via video conference or a tele-intervention by a physician. Where hundreds of parallel videoconferences with thousands of participants in a hospital network (traditional medical practice streamlined the times for these conferences), need enough bandwidth, an intervention needs rather high-quality pictures and delay-free transmission, even when combining pictures and overlays (e.g., digital twin-based data).

Patient engagement is a contributing factor, if the treatment and monitoring happen no longer in the special environment of practices and clinics. At home the patient can also investigate in diagnose and treatment options and the level of trust regarding the medical professionals might change. Intelligent chat bots can be helpful to provide high quality information personalized for the patient, but also digital support devices, which nudge the patient effectively to follow the treatment plan. Such devices have to use intelligent person-centered approaches to be effective.

Medical training and guidance:

Aging populations in almost all regions of the world will continue to increase the need for medical care and change the disease pattern medical professionals will encounter (less children's diseases and pregnancies, more conditions of older age). This will be offset by fewer physicians (decreasing global birth rates since decades), who will not only have to be relieved from routine tasks in medical practice, but who will also no longer be available to the usual extent in training for the students.

So medical education will have to rely more and more on intelligent tutors and intelligent digital or robotic manikins, who allow to learn usual reaction in a certain medical scenario. These combine Digital Twins of patients and infrastructure, Intelligent computing infrastructure, Big Data, Bio-databases, Federated Learning and much more.

Hospital diagnostic, treatment and care:

In treatment and diagnosis intelligent computing is key to work personalized. Intelligent computing has not yet infrastructure and data management methods powerful enough to leverage the full potential, prevention integrated into everyday life, evidence-based diagnostics and stateof-the-art treatment for everyone.

This starts with information retrieval of the biobanks of this world, development of novel pharmaceuticals (and speeding up their path to market access via in silico studies) and ends with personalized care by rehabilitation robots at home after surviving a severe disease like cancer.

### 5.2.2 Online delivery system

Online delivery systems face challenges which are cross spanning over the JTC 1 subcommittees. Such online delivery services should in the best-case use standards from every subcommittee in JTC 1 directly or indirectly.

An overview for the potential of some of the areas covered by JTC 1 committees is given in the 2023 MHI Annual Industry Report [19]. Figure 3 depicts the areas where an impact is seen, but also the predicted usage of these technologies in figure 4.

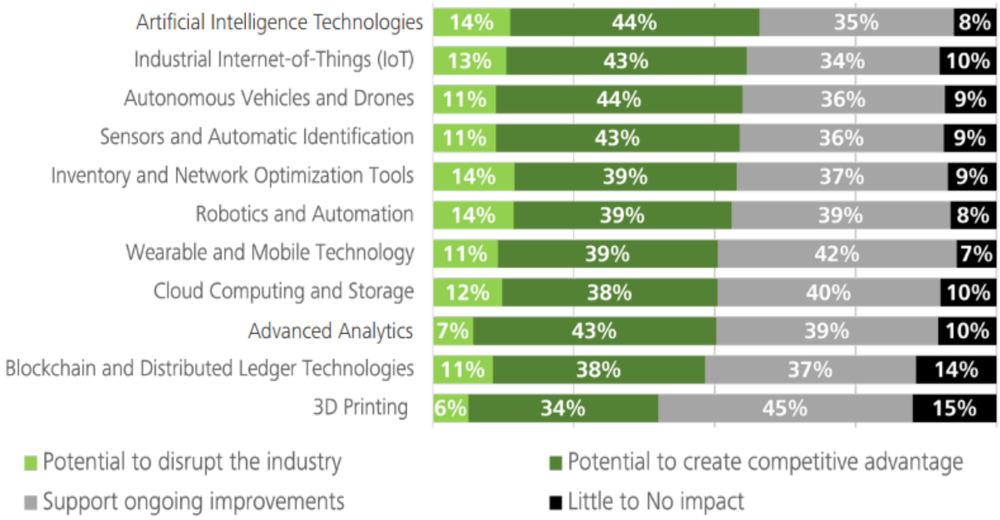


Figure 3. Impact of technologies on industry supply chain [19]

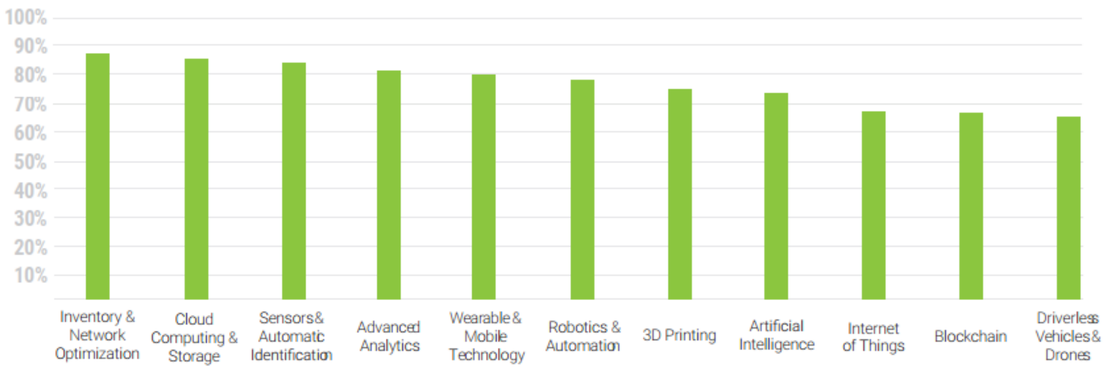


Figure 4. Logistic planning: Predicted adoption of key supply chain technologies [19]

Note: When specific committees are mentioned below, they are only examples of relevant committees, not a comprehensive list of all committees related to these topics.

The standards can be used in the planning phase of the infrastructure of an online delivery shop.

Nowadays, the planning for the building itself, the conveyor and the loader systems is using techniques of digital twins (SC 41), but it has to considers also sustainability of the needed IT and data centers (SC 39) in the entire lifecycle of the infrastructure. It is based on the forecasting of demand, which is based on the big data gained from the past (SC 42, SC 39, SC 35).

The IT infrastructure includes traditional end devices (e.g. SC 28 or SC 6), edge devices as well as the infrastructure for cloud services (SC 38, SC 40). And it uses physical not only logical security including access control (SC 27, SC 17, SC 37). To build up the infrastructure the planning team of such and online delivery system should bring together the standards of half a dozen of JTC 1 SCs before the operation is set up.

In this phase the supply chain has to be planned too. This includes also fleet management, of a fleet which includes human controlled, heteronomous and autonomous vehicles. The ships, self-driving and human driven vehicles, e.g., cars, trucks as well as drones (AG 19) have to be available in a sufficient number and size. Controlling such a fleet is based on powerful and intelligent communication networks. 5G (ITU) with its lower latency and higher speed allows here to maintain solutions of sizes, which were not possible before.

### Automated Warehousing:

When the operation starts, control and maintenance start too. The operation is dependent on working infrastructure with as few and as predictable maintenance as possible, since an interruption of the supply chain can depend on the reach of the online service affect customers and suppliers around the world. Global business means to a certain degree also global jurisdiction.

To predict the impact of a simple interruption for service can to be solved by IT using AI or not, big data and digital twins. If these intelligent solutions fall under AI laws or not depends on the jurisdiction of the country the custumer, the supplier or the company resides. Therefore the prediction of the maintenance is influenced by data gained from the whole network of edge devices (SC 38), contractual environment and supply chain data.

To monitor and control the warehouse and the delivery, edge devices and a powerful and secure communication infrastructure are key. The amount of data is growing exponentially, every item, every customer, every part of the delivery and storage infrastructure may need to communicate simultaneously (e.g., after a power outage in a larger area). Currently, the first minutes of New Year's are even a challenge for some networks.

### Customer service

Marketing might be the entry point of a good customer relationship, but a long lasting relation depends also of reliability, trustworthiness and support.

Intelligent computing can not only advertise based on the preferences of the client, it can also create a dynamic price based on the individual user profile and the current provision cost for the physical (e.g., food or clothing) and virtual (e.g., streams of music and films) products and services.

These goods might be delivered by different means, which might influence the pricing too. Delivering via drones to the location the customer is at the moment of delivery might be cheaper than delivering at the predefined address or costlier due to weather conditions. Delivery by one method might be charged differently than another, not due to speed, but based on carbon footprint due to the traffic situation.

Customers can be supported chatbots (e.g., based on Generative Pre-trained Transformers) and persons can be there only on demand or in specific situations.

The customers will interact in more individual ways than today. Aside of interacting via PC (IEC TC 100) mobiles (SC 6), more and more ordering via smart devices (SC 25, IEC TC 100), and wearables (IEC TC 124) will be common. This needs also new user interfaces to allow a safe and convenient navigation in the data. Voice interfaces can be one solution, but due to the noise surrounding us, smart cities might also provide terminals to track and redirect the shipment of your order.

For the fleet smart cities can also provide information, e.g., about traffic jams on the ground or in the air. The fastest route had never to be the shortest and this will not change with more traffic on more levels (ground, underground, airborne). For virtual goods like films especially when using older infrastructure, the management of bandwidth can still be improved in an intelligent and individual way.

Internal administration:

In the warehouse itself heteronomous and autonomous robots (ISO TC 299), humans supported by exoskeletons (SC 43) or without such a support, self-driving vehicles and normal lifting devices will work together. Collaborative safety will become even more critical than today.

Returns will be handled mostly automatically, using damage control which depends on the right position (robotics ISO TC 299), computer vision capabilities and product specific pattern recognition. Dynamic pricing helps to assess the re-selling price for a product and if reselling is not possible the circular economy system should decide about the right place recycle it.

“Paper work” will be automated, but also internal reporting. Edge devices will increase the amount of data available and by 5+G the data will be available faster and more secure than it is common today.

Digital information will also be analyzed automatically for unlawful content to protect the online delivery and its suppliers (e.g., digital service act (Regulation (EU) 2022/2065))

Such information will also be provided to suppliers and gained by them. The back-office computing will not only manage to inform the right supplier in an intelligent way only about the facts intended and necessary for him but intelligent computing will also help to find an alternative supplier, if needed. It can also help to propose appropriate terms and conditions tailored to the legal framework to the company as well as the supplier have the place of business considering ethical and fair treatment.

### 5.2.3 Scientific discovery

Computing for life science:

Intelligent computing is transforming our understanding and research of life science. In drug discovery and development, intelligent computing can greatly speed up extracting critical information from large amounts of data, analyzing complex protein structures, predicting protein interactions, performing virtual screening, predicting drug efficacy and performing molecular dynamics simulations. In biochemistry synthesis, intelligent computing has the potential to significantly improve the efficiency and effectiveness of biochemistry synthesis by providing tools for designing, optimizing, and analyzing chemical reactions. This can help accelerate the discovery of new drugs and compounds with important applications in fields.

Computing for material science:

Intelligent computing has become a powerful mean of studying materials’ properties and designing new materials. For example, computing can be used to analyze large amounts of data generated during material experiments, allowing researchers to identify patterns and relationships between different material parameters. This can help researchers better understand the behavior of materials and design new materials with specific properties. Computing can also be used to automate the screening of large numbers of potential new materials, allowing researchers to quickly identify promising candidates for further study. With the rapid development of materials science in near future, the application of intelligent computing will become more extensive and profound.

Computing for astronomy science:

In the field of astronomy science, intelligent computing is widely used in analyzing large amounts of astronomical data, including galaxies, planets, stars, and cosmic microwave background radiation. For example, intelligent computing can help astronomers improve the accuracy of black hole detection and recognition, achieve recognition and observation of unknown galaxies, and improve the accuracy of universe evolutionary simulation. In the future, with the continuous growth of astronomical data volume, the role of intelligent computing in astronomical research will become even more important.

Computing for geography and environmental science:

The application of intelligent computing in geography and environmental science is constantly expanding. It provides tools to process, analyze, and visualize large amounts of data for weather prediction, earth simulation, satellite remote sensing detection analysis, soil and water resources monitoring, carbon emissions analysis, and ocean current prediction, allowing researchers to study complex environmental systems and make informed decisions about environmental management and conservation. In the future, with the continuous enrichment of data and improvement of model accuracy, the application of real-time intelligent computing in environmental science will further expand and deepen.

# Section 6

## Status of Industries and Markets

The research presented in this chapter predominantly focuses on the market growth of artificial intelligence, as the available sources prioritize this specific keyword. However, it is worth noting that the term "intelligent computing" is still relatively uncommon in these market studies.

Despite the limited direct references to "intelligent computing," the exponential growth projections for artificial intelligence can still be relevant to the broader concept of intelligent computing. As intelligent computing encompasses not only AI but also other related technologies, the positive market outlook for AI indicates the overall potential for diverse intelligent computing applications.

The research has uncovered a clear indication of exponential market growth for intelligent computing and the application of artificial intelligence. We have not found even one source indicating a linear growth or a decline in this field. In this chapter, we provide illustrative examples from free resources [17-18] that estimate the impressive growth trajectory. These findings substantiate the promising prospects of intelligent computing in shaping the future of technology and its widespread applications across industries.

The global artificial intelligence market size was valued at USD 136.55 billion in 2022 and is projected to expand at a compound annual growth rate (CAGR) of 37.3% from 2023 to 2030. The continuous research and innovation directed by tech giants are driving the adoption of advanced technologies in industry verticals, such as automotive, healthcare, retail, finance, and manufacturing. For instance, in November 2020, Intel Corporation acquired Cnvrg.io, an Israeli company that develops and operates a platform for data scientists to build and run machine learning models, to boost its artificial intelligence business. Technology has always been an essential element for these industries, but artificial intelligence (AI) has brought technology to the center of organizations. For instance, from self-driving vehicles to crucial life-saving medical gear, AI is being infused virtually into every apparatus and program.

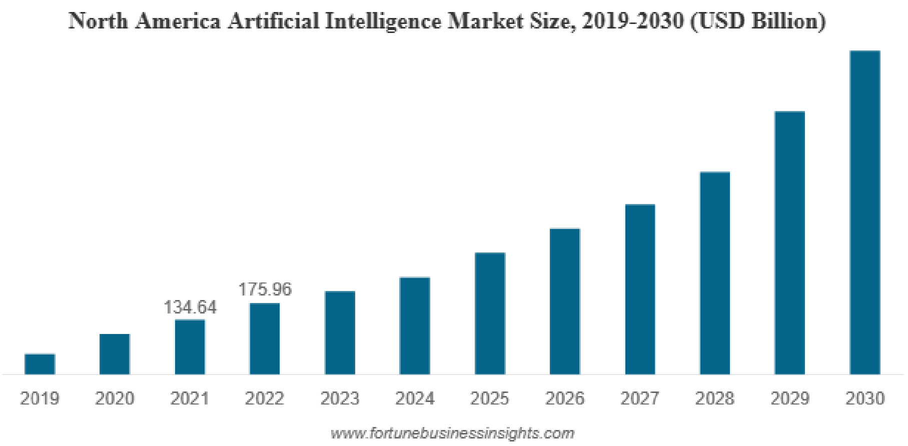


Figure 5. North America AI Market Size, 2019~2030 (USD Billion) [17]

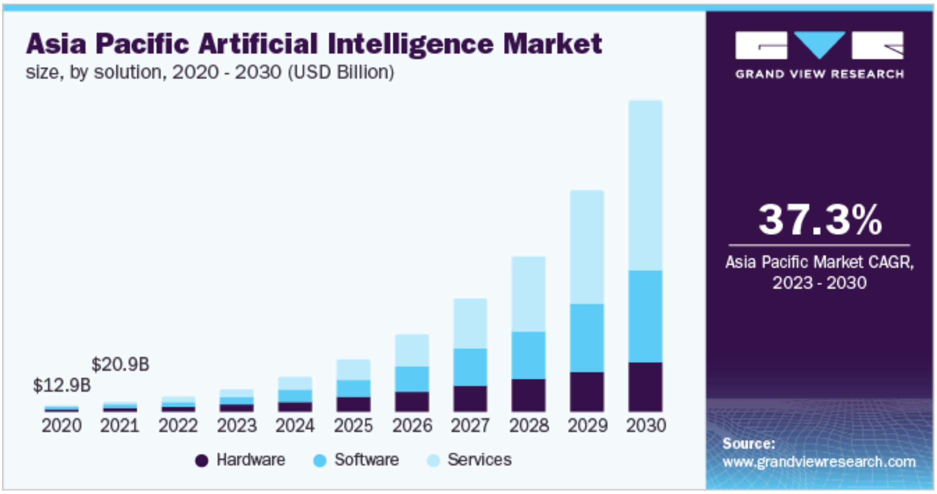


Figure 6. Asia Pacific AI Market Size, 2020~2030 (USD Billion) [18]

AI is proven to be a significant revolutionary element of the upcoming digital era. Tech giants like Amazon.com, Inc.; Google LLC; Apple Inc.; Facebook; International Business Machines Corporation; and Microsoft are investing significantly in the research and development of AI. These companies are working to make AI more accessible for enterprise use cases. Moreover, various companies adopt AI technology to provide a better customer experience. For instance, in March 2020, McDonald's made its most significant tech investment of USD 300 million to acquire an AI start-up in Tel Aviv to provide a personalized customer experience using artificial intelligence.

The essential fact accelerating the rate of innovation in AI is accessibility to historical datasets. Since data storage and recovery have become more economical, healthcare institutions and government agencies build unstructured data accessible to the research domain. Researchers are getting access to rich datasets, from historic rain trends to clinical imaging. The next-generation computing architectures, with access to rich datasets, are encouraging information scientists and researchers to innovate faster.

Furthermore, progress in profound learning and ANN (Artificial Neural Networks) has also fueled the adoption of AI in several industries, such as aerospace, healthcare, manufacturing, and automotive. ANN works in recognizing similar patterns and helps in providing modified solutions. Tech companies like Google Maps have been adopting ANN to improve their route and work on the feedback received using the ANN. ANN is substituting conventional machine learning systems to evolve precise and accurate versions. For instance, recent advancements in computer vision technology, such as GAN (Generative Adversarial Networks) and SSD (Single Shot MultiBox Detector), have led to digital image processing techniques. For instance, images and videos taken in low light, or low resolution, can be transformed into HD quality by employing these techniques. The continuous research in computer vision has built the foundation for digital image processing in security & surveillance, healthcare, and transportation, among other sectors. Such emerging methods in machine learning are anticipated to alter the manner AI versions are trained and deployed.

The WHO (World Health Organization) declared the novel coronavirus (COVID-19) outbreak a pandemic in 2020, causing a massive impact on businesses and humankind. This pandemic has emerged as an opportunity for AI-enabled computer systems to fight against the outbreak, as several tech giants and start-ups started working on preventing, mitigating, and containing the virus. For instance, the Chinese tech giant Alibaba's research institute Damo Academy has developed a diagnostic algorithm to detect new coronavirus cases with the chest CT (Computed Tomography) scan. The AI model used in the system has been trained with sample data from over 5,000 positive coronavirus cases. In June 2020, Lunit developed an AI solution for the X-ray analysis of the chest for simpler management of COVID-19 cases and offered assistance in interpreting, monitoring, and patient trials.

The COVID-19 outbreak is expected to stimulate the market growth of next-generation tech domains, including artificial intelligence, owing to the mandated WFH (work-from-home) policy due to the pandemic. For instance, LogMeIn, Inc., a U.S.-based company that provides SaaS (Software-as-a-Service) and cloud-based customer engagement and remote connectivity & collaboration services, has experienced a significant increase in new sign-ups across its product portfolios amid the pandemic.

Also, tech companies are expanding their product offerings and services to widen availability across the globe. For instance, in April 2020, Google LLC launched an AI-enabled chatbot called Rapid Response Virtual Agent for call centers. This chatbot is built to respond to issues customers might be experiencing due to the coronavirus (COVID-19) outbreak over voice, chat, and other social channels.

Software solutions led the market and accounted for more than 36.7% of the global revenue in 2022. This high percentage can be attributed to prudent advances in information storage capacity, high computing power, and parallel processing capabilities to deliver high-end services. Furthermore, the ability to extract data, provide real-time insight, and aid decision-making, has positioned this segment to capture the most significant portion of the market. Artificial intelligence software solutions include libraries for designing and deploying artificial intelligence applications, such as primitives, linear algebra, inference, sparse matrices, video analytics, and multiple hardware communication capabilities. The need for enterprises to understand and analyze visual content to gain meaningful insights is expected to spur the adoption of artificial intelligence software over the forecast period.

Companies adopt AI services to reduce their overall operational costs, yielding more profit. Artificial Intelligence as a Service, or AIaaS, is being used by companies to obtain a competitive advantage over the cloud. Artificial intelligence services include installation, integration, maintenance, and support undertakings. The segment is projected to grow significantly over the forecast period. AI hardware includes chipsets such as GPU (Graphics Processing Unit), CPU, application-specific integrated circuits (ASIC), and field-programmable gate arrays (FPGAs). GPUs and CPUs currently dominate the artificial intelligence hardware market due to their high computing capabilities required for AI frameworks. For instance, in September 2020, Atomwise partnered with GC Pharma to offer AI-based services to the former and help develop more effective novel hemophilia therapies.

### Key Companies & Market Share Insights

Vendors in the market are focusing on increasing the customer base to gain a competitive edge in the industry. Therefore, key players are taking several strategic initiatives, such as mergers and acquisitions, and partnerships with other major companies. For instance, in April 2020, Advanced Micro Devices announced a strategic alliance with Oxide Interactive LLC, a video game developer company, to develop graphics technologies for the cloud gaming market space. Both companies have planned to create a set of tools & techniques to address the real-time demands of cloud-based gaming. Also, in December 2019, Intel Corporation completed the acquisition of Habana Labs Ltd., an Israel-based deep learning company. This acquisition is anticipated to strengthen Intel Corporation's AI portfolio and boost its efforts in the AI silicon market.

In September 2019, IBM Watson Health signed an agreement with Guerbet, a France-based medical imaging company, to develop an AI software solution for cancer diagnostics and monitoring. This partnership has marked an extension of their earlier collaboration with live cancer diagnostics and monitoring. Furthermore, in January 2019, Intel Corporation announced its partnership with Alibaba Group Holding Limited (China) to co-develop an AI-powered tracking technology to be deployed at the Olympic Games 2020. This technology is based on Alibaba's cloud computing technology and Intel's hardware to power a deep learning application to extract athletes' 3D forms in competition or training.

### Recent Developments

- In June 2023, AMD unveiled its AI Platform strategy with the introduction of the AMD Instinct MI300 Series accelerator family, which included a first look at the AMD Instinct MI300X accelerator. The accelerator has been developed for the purpose of large language model training and inference for generative AI workloads.
- In September 2022, AiCure launched its clinical site services program that partners with sponsors and sites through the course of research and offers data-driven, actionable insights to minimize study risks and optimize the workflow.
- In August 2022, Atomwise announced an exclusive, strategic research collaboration with Sanofi for AI-powered drug discovery. As part of the deal, Sanofi is leveraging Atomwise's AtomNet platform for the purpose of computational discovery & research of up to 5 drug targets.
- In April 2023, H20.ai announced a strategic partnership with GeoTechnologies, a Japan-based provider of map data & location information solutions for vehicle navigation systems. The company has leveraged H20.ai's H2O AI Cloud to develop an AI-powered platform that uses on-board camera footage for gauging sidewalk safety.
- In July 2022, Clarifai announced the launch of its 'Clarifai Community' free service for enabling everyone to share, create, and use The World's AI. Moreover, it

also announced the development of the ‘AI Lake’ product category, which collects and centralizes every AI resource of an enterprise, and offers tools for sharing across the enterprise.

- In January 2023, Iris.ai announced that it had received the EIC Accelerator Blended finance, which is EIC’s flagship startup funding program. The funding includes a €2.4 million grant as well as up to €12 million in investments from the EIC and the European Investment Grant.
- In June 2022, Francisco Partners announced that it had acquired the healthcare analytics and data assets that formed a part of the Watson Health business of IBM. As part of this development, the new standalone company was named Merative, with its products organized in 6 product categories.
- In June 2023, IBM announced that it would be partnering with The All England Lawn Tennis Club at the 2023 Wimbledon Championship. The company would be leveraging IBM watsonx’s generative AI technology to product commentary for video highlights during the tournament. Additionally, the IBM AI Draw Analysis will offer insights regarding how favorable the draws would be for every singles player.
- In April 2022, Sensely and Keralty S.A.S, along with its American affiliate Sanitas USA, Inc., announced a multi-year partnership. Through this collaboration, Sanitas aims to power its next-gen mySanitas application by leveraging Sensely’s advanced visual UI and multilingual symptom assessment tool.
- In March 2023, Enlitic introduced the latest release of Enlitic Curie, a platform that makes it easy for radiology departments to manage their workflow. The platform hosts CurieIENDEX, which utilizes NLP and computer vision for the analysis & processing of medical images; and CurieIENCOG, which leverages AI to identify and protect Protected Health Information.

 

# Section 7

## Relevant Standardization Activities

This section provides standardization activities related to intelligent computing in ISO/IEC JTC 1, ISO/IEC committees and other international standardization organizations. Table 1 summarizes the relevant standardization activities.

Table 1. Relevant Standardization Activities

| Standard Organizations | Related groups |
|---|---|
| ISO/IEC JTC 1 | • SC 6 - Telecommunications and information exchange between systems<br>• SC 25 - Interconnection of information technology equipment<br>• SC 38 - Cloud computing and distributed platforms<br>• SC 41 - Internet of things and digital twin<br>• SC 42 - Artificial intelligence |
| ISO/IEC Sectoral | • IEC TC 62 - Medical equipment, software, and systems<br>• ISO TC 276 - Biotechnology |
| IEEE | • SA (Standards Association) |
| ETSI | • GS MEC (Group specification - Multi-access Edge Computing) |
| ITU-T | • SG11 - Signalling requirements, protocols, test specifications and combating counterfeit telecommunication/ICT devices<br>• SG13 - Future networks and emerging network technologies<br>• FG-AN - Focus group on Autonomous Networks |
| IETF | • SPRING (Source Packet Routing in Networking) WG<br>• 6MAN (IPv6 Maintenance) WG |

### 7.1 Overview of standardization activities in JTC 1

#### 7.1.1 General

Terms and Concepts:

SC 38, SC 41, and SC42 published 9 documents (4 additional ones are in work) regarding the vocabulary and concepts which can be considered under the umbrella term “intelligent computing”. The cover areas like Internet of Things (IoT), Digital Twin, Big data, AI and distributed platforms. For a detailed list see Annex A 1.1. Terms and Concepts.

Framework and Architectures:

SC38, SC 41, and SC42 published 10 documents (4 additional ones are in work) regarding the frameworks and architectures which can be considered under the umbrella term “intelligent computing”. The cover areas like Internet of Things (IoT), Digital Twin, Big data, AI and distributed platforms. For a detailed list see Annex A 1.1. Terms and Concepts.

Diverse:

Standards in this section are rather focused on formal topics like the evaluation process, electronic labeling or the development of policies and contracts. 12 documents are already published at the time of the publication of this standard, 5 are in work.

#### 7.1.2 Compute resource (Intelligent provisioning of computing power)

Computing resources are in two ways part of the AI ecosystem. One is the artificial intelligence centric point of view as described in ISO/IEC 22989:2022. The resource pools are mainly a base layer for the artificial intelligence. They are here only scarcely seen as major part of intelligent systems or as vertical sector on its own rights.

Another architectural overview in the field of intelligent computing is the diagram provided in ISO/IEC 30141:2018 Internet of Things (IoT) – Reference architecture [6]. In this view, AI might be assumed in the yellow hexagons at the Application & Services Level and at the level of user applications.

Although both modes of representation are, of course, correct, and important for intelligent computing, they differ considerably from each other. However, both present the world very differently from their respective perspectives and have on first glance little in common with each other.

### Servers

SC 38 and SC 42 published 3 overview documents about the computing infrastructure, 2 additional ones are under work.

### Firmware, middleware and other infrastructure related software

Firmware, middleware and other infrastructure related software is basically covered by JTC 1/SC 6 “Telecommunications and information exchange between systems “, SC 7 “software” and SC 25 “Interconnection of information technology equipment”.

SC 6 is focused on the telecommunication infrastructure, which we daily use in our lives and which makes the cooperation between different entities of the infrastructure possible with the required bandwidth and under the required controllable circumstances. SC 6 also cooperates in JTC 1/AG 19 to develop unmanned vehicles. JTC 1/SC 7 provides the basic software processes and techniques, which are at the end of the day also used to develop AI and ML applications. JTC 1/ SC 25 is responsible for the infrastructure of distributed systems.

SC 41 and SC 42 published several documents related to software technology, but on a higher level.

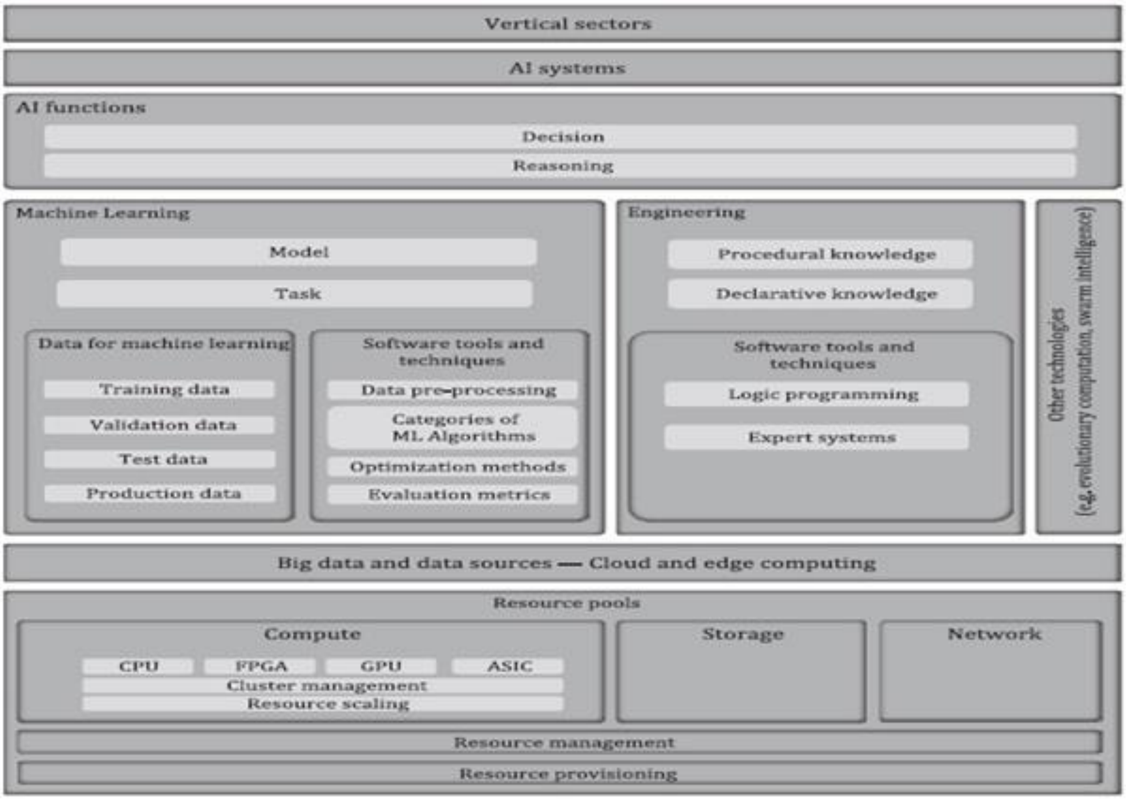


Figure 7. AI ecosystem [3]

 

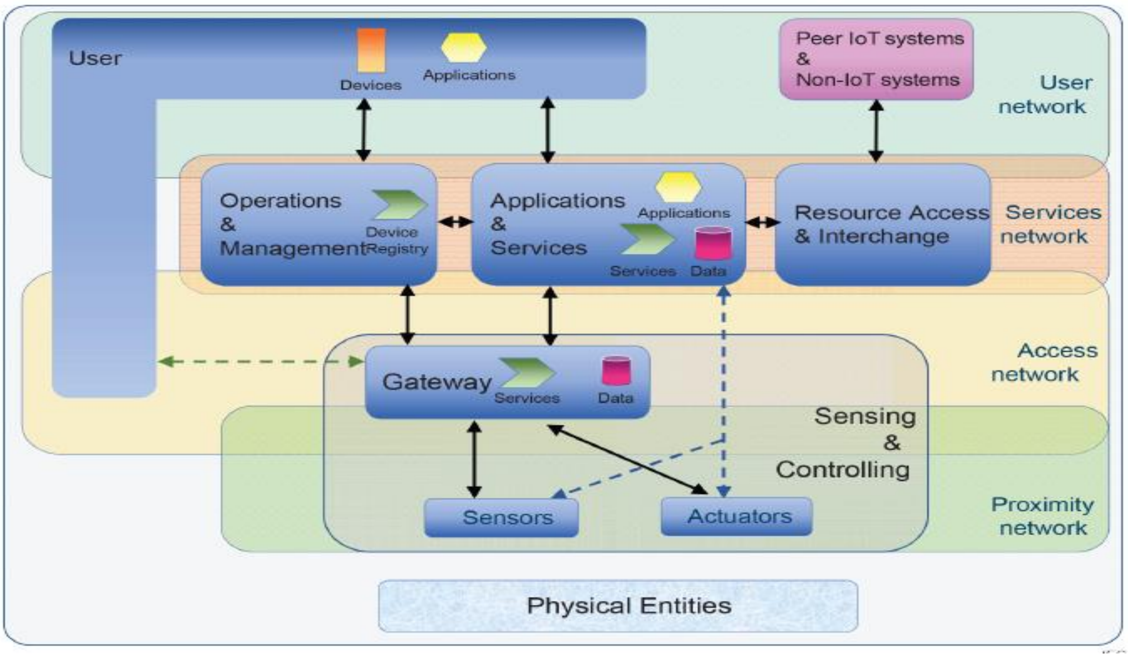


Figure 8. IoT RA networking view [6]

### 7.1.3 Data resource (Intelligent provisioning of Data resources)

JTC 1/SC 38 is currently the leading committee regarding standards for data use in intelligent computing with 5 published documents, but JTC 1/SC 42 has started several (6) projects focussed on data for artificial intelligence

Further details can be found in Annex A

### 7.1.4 Network resource (Intelligent interoperability and communication)

**Network**

Network standards are currently mainly published in JTC 1/SC 41 (Sensor Network are the area in focus). JTC 1/SC 38 has also published some standards in the area of intelligent computing. An important source of standards regarding intelligent networks are the established committees for networking and communication like JTC 1/SC 6 and SC 25.

**Interoperability**

JTC 1/SC 41 is also the committee with the most published horizontal standards regarding interoperability, again with a focus on sensor networks and IoT.

JTC 1/SC 38 has also published one standard regarding interoperability in a cloud environment.

Further details can be found in Annex A.

### 7.1.5 Applications and Use Cases

JTC 1/SC 41 and SC 42 have also published use cases for IoT, Big Data and AI and work on new ones or on updating the existing standards.

Further details can be found in Annex A.

## 7.2 Sectoral activities in ISO/IEC

There is a lot of activity inside of ISO/IEC related to intelligent computing.

Examples from the health-related sector:
- IEC 60601-4-1 “Degrees of autonomy”
- ISO/AWI 18374 Dentistry — Artificial intelligence (AI) based 2D X-ray analysis — Data generation, data annotation and data processing
- ISO 20691:2022 Biotechnology — Requirements for data formatting and description in the life sciences
- IEC 63450 Testing of Artificial Intelligence / Machine Learning-enabled Medical Devices

## 7.3 Other standardization activities

### 7.3.1 IEEE SA

IEEE SA stands for IEEE Standards Association, which is a global standards development organization within the Institute of Electrical and Electronics Engineers (IEEE). IEEE SA is responsible for developing and publishing technical standards for various fields, including telecommunications, power and energy, information technology, and many others. These standards are developed through a collaborative and consensus-based process that involves industry experts, academics, government representatives, and other stakeholders from around the world.

IEEE SA has published several standards related to intelligent computing and currently under development by IEEE SA.

Further details can be found in Annex A.

### 7.3.2 ETSI

ETSI (European Telecommunications Standards Institute) is an independent, non-profit organization that develops standards for information and communication technologies (ICT) in Europe. ETSI's mission is to develop and promote standards that ensure the interoperability, reliability, and security of ICT systems, and to facilitate their global deployment. ETSI works closely with industry stakeholders, governments, and other standardization organizations to develop consensus-based standards that address emerging technologies and market requirements. ETSI's scope of work covers a wide range of ICT domains, including telecommunications, broadcasting, mobile communications, digital television, and intelligent transport systems, among others.

ETSI has published several standards related to intelligent computing and developed several standards related to Artificial Intelligence (AI) and Machine Learning (ML), which are closely related to intelligent computing.

Further details can be found in Annex A.

### 7.3.3 ITU-T

The Study Groups of ITU's Telecommunication Standardization Sector (ITU-T) assemble experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs).

#### 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. As part of its work SG11 develops signalling requirements and protocols for VoLTE/ViLTE interconnection, including signalling requirements for ENUM infrastructure and IMS interconnection. This work focuses on protocol enhancements required in support of roaming, interworking, security, and real-time services innovation such as interactive services in LTE/IMT-2020 networks and beyond. Ongoing SG11 research considers IMT-2020 and network 2030, including the use of AI-based algorithms in signalling exchange. ITU-T SG11 is developing several recommendations related to intelligent computing and intelligent networks. Further details can be found in Annex A.

#### ITU-T SG13

The ITU-T Recommendations developed by ITU-T Study Group 13 (SG13) address the requirements, architectures, functional capabilities and application programming interfaces of converged future networks. It is responsible for studies relating to future computing, including cloud computing and data handling in ICT networks. This work covers network capabilities and technologies to support data utilization, exchange, sharing, and data quality assessment. It also covers computing-aware networking as well as end-to-end awareness, control and management of future computing, including cloud, cloud security and data handling. ITU-T SG13 is developing several recommendations related to intelligent computing and intelligent networks. Further details can be found in Annex A.

#### ITU-T FG-AN

The ITU-T Focus Group on Autonomous Networks (FG-AN) was established in 2017 by the International Telecommunication Union (ITU) as a platform for experts from industry, academia, and government to discuss and collaborate on the development of autonomous networks.

The goal of FG-AN is to define a common framework for the design, deployment, and operation of autonomous networks, which can operate and adapt to changes without human intervention. This includes technologies such as artificial intelligence, machine learning, and distributed computing.

The focus group aims to develop technical specifications, use cases, and best practices for autonomous networks, with a particular focus on the telecommunications industry. The group also collaborates with other standardization organizations, such as the IEEE and ETSI, to ensure alignment and avoid duplication of efforts.

FG-AN has several working groups that focus on different aspects of autonomous networks, such as architecture, security, and performance. The outputs of FG-AN are intended to inform the work of ITU-T Study Group 13, which is responsible for the standardization of network and service management. Ultimately, the goal is to promote the development and adoption of autonomous networks to improve the efficiency, reliability, and security of telecommunications networks.

Autonomous networks, which are the focus of FG-AN, are a prime example of intelligent computing applied to telecommunications networks. The goal of autonomous networks is to create systems that can adapt and optimize their performance without human intervention, using machine learning and other AI techniques to make decisions based on real-time data.

In addition to autonomous networks, there are many other applications of intelligent computing in various fields such as healthcare, finance, and transportation. For example, machine learning algorithms can be used to analyze medical images and assist in diagnosing diseases, while predictive analytics can be used to forecast financial trends and inform investment decisions.

The ITU-T FG-AN has identified several working items that it is currently focusing on:

- Architecture and Frameworks: This working item aims to develop a common architecture and framework for autonomous networks that can be used by network operators, vendors, and other stakeholders. It includes defining the functional blocks, interfaces, and protocols required to enable autonomous operation.
- Use Cases and Requirements: This working item focuses on developing a set of use cases and requirements that can guide the development and implementation of autonomous networks. It includes identifying the scenarios where autonomous operation can provide the most value and defining the specific capabilities required to support those scenarios.
- Security: This working item focuses on ensuring the security of autonomous networks. It includes identifying potential threats and vulnerabilities and developing security mechanisms to mitigate those risks. It also includes developing guidelines for securing autonomous networks, including authentication, access control, and encryption.
- Performance: This working item focuses on optimizing the performance of autonomous networks. It includes defining metrics for measuring the performance of autonomous networks and developing algorithms and techniques for improving performance.
- Network Management and Operations: This working item focuses on developing new approaches to network management and operations that can support autonomous networks. It includes identifying the new roles and responsibilities required for autonomous operation and developing the tools and processes needed to manage and operate these networks.

### 7.3.4 IETF

The Internet Engineering Task Force (IETF), established at the end of 1985, is the most authoritative technical standardization organization for the global internet. The IETF brings together a large number of network designers, operators, suppliers, and researchers who focus on the development and operation of internet architecture, forming a large open international technology community. The mission of IETF is to influence the way people design, operate, use, and manage the Internet by publishing high-quality technical documents, so that the Internet can operate better. Its main task is to be responsible for the research and development of internet related technical specifications. Currently, the majority of international internet technology standards come from the IETF. IETF has published several RFCs related to network resource in intelligent computing. Further details can be found in Annex A.

# Section 8

## Challenges to JTC 1

The use cases for intelligent computing are so broad that they go beyond the scope of individual SCs.

It is therefore necessary to identify the strategic use case areas that make it necessary to develop a unified approach across SC boundaries. The IEC white papers on Artificial Intelligence across industries [14] and Edge Intelligence [15] can be used as a starting point in this regard.

For the most important use cases an aligned approach across all related committees regarding the concepts, terms and approaches would be beneficial. It should be applicable in real life without the uncertainty and need of country or even company-specific interpretations how such an alignment can look like, and which concepts or terms are the leading ones.

Examples, where such a necessity has already been recognized, are drones, and the first initiatives in the direction of functional safety and medicine have already been set up or are under discussion.  Other important use cases could be, Industry 4.0 – Logistic and intelligent transport, Intelligent Communication Networks in smart cities, or Brain Computer Interfaces, which are ripe for medical approval.

New challenges due to new technologies, will arise in the next few years and will again require a look beyond the horizon of individual SCs and maybe even across the ISO/IEC borders (e.g., ITU network standards).

 

# Section 9

## Conclusion

This report has been compiled with the objective of advancing the field of intelligent computing and fostering coherence among various committees. It acknowledges that the concept of intelligent computing, serving as an umbrella term, undergoes continuous evolution with the emergence of new technologies and applications. Additionally, it provides use cases for intelligent computing and emphasizes the necessity for standardizing terms and concepts. This standardization is essential to accurately identify and elaborate on the most impactful and relevant use cases for intelligent computing, thereby facilitating clearer communication and more effective implementation across the field.

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[20] IETF RFC 8968 - Segment Routing over IPv6 (SRv6) Network Programming (February 2021)

# Annex A

## List of standards related to "Intelligent Computing"

### A-1. General

#### Terms and Concepts

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 20924:2024 | 60.60 | Information technology — Internet of Things (IoT) and digital twin — Vocabulary | SC 41 |
| ISO/IEC AWI 30173:2023 | 60.60 | Digital twin — Concepts and terminology | SC 41 |
| ISO/IEC DIS 12792 | 40.20 | Information technology — Artificial intelligence — Transparency taxonomy of AI systems | SC 42 |
| ISO/IEC 20546:2019 | 90.60 | Information technology — Big data — Overview and vocabulary | SC 42 |
| ISO/IEC 22989:2022 | 60.60 | Information technology — Artificial intelligence — Artificial intelligence concepts and terminology | SC 42 |
| ISO/IEC TR 24028:2020 | 60.60 | Information technology — Artificial intelligence — Overview of trustworthiness in artificial intelligence | SC 42 |
| ISO/IEC TR 24368:2022 | 60.60 | Information technology — Artificial intelligence — Overview of ethical and societal concerns | SC 42 |
| ISO/IEC TS 5928:20203 | 60.60 | Information technology — Cloud computing and distributed platforms — Taxonomy for digital platforms | SC 38 |
| ISO/IEC 18384-1:2016 | 90.93 | Information technology — Reference Architecture for Service Oriented Architecture (SOA RA) — Part 1: Terminology and concepts for SOA | SC 38 |
| ISO/IEC 19086-1:2016 | 90.93 | Information technology — Cloud computing — Service level agreement (SLA) framework — Part 1: Overview and concepts | SC 38 |
| ISO/IEC 22123-1:2023 | 60.60 | Information technology — Cloud computing — Part 1: Vocabulary | SC 38 |
| ISO/IEC DIS 22123-2 | 60.60 | Information technology — Cloud computing — Part 2: Concepts | SC 38 |

#### Framework and Architecture

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|

| | | | |
|---|---|---|---|
| ISO/IEC 30141:2018 | 60.60 | Internet of Things (IoT) — Reference Architecture | SC 41 |
| ISO/IEC TS 30141:2024 | 60.60 | Internet of Things (IoT) — Trustworthiness principles | SC 41 |
| ISO/IEC 5392:2024 | 60.60 | Information technology — Artificial intelligence — Reference architecture of knowledge engineering | SC 42 |
| ISO/IEC TR 20547-1:2020 | 60.60 | Information technology — Big data reference architecture — Part 1: Framework and application process | SC 42 |
| ISO/IEC 20547-3:2020 | 60.60 | Information technology — Big data reference architecture — Part 3: Reference architecture | SC 42 |
| ISO/IEC 23053:2022 | 60.60 | Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML) | SC 42 |
| ISO/IEC DTS 10866 | 50.20 | Information technology — Cloud computing and distributed platforms — Framework and concepts for organizational autonomy and digital sovereignty | SC 38 |
| ISO/IEC 17789:2014 | 90.92 | Information technology — Cloud computing — Reference architecture | SC 38 |
| ISO/IEC 18384-2:2016 | 90.93 | Information technology — Reference Architecture for Service Oriented Architecture (SOA RA) — Part 2: Reference Architecture for SOA Solutions | SC 38 |
| ISO/IEC 18384-3:2016 | 90.93 | Information technology — Reference Architecture for Service Oriented Architecture (SOA RA) — Part 3: Service Oriented Architecture ontology | SC 38 |
| ISO/IEC 19086-2:2018 | 60.60 | Cloud computing — Service level agreement (SLA) framework — Part 2: Metric model | SC 38 |
| ISO/IEC 19086-2:2018/Amd 1:2023 | 60.60 | Cloud computing — Service level agreement (SLA) framework — Part 2: Metric model — Amendment 1 | SC 38 |
| ISO/IEC 22123-3:2023 | 60.60 | Information technology — Cloud computing — Part 3: Reference architecture | SC 38 |

## Diverse

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 30169:2022 | 60.60 | Internet of Things (IoT) — IoT applications for electronic label system (ELS) | SC 41 |
| ISO/IEC TR 30174:2021 | 60.60 | Internet of Things (IoT) — Socialized IoT system resembling human social interaction dynamics | SC 41 |
| ISO/IEC TS 8200:2024 | 60.60 | Information technology — Artificial intelligence — Controllability of automated artificial intelligence systems | SC 42 |
| ISO/IEC TR 20547-5:2018 | 60.60 | Information technology — Big data reference architecture — Part 5: Standards roadmap | SC 42 |
| ISO/IEC TR 24029-1:2021 | 60.60 | Artificial Intelligence (AI) — Assessment of the robustness of neural networks — Part 1: Overview | SC 42 |

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|---|---|---|---|
| ISO/IEC 24029-2:2023 | 60.60 | Artificial intelligence (AI) — Assessment of the robustness of neural networks — Part 2: Methodology for the use of formal methods | SC 42 |
| ISO/IEC 24668:2022 | 60.60 | Information technology — Artificial intelligence — Process management framework for big data analytics | SC 42 |
| ISO/IEC TS 25058:2024 | 60.60 | Software and systems engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Guidance for quality evaluation of AI systems | SC 42 |
| ISO/IEC 25059:2023 | 90.92 | Software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Quality model for AI systems | SC 42 |
| ISO/IEC 38507:2022 | 60.60 | Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations | SC 42 |
| ISO/IEC 42001:2023 | 60.60 | Information technology — Artificial intelligence — Management system | SC 42 |
| ISO/IEC TR 3445:2022 | 60.60 | Information technology — Cloud computing — Audit of cloud services | SC 38 |
| ISO/IEC TR 5469:2024 | 60.60 | Artificial intelligence — Functional safety and AI systems | SC 42 |
| ISO/IEC 19086-3:2017 | 90.93 | Information technology — Cloud computing — Service level agreement (SLA) framework — Part 3: Core conformance requirements | SC 38 |
| ISO/IEC TR 22678:2019 | 60.60 | Information technology — Cloud computing — Guidance for policy development | SC 38 |
| ISO/IEC TR 23187:2020 | 60.60 | Information technology — Cloud computing — Interacting with cloud service partners (CSNs) | SC 38 |
| ISO/IEC TR 23613:2020 | 60.60 | Information technology — Cloud computing — Cloud service metering elements and billing modes | SC 38 |
| ISO/IEC TR 23951:2020 | 60.60 | Information technology — Cloud computing — Guidance for using the cloud SLA metric model | SC 38 |

## A-2. Computing Infrastructure

### Servers

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC TR 17903:2024 | 60.60 | Information technology — Artificial intelligence — Overview of machine learning computing devices | SC 42 |
| ISO/IEC TR 24372:2021 | 60.60 | Information technology — Artificial intelligence (AI) — Overview of computational approaches for AI systems | SC 42 |
| ISO/IEC DTS 7339 | 50.92 | Information technology — Cloud computing — Overview of platform capabilities type and platform as a service | SC 38 |

| | | | |
|---|---|---|---|
| ISO/IEC TS 23167:2020 | 90.20 | Information technology — Cloud computing — Common technologies and techniques | SC 38 |
| ISO/IEC TR 23188:2020 | 60.60 | Information technology — Cloud computing — Edge computing landscape | SC 38 |

### Software

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 18598:2016 | 60.60 | Information technology — Automated infrastructure management (AIM) systems — Requirements, data exchange and applications | SC 25 |
| ISO/IEC 18598:2016/Amd 1:2021 | 60.60 | Information technology — Automated infrastructure management (AIM) systems — Requirements, data exchange and applications — Amendment 1 | SC 25 |

## A-3. Date resource (Intelligent provisioning of Data Resources)

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 5259-1:2024 | 60.60 | Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 1: Overview, terminology, and examples | SC 42 |
| ISO/IEC FDIS 5259-2 | 50.20 | Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 2: Data quality measures | SC 42 |
| ISO/IEC 5259-3:2024 | 60.60 | Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 3: Data quality management requirements and guidelines | SC 42 |
| ISO/IEC CD 5259-4:2024 | 60.60 | Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 4: Data quality process framework | SC 42 |
| ISO/IEC FDIS 5259-5 | 50.00 | Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 5: Data quality governance framework | SC 42 |
| ISO/IEC 8183:2023 | 60.60 | Information technology — Artificial intelligence — Data life cycle framework | SC 42 |
| ISO/IEC 19944-1:2020 | 60.60 | Cloud computing and distributed platforms — Data flow, data categories and data use — Part 1: Fundamentals | SC 38 |
| ISO/IEC 19944-2:2022 | 60.60 | Cloud computing and distributed platforms — Data flow, data categories and data use — Part 2: Guidance on application and extensibility | SC 38 |
| ISO/IEC 22624:2020 | 60.60 | Information technology — Cloud computing — Taxonomy based data handling for cloud services | SC 38 |
| ISO/IEC TR 23186:2018 | 60.60 | Information technology — Cloud computing — Framework of trust for processing of multi-sourced data | SC 38 |
| ISO/IEC 23751:2022 | 60.60 | Information technology — Cloud computing and distributed platforms — Data sharing agreement (DSA) framework | SC 38 |

## A-4. Network resource

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 19637:2016 | 60.60 | Information technology — Sensor network testing framework | SC 41 |
| ISO/IEC 20005:2013 | 90.60 | Information technology — Sensor networks — Services and interfaces supporting collaborative information processing in intelligent sensor networks | SC 41 |
| ISO/IEC TR 22560:2017 | 60.60 | Information technology — Sensor networks — Use cases of aeronautics industry: Active Air-flow Control | SC 41 |
| ISO/IEC 29182-1:2013 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 1: General overview and requirements | SC 41 |
| ISO/IEC 29182-2:2013 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 2: Vocabulary and terminology | SC 41 |
| ISO/IEC 29182-3:2014 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 3: Reference architecture views | SC 41 |
| ISO/IEC 29182-4:2013 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 4: Entity models | SC 41 |
| ISO/IEC 29182-5:2013 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 5: Interface definitions | SC 41 |
| ISO/IEC 29182-6:2014 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 6: Applications | SC 41 |
| ISO/IEC 29182-7:2015 | 60.60 | Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 7: Interoperability guidelines | SC 41 |
| ISO/IEC 30101:2014 | 60.60 | Information technology — Sensor networks: Sensor network and its interfaces for smart grid system | SC 41 |
| ISO/IEC 30128:2014 | 60.60 | Information technology — Sensor networks — Generic Sensor Network Application Interface | SC 41 |
| ISO/IEC 30140-1:2018 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Part 1: Overview and requirements | SC 41 |
| ISO/IEC 30140-2:2017 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Part 2: Reference architecture | SC 41 |
| ISO/IEC 30140-3:2018 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Part 3: Entities and interface | SC 41 |
| ISO/IEC 30142-2:2022 | 60.60 | Internet of Things (IoT) — Underwater acoustic sensor network (UWASN) — Network management system — Part 2: Underwater management information base (u-MIB) | SC 41 |
| ISO/IEC 30142:2020 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Network management system overview and requirements | SC 41 |

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|---|---|---|---|
| ISO/IEC 30143:2020 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Application profiles | SC 41 |
| ISO/IEC 30144:2020 | 60.60 | Information technology — Sensor network system architecture for power substations | SC 41 |
| ISO/IEC TR 30148:2019 | 60.60 | Internet of Things (IoT) — Technical requirements and application of sensor network for wireless gas meters. | SC 41 |
| ISO/IEC TR 30164:2020 | 60.60 | Internet of things (IoT) — Edge computing | SC 41 |
| ISO/IEC 30165:2021 | 60.60 | Internet of Things (IoT) — Real-time IoT framework | SC 41 |
| ISO/IEC TR 30166:2020 | 60.60 | Internet of things (IoT) — Industrial IoT | SC 41 |
| ISO/IEC 30171-1:2022 | 60.60 | Internet of Things (IoT) — Base-station based underwater wireless acoustic network (B-UWAN) — Part 1: Overview and requirements | SC 41 |
| ISO/IEC 5140:2024 | 60.60 | Information technology — Cloud computing — Concepts for multi-cloud and the use of multiple cloud services | SC 38 |
| ISO/IEC 17203:2017 | 90.93 | Information technology — Open Virtualization Format (OVF) specification | SC 38 |
| ISO/IEC 17963:2013 | 90.93 | Web Services for Management (WS-Management) Specification | SC 38 |
| ISO/IEC TR 30102:2012 | 60.60 | Information technology — Distributed Application Platforms and Services (DAPS) — General technical principles of Service Oriented Architecture | SC 38 |

### A-5. Interoperability

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC 21823-1:2019 | 60.60 | Internet of things (IoT) — Interoperability for IoT systems — Part 1: Framework | SC 41 |
| ISO/IEC 21823-2:2020 | 60.60 | Internet of things (IoT) — Interoperability for IoT systems — Part 2: Transport interoperability | SC 41 |
| ISO/IEC 21823-3:2021 | 60.60 | Internet of things (IoT) — Interoperability for IoT systems — Part 3: Semantic interoperability | SC 41 |
| ISO/IEC 21823-4:2022 | 60.60 | Internet of things (IoT) — Interoperability for IoT systems — Part 4: Syntactic interoperability | SC 41 |
| ISO/IEC 30140-4:2018 | 60.60 | Information technology — Underwater acoustic sensor network (UWASN) — Part 4: Interoperability | SC 41 |
| ISO/IEC 30161:2020 | 60.60 | Internet of Things (IoT) — Requirements of IoT data exchange platform for various IoT services | SC 41 |
| ISO/IEC 30162:2022 | 60.60 | Internet of Things (IoT) — Compatibility requirements and model for devices within industrial IoT systems | SC 41 |

| | | | |
|---|---|---|---|
| ISO/IEC 30163:2021 | 60.60 | Internet of Things (IoT) — System requirements of IoT/SN technology-based integrated platform for chattel asset monitoring supporting financial services | SC 41 |
| ISO/IEC TR 30167:2021 | 60.60 | Internet of Things (IoT) — Underwater communication technologies for IoT | SC 41 |
| ISO/IEC TR 30176:2021 | 60.60 | Internet of Things (IoT) —- Integration of IoT and DLT/blockchain: Use cases | SC 41 |
| ISO/IEC 30179:2023 | 60.60 | Internet of Things (IoT) — Overview and general requirements of IoT system for ecological environment monitoring | SC 41 |
| ISO/IEC TR 5469:2024 | 60.60 | Artificial intelligence — Functional safety and AI systems | SC 42 |
| ISO/IEC 19941:2017 | 90.20 | Information technology — Cloud computing — Interoperability and portability | SC 38 |

### A-6. Applications and Use Case

| Standard Number | Stage | Standard Title | JTC 1/SC |
|---|---|---|---|
| ISO/IEC TR 22417:2017 | 60.60 | Information technology — Internet of things (IoT) use cases | SC 41 |
| ISO/IEC 30172:2023 | 60.60 | Digital Twin — Use cases | SC 41 |
| ISO/IEC 5338:2023 | 60.60 | Information technology — Artificial intelligence — AI system life cycle processes | SC 42 |
| ISO/IEC 5339:2024 | 60.60 | Information technology — Artificial intelligence — Guidance for AI applications | SC 42 |
| ISO/IEC TR 20547-2:2018 | 60.60 | Information technology — Big data reference architecture — Part 2: Use cases and derived requirements | SC 42 |
| ISO/IEC TR 24030:2021 | 90.92 | Information technology — Artificial intelligence (AI) — Use cases | SC 42 |
| ISO/IEC TR 24030:2024 | 60. 60 | Information technology — Artificial intelligence (AI) — Use cases | SC 42 |
| ISO/IEC 30147:2021 | 60.60 | Information technology — Internet of things — Methodology for trustworthiness of IoT system/service | SC 41 |
| ISO/IEC TS 4213:2022 | 60.60 | Information technology — Artificial intelligence — Assessment of machine learning classification performance | SC 42 |
| ISO/IEC CD TS 6254 | 30.60 | Information technology — Artificial intelligence — Objectives and approaches for explainability and interpretability of ML models and AI systems | SC 42 |
| ISO/IEC DTS 12791.2 | 50.20 | Information technology — Artificial intelligence — Treatment of unwanted bias in classification and regression machine learning tasks | SC 42 |
| ISO/IEC AWI TS | 20.00 | Information technology — Artificial intelligence — Verification and | SC 42 |

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|---|---|---|---|
| 17847 | | validation analysis of AI systems | |
| ISO/IEC CD TR 20226 | 30.60 | Information technology — Artificial intelligence — Environmental sustainability aspects of AI systems | SC 42 |
| ISO/IEC 23894:2023 | 60.60 | Information technology — Artificial intelligence — Guidance on risk management | SC 42 |
| ISO/IEC TR 24027:2021 | 60.60 | Information technology — Artificial intelligence (AI) — Bias in AI systems and AI aided decision making | SC 42 |
| ISO/IEC AWI TS 29119-11 | 20.00 | Software and systems engineering — Software testing — Part 11: Testing of AI systems | SC 42 |
| ISO/IEC DIS 42005 | 40.60 | Information technology — Artificial intelligence — AI system impact assessment | SC 42 |

## A-7. IEEE SA

### Published standards

| Standard Number | Standard Title | Description |
|---|---|---|
| IEEE 1872-2015 | Standard for Ontologies for Robotics and Automation | Provides a framework for developing ontologies for robotics and automation, which can help improve the interoperability and reuse of knowledge in these domains. |
| IEEE 2089-2021 | Standard for an Age-Appropriate Digital Services Framework Based on the 5Rights Principles for Children | Provides guidelines for designing digital services that are age-appropriate and protect children's rights. |
| IEEE 1876-2019 | Standard for Networked Smart Learning Objects for Online Laboratories | Provides a framework for developing networked smart learning objects (NSLOs) for online laboratories, which can help improve the quality and accessibility of remote and distance learning. |
| IEEE 2830-2021 | Standard for Technical Framework and Requirements of Trusted Execution Environment based Shared Machine Learning | Specifies the framework and requirements for machine learning models operating in trusted execution environments. |
| EEE 3652.1-2020 | Guide for Architectural Framework and Application of Federated Machine Learning | Provides a framework for federated machine learning, promoting secure and efficient distributed AI systems. |
| IEEE 7000-2021 | Standard for Model Process for Addressing Ethical Concerns During System Design | Provides a systematic approach for identifying and addressing ethical concerns during the design and development of automated and intelligent systems. |
| IEEE 7001-2021 | Standard for Transparency of Autonomous Systems | Defines requirements for transparency in the operation of autonomous systems, ensuring their decisions and actions are understandable. |
| IEEE 1856-2017 | Standard Framework for Prognostics and Health Management of Electronic Systems | Provides a framework for implementing prognostics and health management (PHM) in electronic systems, including guidelines for classification, planning, and technique selection. It covers all PHM aspects and aids practitioners in choosing the best strategies for their needs. |

### Under development

| Project Number | Project Title | Description |
|---|---|---|
| IEEE P7003 | Algorithmic Bias Considerations | Develop guidelines and best practices to identify, mitigate, and prevent algorithmic bias in automated and intelligent systems. |
| IEEE P3123 | Artificial Intelligence and Machine Learning (AI/ML) Terminology and Data Formats | Defines specific terminology and data formats used in AI/ML to ensure clarity and consistency. |
| IEEE P3119 | Procurement of Artificial Intelligence and Automated Decision Systems | Provides a framework for government procurement of AI and ADS, emphasizing ethical design, responsible innovation, and participatory processes across all stages, including development and public-private partnerships. |
| IEEE P2784 | Guide for the Technology and Process Framework for Planning a Smart City | Develops a framework for planning smart city evolution, emphasizing technology standards and processes to ensure interoperable, scalable, and sustainable solutions using the Internet of Things. |
| IEEE P3142 | Recommended Practice on Distributed Training and Inference for Large-scale Deep Learning Models | Provides guidelines for distributed training and inference processes for large-scale deep learning models, including performance indicators. |
| IEEE P3109 | Arithmetic Formats for Machine Learning | Standardizes arithmetic formats crucial for consistent and accurate AI computations in machine learning systems. |
| IEEE P2840 | Responsible AI Licensing | Specifies the development of AI licenses with a focus on ethical and legal considerations, including geographic-specific legislation. |

## A-8. ETSI

| Standard Number | Standard Title | Description |
|---|---|---|
| ETSI GS MEC 001 | Multi-access Edge Computing (MEC); Overview and Architectural Framework | Provides an overview and architectural framework for MEC, enabling the deployment of applications at the network edge to reduce latency and improve user experience. |
| ETSI GS MEC 003 | Multi-access Edge Computing (MEC); Framework and Reference Architecture | Defines the framework and reference architecture for MEC, detailing how it integrates with existing networks and supports intelligent edge services. |
| ETSI GS MEC 004 | Multi-access Edge Computing (MEC); Service Scenarios | Describes various service scenarios and use cases for MEC, highlighting its role in supporting intelligent and latency-sensitive applications. |
| ETSI GS MEC 005 | Multi-access Edge Computing (MEC); API Framework | Specifies the APIs for MEC services, ensuring interoperability and enabling the development of edge applications that can leverage MEC infrastructure. |
| ETSI GS MEC 006 | Multi-access Edge Computing (MEC); Metrics and KPIs | Defines the metrics and key performance indicators (KPIs) for MEC, providing a basis for evaluating the performance of intelligent applications deployed at the edge. |
| ETSI GS MEC 007 | Multi-access Edge Computing (MEC); Security; Threat Analysis and Countermeasures | Provides a comprehensive threat analysis for MEC and recommends security countermeasures to protect edge computing resources and applications. |

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| ETSI GS MEC 010 | Multi-access Edge Computing (MEC) Support for Network Slicing | Discusses how MEC can support network slicing in 5G, enabling the deployment of isolated and customized intelligent services at the edge. |
| ETSI ISG ARF 006 | Augmented Reality Framework (ARF) | Defines a framework for augmented reality applications, ensuring interoperability and effective deployment of AR technologies. |
| ETSI ISG ENI 005 | Experiential Networked Intelligence (ENI) | Focuses on AI-driven network management, optimizing network resources based on real-time conditions and user experiences. |
| ETSI ISG MEC 011 | Edge Cloud System | Establishes standards for integrating edge computing with cloud services, enhancing the performance and reliability of distributed AI applications. |
| ETSI ISG SAI 001 | Securing Artificial Intelligence (SAI) | Provides guidelines for identifying and mitigating security risks in AI systems, ensuring their safe and secure deployment. |
| ETSI ISG ZSM 006 | Zero-touch Service Management (ZSM) | Defines standards for automating network and service management using AI, improving efficiency and reducing human intervention. |
| ETSI TR 103 546 | Artificial Intelligence in Autonomous Systems | Examines the role of AI in autonomous systems, providing a framework for their safe and effective deployment in various industries. |
| ETSI TS 103 457 | Smart Body Area Network (BAN) | Establishes standards for smart wearable devices, focusing on their interoperability, security, and integration with other intelligent systems. |
| ETSI TS 123 501 | 5G System Architecture | Defines the architecture of 5G networks, incorporating AI-driven features to enhance network performance and user experience. |

## A-9. ITU-T

### Published standards

| Standard Number | Standard Title | Description |
|---|---|---|
| ITU-T Q.4140 | Signalling requirements for service deployment in computing power networks | Provides the signalling procedures and signalling requirements for service deployment in computing power networks (CPNs) based on Recommendation ITU-T Y.2501 |
| ITU-T Y.2501 | Computing power network – Framework and architecture | Describes the framework and architecture of the computing power network (CPN), which combines network context and user requirements to provide the optimal distribution, association, transaction and scheduling of computing, storage and network resources. |
| ITU-T Q.4141 | Requirements and signalling of intelligence control for the border network gateway in computing power network | Provides a network solution to dynamically schedule computing tasks at the network gateway, optimizing resource and network utilization while enhancing user experience based on real-time performance and business needs. |

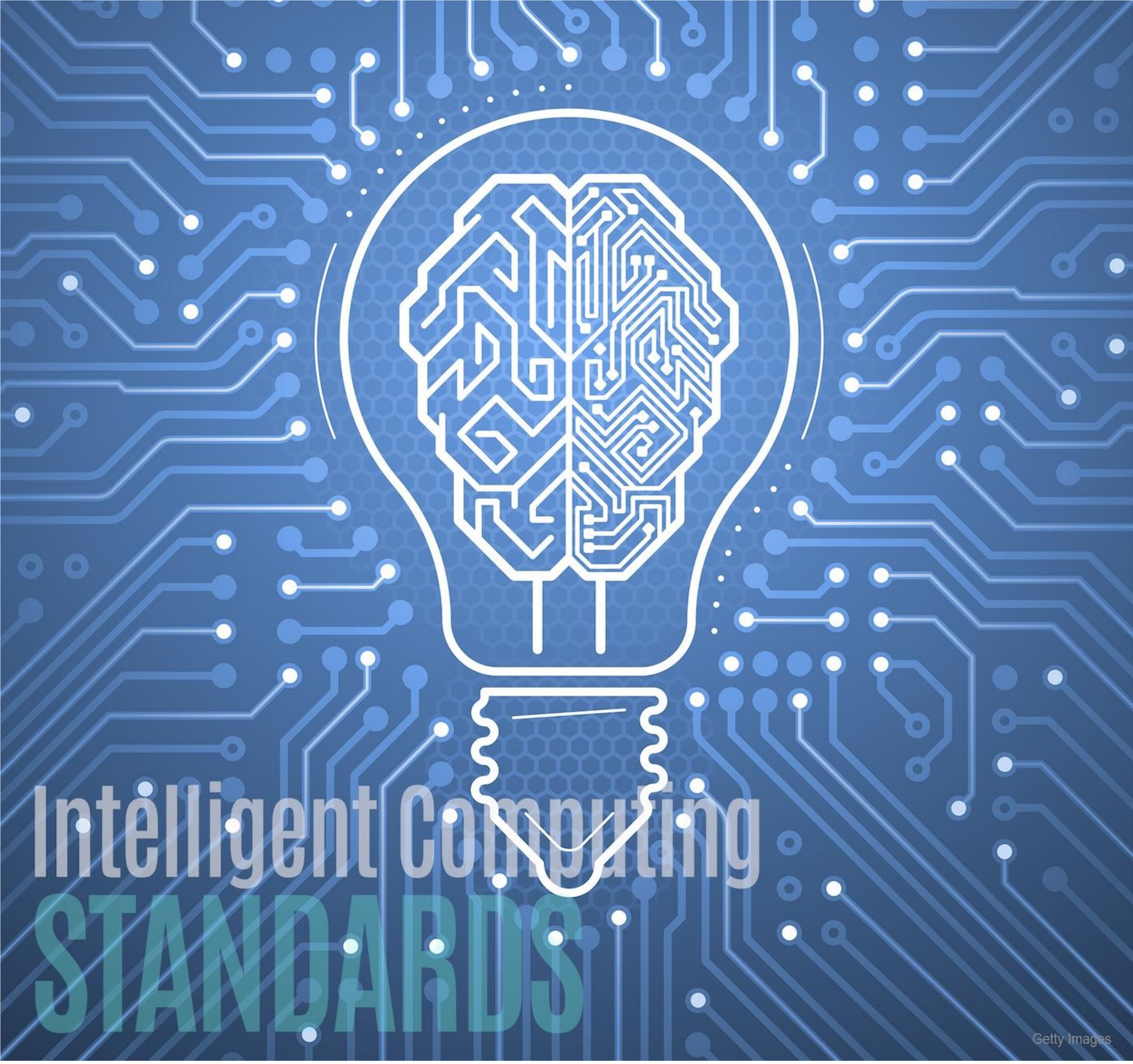
### Under development

| Standard | Standard Title | Description |
|---|---|---|

| Number | | |
|---|---|---|
| ITU-T Y.cro-reqts | Cloud computing - Functional requirements of computing-aware networking | Provides the overview of computing-aware networking and the functional requirements of computing-aware networking in the several aspects. |

### A-10. IETF

| Standard Number | Standard Title | Description |
|---|---|---|
| RFC 8986 | SRv6 Network Programming | Defines the SRv6 Network Programming concept and specifies the base set of SRv6 behaviors that enables the creation of interoperable overlays with underlay optimization. |
| RFC 8754 | IPv6 Segment Routing Header (SRH) | Describes the SRH and how it is used by nodes that are Segment Routing (SR) capable. |

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