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REVIEW

# International Standardization of Blockchain and Distributed Ledger Technology: Overlaps, Gaps and Challenges

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## ABSTRACT

As one of the most concerned digital technologies in recent years, blockchain and distributed ledger technology are an important driving force for a new round of technological development. It is currently in the process of accelerating its evolution and maturity, and has gradually integrated with other digital technologies. It has been applied in many industries, providing decentralized solutions for various industries, realizing innovative storage models, and building a new trust system. As blockchain technology is officially incorporated into China's new information infrastructure category, the application fields of blockchain have expanded rapidly, gradually extending from the financial field and government affairs to other fields in the real economy. At the same time, with the continuous development of the globalized economy, blockchain technology will also have a profound impact on international technological and economic development. Therefore, for the healthy and orderly development and real implementation of the blockchain industry, standardize the application of blockchain, effectively break through the cognitive and technical barriers between different countries, industries and systems on a global scale, prevent application risks, the development of the global blockchain industry needs standardization basis, which is particularly important and urgent. A sound standard system is an important key to the successful development of technology, and formulating the right standard at the right time for technology development helps ensure the ease of use and interoperability of the technology. From the perspective of international standardization, this article first introduces the general situation of ISO, ITU-T, IEEE, W3C and other international standardization organizations, and sorts out the status quo of the blockchain standardization working groups of mainstream international standardization organizations. All blockchain-related standards under development have been analyzed for the characteristics of international blockchain technology standards and industry application standards. Through data analysis, the overlaps, differences and conflicts in the field of international blockchain standard formulation are sorted out, and suggestions for blockchain standardization work in the application and development of blockchain technology standardization by international organizations and industries are put forward. The plans and layouts of future international standards are summarized to help the development of the international standardization of blockchain.

## KEYWORDS

ISO; ITU-T; IEEE; blockchain; distributed ledger technology; international standard; standardization; status; overlaps; gaps; challenges

## 1 Introduction

The term "Blockchain" was first coined by Satoshi Nakamoto in 2008 [1], and the first Bitcoin software was published a year later. With the birth of Bitcoin, the blockchain technology, which is the core component of the Bitcoin system, has entered the public eye. Blockchain is a specific type of distributed ledger technology (DLT) in *ISO 22739:2020 blockchain and distributed ledger technologies–Vocabulary* [2]. Blockchain is defined as "distributed ledger with confirmed blocks organized in an append-only, sequential chain using cryptographic links". DLT is defined as "technology that enables the operation and use of distributed ledgers".

The essence of blockchain is a shareable data storage medium. Through blockchain data structure, consensus mechanism, smart contract, cryptography, P2P network and other technologies, it constitutes a new distributed infrastructure and computing paradigm [3]. It has the characteristics of multi-centralization, non-tampering, full-process traceability, and collective maintenance. Provide multi-party mutual trust solutions for high-value scenarios such as asset and data exchange. With its unique trust establishment mechanism, blockchain technology is changing the application scenarios and operating rules of many industries. It is one of the indispensable technologies for developing the digital economy and building a new trust system in the future.

Blockchain technology is increasingly valued and applied by countries and enterprises around the world. In the early stage of standardization work, European and American countries have laid a good foundation for the substantial preparation and publication of standards in the blockchain field by formulating standardization strategic plans, fully carrying out research in the field of blockchain, and strengthening the construction of standardization organizations. In participating in international standardization work, developed countries have increased their investment, competed for the right to formulate international standards, took the lead in formulating international standards in the field of blockchain, and actively seized the right to speak internationally. In China, the status of blockchain has been greatly improved in the national strategic emerging industries. China has successively issued several blockchain standardization policies. On January 19, 2019, the Cyberspace Administration of China issued the Regulations on the Administration of Blockchain Information Services [4]. On October 24, 2019, General Secretary Xi Jinping emphasized in the 18th collective study of the Political Bureau of the Central Committee that "taking blockchain as an important breakthrough for independent innovation of core technologies" and "accelerating the development of blockchain technology and industrial innovation" [5,6]. In 2020, blockchain technology was included in China's new information infrastructure. In 2021, the "14th Five-Year Plan Outline" was announced, and in the chapter "Accelerating Digital Development and Building a Digital China", blockchain was listed as one of the seven key industries of the digital economy [7]. Active policies have brought strong impetus to the technological development and application of blockchain, and promoted the application, innovation and development of blockchain technology in digital finance, smart cities, digital politics and law, energy transformation and many other fields.

With the continuous development of economic globalization, more and more blockchain applications have been implemented, and blockchain technology has also brought challenges to various fields. To prevent the misunderstanding and abuse of blockchain technology, blockchain-related standards are urgently needed to guide and support technology R&D innovation, regulate the application and healthy development of blockchain, and effectively connect different countries, industries and systems on a global scale, provide an important standardization basis for the development of the global blockchain industry [8]. At this stage, the mainstream international standardization organizations, like ISO (International Organization for Standardization), ITU-T (International Telecommunication

Union Telecommunication standardization sector), IEEE (Institute of Electrical and Electronics Engineers) and W3C (World Wide Web Consortium), have all carried out standard development work on blockchain and related technologies, and successively established blockchain-related standards committees and working groups, and have published some blockchain-related international standards, and have played an important role in promoting the international standardization process of blockchain [9]. This paper analyzes the status of mainstream international blockchain standardization based on the international blockchain standards that have been published and under development. Finally, it proposes work recommendations for international blockchain standardization, summarizes the current standardization work and provides guidance for planning and development of the future international standardization [10].

## 2 Overview of the International Organizations for Standardization

In today's world, with the improvement of the economic strength and political status of various countries, more and more countries are participating in the development of international standardization. In order to actively introduce advanced technology and improve the level of national economic development, some developing countries have adopted a large number of international standards; in order to compete for the international market, some developing countries and developed countries seize the right to speak and dominate the relevant fields, actively lead and participate in the formulation of international standards, or develop their own standards into international standards [11]. The Global Standards Mapping Initiative: An overview of blockchain technical standards states that many standards-setting activities are headquartered in Europe, North America, and China. At present, dozens of the international organizations develop blockchain standards, include ISO, ITU-T, IEEE, W3C, IEC (International Electrotechnical Commission), IRTF (Internet Research Task Force), IETF (Internet Engineering Task Force), SA (Standards Australia), BSI (British Standards Institution), SAC (Standardization Administration of China), BRIBA (Belt and Road Initiative Blockchain Alliance), CESI (China Electronics Standardization Institute), Hyperledger, etc. ISO, ITU-T, IEEE and W3C have issued and are developing a prominent number of blockchain standards, which have played important roles in promoting the international standardization process of blockchain and DLT.

### *2.1 Overview of ISO*

#### *2.1.1 Overview of ISO Organization*

The ISO is the world's most authoritative specialized agency for international standardization and the largest non-governmental specialized agency for standardization in the world. It is responsible for standardization activities in most fields in the world today [12]. The predecessor of ISO was the International Association for Standardization (ISA) and the United International Standards Coordination Committee (UNSCC). On February 23, 1947, the new organization ISO was formally established and started to operate. China was both the initiator and the first member country. ISO's members are national standards bodies, and through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market-relevant international standards to support innovation and provide solutions to global challenges [13]. As of November, 2022, there are 167 national standards body members and 24,462 published standards. At present, ISO consists of a general assembly, a council, a technical management bureau, etc. The architecture diagram of ISO is shown in Fig. 1.

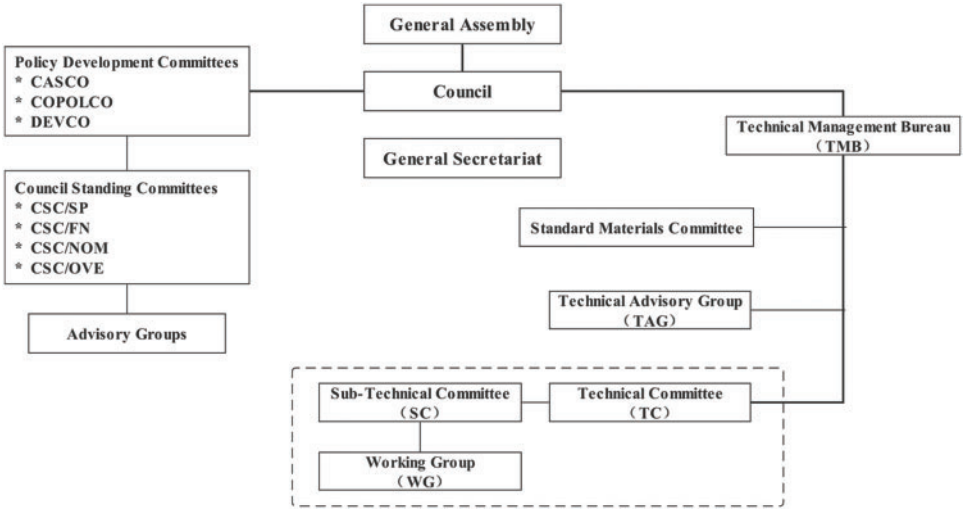


**Figure 1:** ISO architecture diagram

ISO's highest authority and non-permanent organization is the annual "plenary meeting", which mainly discusses the implementation and financial situation of relevant projects in the report of the year. Its daily office is the central secretariat, located in Geneva, Switzerland; the council is Permanent body when the General Assembly is not in session [14]. The Council consists of a policy-making committee, a standing committee of the council, and a special advisory group; the Technical Management Bureau (TMB), as the highest institution for ISO processing and coordinating technical work, has a reference material committee, a technical advisory group (TAG) and a technical committee (TC). Among them, the Technical Committee (TC) is the technical body responsible for the formulation of international standards, with sub-technical committees (SC) and working groups (WG) under it. The establishment of TC proposes that it must be a national member body, and only after two rounds of voting by all member states and TMB members can be eligible to be established.

### *2.1.2 Standardization Development Groups of Blockchain and DLT in ISO*

ISO's research on blockchain and DLT can be traced back to 2016. To study and guide the development of the blockchain and DLT field and meet the growing demand for standardization in this field, ISO passed and established the Blockchain and distributed ledger technologies (ISO/TC 307) in September 2016. Its secretariat is set up in the Australian, and mainly responsible for formulating international standards in the field of blockchain and DLT, cooperating with other international organizations to study standardization issues related to this field. In addition, the committee is responsible for cooperating with other international standards organizations to study standardization questions related to this field. As of August 2022, ISO/TC 307 has 42 participating members and 21 observing members worldwide.

In March 2018, ISO/TC307 established 3 working groups (basic working group, security, privacy and authentication working group, smart contract and its application working group) and 3 study groups (use case study group, governance study group and Interoperability study group) [15], as of December 2022, TC307 has set up and is responsible for 14 working groups, as shown in Table 1.

**Table 1:** Groups of ISO/TC 307

| Working group | Name | Working group | Name |
|---|---|---|---|
| ISO/TC 307/AG 1 | SBP review advisory group | ISO/TC 307/JWG 4 | Joint WG: Security, privacy and identity for blockchain and DLT |
| ISO/TC 307/AG 2 | Liaison advisory group | ISO/TC 307/SG 7 | Interoperability of blockchain and distributed ledger technology systems |
| ISO/TC 307/AG 3 | Digital currencies | ISO/TC 307/WG 1 | Foundations |
| ISO/TC 307/AHG 2 | Guidance for auditing DLT systems | ISO/TC 307/WG 3 | Smart contracts and their applications |
| ISO/TC 307/AHG 3 | Representation of physical assets as non-fungible tokens (NFT) | ISO/TC 307/WG 5 | Governance |
| ISO/TC 307/AHG 4 | DLT and carbon markets | ISO/TC 307/WG 6 | Use cases |
| ISO/TC 307/CAG 1 | Convenors coordination group | ISO/TC 307/WG 7 | Interoperability |

ISO is now involved in standardization work in sub-fields such as foundation, security privacy identity, smart contracts, use cases, interoperability, digital currency, DLT auditing, etc. In addition, it is established a joint working group on blockchain with ISO/TC 46/SC 11/JWG1 [16–18].

### *2.2 Overview of ITU-T*

#### *2.2.1 Overview of ITU-T Organization*

The ITU is an intergovernmental international organization dealing with telecommunication affairs in the United Nations system. It was established on May 17, 1865, and headquartered in Geneva. The communication sector (ITU-R), the telecommunication standardization sector (ITU-T), and the telecommunication development sector (ITU-D) together form the ITU organizational structure. As of December 2022, the ITU has 193 member states and about 900 members including companies, universities and other academic and research institutions and international and regional organizations [19].

The ITU is governed by a Plenipotentiary Conference and a Council. The Plenipotentiary Conference is the highest policy-making body of the ITU and is held every four years [20]. It is a pivotal meeting for ITU Member States to decide on the future role of the organization, thereby determining the organization's ability to influence and drive global ICT. The Council acts as the governing body of ITU between two plenipotentiary conferences. Its role is to review a wide range of telecommunication policy issues to ensure that ITU's activities, policies and strategies are adequately adapted to today's dynamic and rapidly changing telecommunication environment. The General Secretariat manages the administrative and financial aspects of ITU's activities, including the provision of conference services, planning and organization of major conferences, information services, security, strategic planning, and

corporate functions such as: communications, legal advice, finance, personnel, procurement, Internal Audit, etc. [21]. The architecture diagram of ITU is shown in Fig. 2.

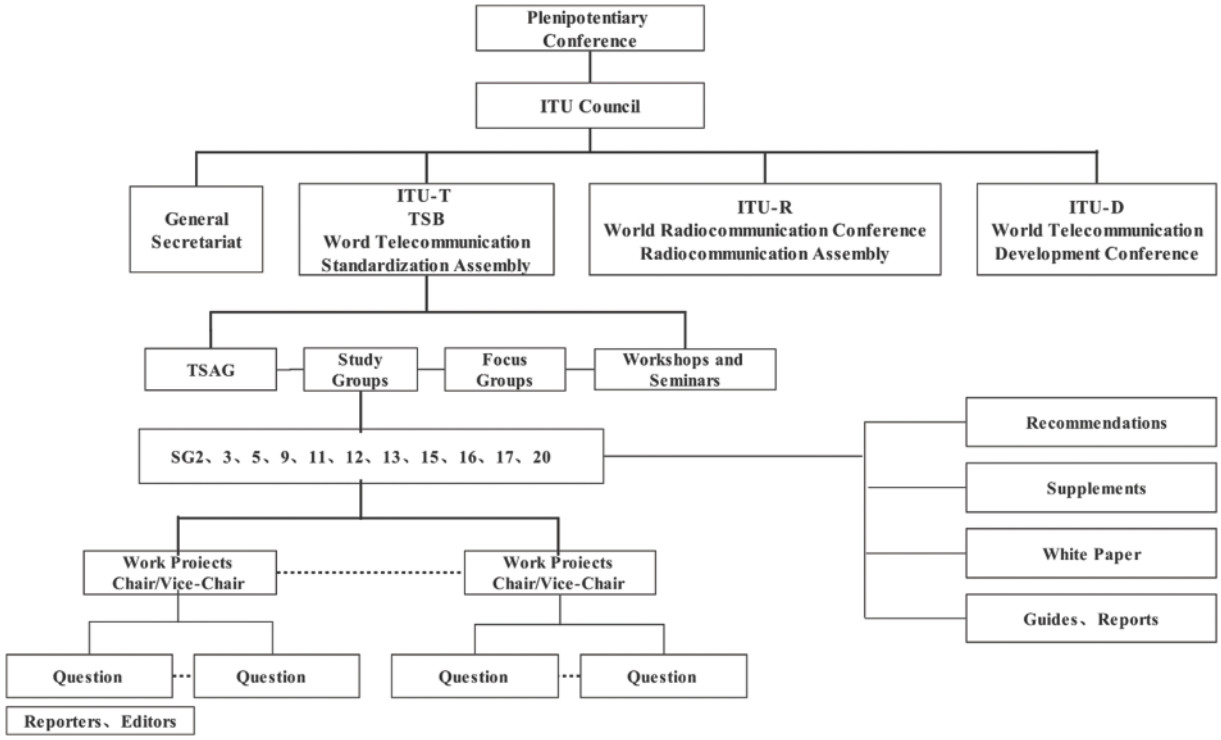


**Figure 2:** ITU architecture diagram

The ITU-T is a branch under the management of ITU that specializes in formulating telecommunication standards. It was founded in 1993 [22]. ITU-T study groups bring together experts from all over the world, mainly to study telecommunication technology, operating tariffs and other issues and formulate standardization proposals, study and formulate unified telecommunication network standards, including interface standards with radio systems, to promote and realize global telecommunication standardization. The affairs of ITU-T are mainly determined by the World Telecommunication Standardization Assembly (WTSA), which meets every four years to set the overall direction and structure for ITU-T, determine the overall policy of the department, establish study groups, approve Expected work plan to be completed over the next four years, appointment of chair and vice-chair. The Telecommunication Standardization Advisory Group (TSAG) is an advisory body for ITU-T study groups, members and staff, responsible for the organization of work procedures and ITU-T work plans, and for the department's work priorities, plans, operations, financial matters and strategies are reviewed [23]. A SG (study group) is a technical group composed of representatives of ITU-T members and is responsible for formulating standards applicable to different fields of information and communication technology. The work of the study group is the top priority of the work of ITU-T. In SG, a series of topics related to a specific research field are studied, and standards (recommendations) in various fields of international telecommunications are formulated.

There are two standard approval procedures in ITU-T, namely TAP (Traditional Approval Procedure) and AAP (Accelerated Approval Procedure). Except for standards with regulatory impact, most standards can be approved through AAP, which can shorten the time by 80%–90% compared

with TAP. Regional groups within ITU-T study groups ensure that ITU-T standards are studied to meet the needs of all regions of the world [24]. To facilitate the development of the work, the study group may set up a working group (Work Project, WP), a joint working group and a rapporteur group (Q) to deal with the task of the study group. Focus groups are groups established to respond to ICT standard's needs, open to organizations other than ITU membership, and enjoying full flexibility in the choice of work outcomes and working methods.

#### *2.2.2 Standardization Development Groups of Blockchain and DLT in ITU-T*

ITU-T has set up three blockchain-related focus groups to conduct research on blockchain and DLT from different directions, namely, FG DLT (Focus Group on Application of Distributed Ledger Technology), FG DFC (Focus Group on Digital Currency including Digital Fiat Currency), and FG DPM (Focus Group on Data Processing and Management to support IoT and Smart Cities & Communities). In addition, ITU-T has also established the Distributed Ledger Standards Task Force, the DLT Security Standards Research Group, the IoT, smart cities & communities and the Future networks, namely SG16 Q22, SG17 Q14, SG20 and SG13 [25], responsible for Research and formulate international standards for blockchain in various technical application fields. Among them, the Distributed Ledger Standards Task Force (SG16 Q22) has undertaken most of the results of the Distributed Ledger Focus Group (FG DLT), and the main research contents include the application and supervision of DLT, legal tokens, etc. The DLT Security Standards Research Group (SG17 Q14) mainly studies DLT security, including network attack methods, requirements and architecture, as well as the application security of various types of distributed databases based on DLT. At present, ITU-T is developing the reference architecture, digital copyright, security system and other standardization directions of blockchain [26].

FG DLT was established in May 2017, it consists of four working groups: general, technology and architecture, application, and policy. FG DLT researches on concepts, reference architectures, application scenarios, policy and regulation, identifies and analyzes DLT-based applications and services, and develops best practices and guidelines to support the implementation of these applications and services on a global scale. FG DLT completed its task on August 01, 2019, and the submissions included DLT terms and definitions, concepts and ecosystems, use cases, reference architectures, platform evaluation criteria, Regulatory framework and outlook [27].

FG DFC was established in May 2017. Its main work objective is to study the economic benefits and impact of introducing digital currency relative to mobile currency, investigate the ecosystem of digital fiat currency implementation to achieve financial inclusion, realize the network architecture, process components, security, regulation, verifiability of digital fiat currency, explore the risks and challenges of blockchain to promote the implementation of central bank digital currency, and identify new areas of standardization in ITU-T study groups. FG DFC's work was completed in June 2019 and deliverables include a taxonomy and definition of digital fiat currency terms, a report on reference architecture and use cases, a report on governance aspects of digital fiat currency, a list of digital currency implementations reported by central banks, a report on central bank digital currency regulatory challenges and risks, digital currency security report, etc. [28–29].

FG DPM was established by SG20 in March 2017 and ended in July 2019. Several working groups were established under FG DPM, which were responsible for different research directions. The WG1 Use Cases, Requirements and Applications/Services group is responsible for terminology, data processing and management concept building, use case analysis and general requirements for DPM; WG2 DPM Framework, Architecture and Core Components Web-Based Data Models for Connected

and Smart Cities; WG3 Data Sharing, Interoperability and Blockchain Group is responsible for research on sensor interfaces, frameworks to support data interoperability in IoT environments, and overview of blockchains to support IoT and smart cities, Blockchain-based data exchange and sharing technology, Blockchain-based data management supporting IoT and smart cities, Identity framework in blockchain supporting IoT and smart cities; WG4 Security, Privacy, Trust and Governance The group is responsible for studying the security, privacy and governance framework in the DMP, the requirements and risks driven by trusted data technologies, and the quality management of trusted data; the WG5 Data Economy, Commercialization and Monetization group is responsible for studying the data economy: commercialization, ecosystem and Impact assessment [30–31].

### *2.3 Overview of IEEE*

#### *2.3.1 Overview of IEEE Organization*

The IEEE was formed in 1963 by the merger of the American Institute of Electrical Engineers and the Institute of Radio Engineers [32]. The for-profit professional technical society has more than 430,000 members worldwide, most of whom are electrical engineers, computer engineers and computer scientists. IEEE is committed to the development and research of electrical and electronic engineering, computer, communications and other fields, and has formulated more than 1,300 industry standards in the fields of space, computer, telecommunications, biomedicine, power and consumer electronics.

The IEEE Standards Association (IEEE SA) mainly consists of official staff such as the Program Committee (AdCom), the New Standards Committee (NesCom), the Standards Review Committee (RevCom), the Audit Committee (AudCom), and the Patent Committee (PatCom). AdCom mainly reviews the revisions of the IEEE-SA Standards Association's Operation Manual, Standard Regulations, and IEEE Standard Format Manual, and submits its recommendations to the Standards Board (IEEE SASB). NesCom is primarily responsible for reviewing Project Authorization Requests (PARs) and submitting their recommendations to the IEEE SASB for approval [33]. RevCom mainly makes recommendations for approval or disapproval of standards submitted to IEEE SASB for approval or adoption. AudCom is primarily responsible for routine review, through its constituencies and working group policies and procedures (P&P), to ensure that each standards-setting entity complies with the IEEE SASB regulations and operating manuals. PatCom mainly examines the patent guarantees and other patent information submitted to the IEEE Standards Department, examines the matters that should be paid attention to in relation to the formulation of IEEE standards and patents, and makes recommendations to the IEEE SASB at an appropriate time. NesCom and RevCom interact most with the standards development process [34].

Under the Standards Committee, standard working groups (Working Groups) of different dimensions can be established to carry out specific standard development work, and multiple standards can be established in one working group. The roles in a working group are divided into chair, vice-chair, secretary and working group members. The chairman is responsible for compiling standard PAR documents, submitting projects, creating standard working groups, convening working group meetings, and promoting standard technology development and standard release. The Vice-Chair is responsible for undertaking the work delegated by the Chair, assisting the Chair in ensuring that processes and procedures are followed, and temporarily performing the Chair's duties when the Chair is unavailable. The secretary is responsible for coordinating and arranging meetings with the chairman, distributing meeting notices and agendas, recording meeting minutes, creating and maintaining membership lists, and managing and distributing working group documents. The architecture diagram of IEEE is shown in Fig. 3.

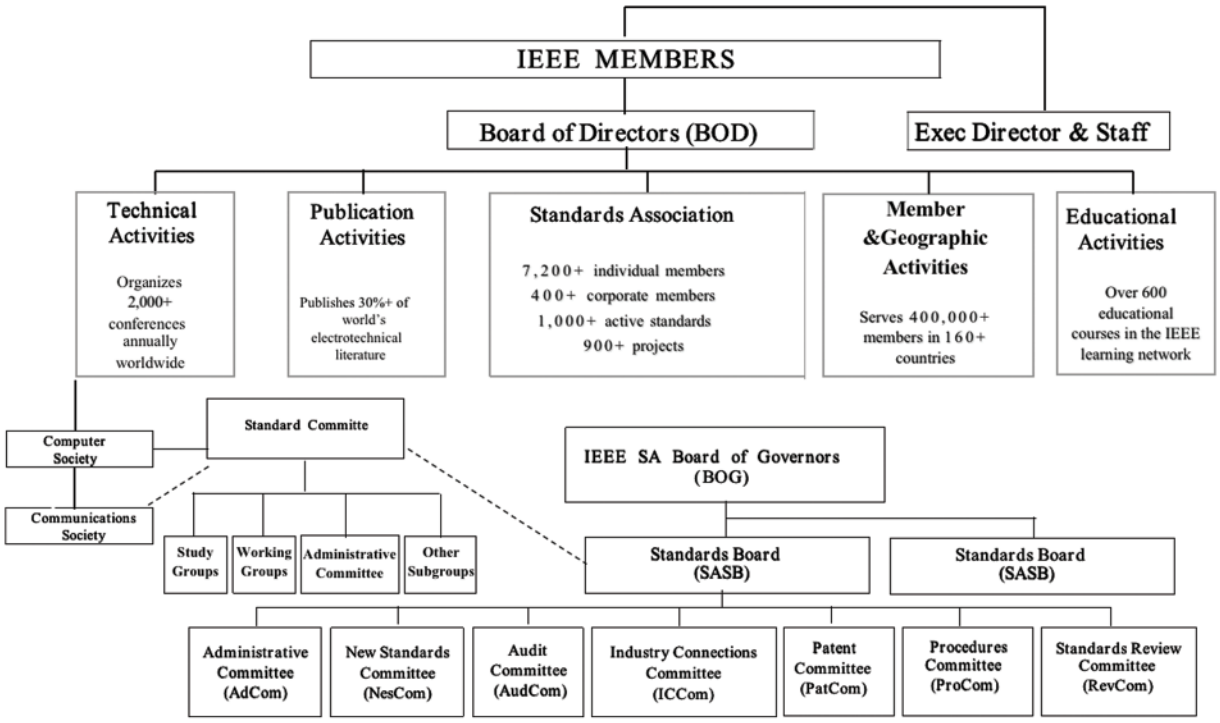


**Figure 3:** IEEE architecture diagram

### *2.3.2 Standardization Development Groups of Blockchain and DLT in IEEE*

In January 2018, IEEE established the IEEE Blockchain Initiative, which became the center of all IEEE blockchain projects and activities. Subsequently, IEEE successively established three blockchain-related committees, namely CTS/BSC (IEEE Consumer Technology Society Blockchain Standards Committee), C/BDL (IEEE Computer Society Blockchain and Distributed Ledger Standards Committee) and CTS/DFESC ((IEEE Consumer Technology Society Digital Finance and Economy Standards Committee), which are mainly responsible for guiding, managing and supervising the project establishment, development, review, release, publicity and implementation of blockchain standards and related application practices.

The IEEE CTS/BSC was established in December 2018. It is the first IEEE standards committee in the blockchain field to be authorized to supervise standard working groups and standard projects. As of December 2022, IEEE CTS/BSC has set up 12 working groups related to blockchain, of which 8 standards have been published, namely 2140.1–2020, 2140.2–2021, 2140.5–2020, 2142.1–2021, 2143.1–2020, 2144.1–2020, 2146.1–2022 and 2418.10–2022. It mainly focuses on technical and application standards in the fields of cryptocurrencies, electronic invoices and IoT [35].

The IEEE C/BDL was established in September 2019. This committee aims to promote the standardization and application of blockchain and DLT. IEEE C/BDL is responsible for guiding, managing and supervising the process of project establishment, development, review, release, publicity and implementation of blockchain standards and related application practices. The standard development scope of IEEE C/BDL includes but is not limited to basic standards, application standards, asset standards, technical standards and service standards. As of December 2022, there are 30 standard working groups under IEEE C/BDL, covering basic, data, technology, applications, services and

assets related to blockchain. At present, 2418.2-2020 and 2418.7-2021 under IEEE C/BDL have been published, and there are 28 blockchain standards under research, namely P3201∼P3230, which mainly focus on blockchain technology and application standards for distributed ledger systems, including data format, blockchain-based digital assets, cross-chain interoperability, key management, blockchain system consensus framework, etc.

The IEEE CTS/DFESC was established in March 2020. It is one of the committees in the IEEE Standards Association that has the authority to support, approve new standards, and approve standards. The standard development scope of IEEE CTS/DFESC includes but is not limited to business specifications, technical implementation, software and hardware products and services involved in digital economy, digital finance, digital credit and other fields. As of December 2022, there are 9 working groups under IEEE CTS/DFESC, of which 3801–2022 and 3802–2022 have been published. The release of these two standards has promoted the application and development of electronic evidence in the field of e-commerce. At present, there are 9 standards under research under IEEE CTS/DFESC, namely P3800∼P3814 , which mainly focus on blockchain applications and services related to digital finance and economy [36–38].

## 3 Mainstream International Blockchain and DLT Standards Status

Mainstream international blockchain standards are mainly developed and published by ISO, ITU-T, IEEE, and W3C. As of December 2022, the number of blockchain standards published and under development by ISO is 9 and 7, respectively, the number of blockchain standards published and under development by ITU-T is 31 and 57, respectively, and the number of blockchain standards published and under development by IEEE is 12 and 78, respectively, and W3C has published 1 blockchain standard, which is the digital identity-related standard "Decentralized Identifiers (DIDs) v1.0" [39]. China is actively carrying out international standardization work in the field of blockchain and DLT, leading and participating in about 50% of the total international blockchain standards, of which the 12 international blockchain standards published by IEEE are all developed by Chinese companies and units, and more than 60% of the international blockchain standards formulated by IEEE are led by Chinese companies and units. The standard comparison of ISO, ITU-T, IEEE and W3C is shown in Fig. 4. In Fig. 4, the horizontal axis represents different organizations, and the vertical axis represents the number of standards.

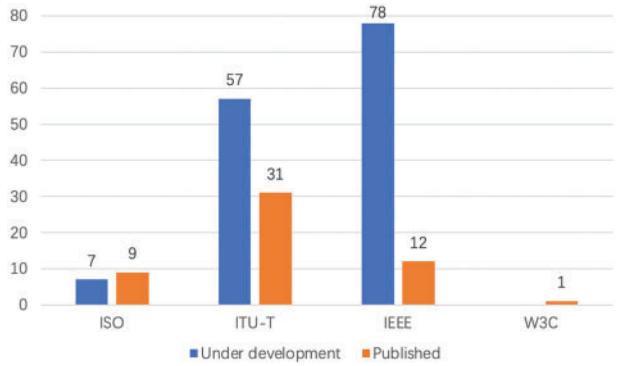


**Figure 4:** Standard comparison of ISO, ITU-T, IEEE and W3C

### *3.1 Current Situation of ISO*

ISO divides the standard status in the form of two-level codes in the standard stage. The first-level ISO divides the standard status by using the form of two-level codes in the standard stage. The first-level classification can be divided into: preliminary stage (00.00–00.99), proposal stage (10.00–10.99), preparatory stage (20.00–20.99), committee stage (30.00–30.99), enquiry stage (40.00∼40.99), approval stage (50.00∼50.99), publication stage (60.00, 60.60), review stage (90.20∼90.99), withdrawal stage (95.20∼95.99), etc. As of August 2022, ISO/TC 307 has published 2 international standards, 5 technical reports (TR), 2 technical specifications (TS), and 7 standardization documents under development (ISO/DIS 22739 is ISO 22739:2020 review version). A summary of ISO blockchain-related standards is shown in Table 2.

**Table 2:** ISO Blockchain related standards

| Standard encoding | Standard name | Standard status |
|---|---|---|
| ISO 22739:2020 | Blockchain and distributed ledger technologies—Vocabulary | Publication stage |
| ISO/TR 23244:2020 | Blockchain and distributed ledger technologies—Privacy and personally identifiable information protection considerations | Publication stage |
| ISO/TR 23249:2022 | Blockchain and distributed ledger technologies—Overview of existing DLT systems for identity management | Publication stage |
| ISO 23257:2022 | Blockchain and distributed ledger technologies—Reference architecture | Publication stage |
| ISO/TS 23258:2021 | Blockchain and distributed ledger technologies—Taxonomy and Ontology | Publication stage |
| ISO/TR 23455:2019 | Blockchain and distributed ledger technologies—Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems | Publication stage |
| ISO/TR 23576:2020 | Blockchain and distributed ledger technologies—Security management of digital asset custodians | Publication stage |
| ISO/TS 23635:2022 | Blockchain and distributed ledger technologies—Guidelines for governance | Publication stage |
| ISO/TR 3242 | Blockchain and distributed ledger technologies—Use cases | Publication stage |
| ISO/CD TR 6039 | Blockchain and distributed ledger technologies—Identifiers of subjects and objects for the design of blockchain systems | Committee stage |
| ISO/WD TR 6277 | Blockchain and distributed ledger technologies—Data flow model for blockchain and DLT use cases | Preparatory stage |

(Continued)

**Table 2 (continued)**

| Standard encoding | Standard name | Standard status |
|---|---|---|
| ISO/AWI 7603 | Decentralized Identity standard for the identification of subjects and objects | Preparatory stage |
| ISO/DIS 22739 | Blockchain and distributed ledger technologies—Vocabulary | Enquiry stage |
| ISO/AWI TS 23516 | Blockchain and distributed ledger technology—Interoperability framework | Preparatory stage |
| ISO/WD TR 23642 | Blockchain and distributed ledger technologies—Overview of smart contract security good practice and issues | Preparatory stage |
| ISO/CD TR 23644 | Blockchain and distributed ledger technologies—Overview of trust anchors for DLT-based identity management (TADIM) | Committee stage |

### *3.2 Current Situation of ITU-T*

As of December 2022, 8 of 11 study groups in ITU-T have established projects for blockchain and DLT-related standards, a total of 31 blockchain and DLT-related standards have been published, and 57 standards are under development. The study group is mainly responsible for the standardization of blockchain and distributed ledger technology in the areas of security and trust, identity management, environmental sustainability, protocol and testing specifications, multimedia, digital financial services, smart cities, and data processing and management. The 8 study groups are: Operational aspects of service provision and telecommunications management (SG2), Tariff and accounting principles including related telecommunication economic and policy issues (SG3), Environment and circular economy (SG5), Signaling requirements, protocols and test specifications (SG11), Future networks, with focus on IMT-2020, cloud computing and trusted network infrastructure (SG13), Multimedia coding, systems and applications (SG16), Security (SG17), Internet of Things (IoT) and smart cities and communities (SC&C)(SG20).

SG13, SG16, SG17 and SG20 carried out research on blockchain and DLT-related standards earlier. At present, these four groups have more blockchain and DLT standards, reaching 90% of the total. SG2 mainly studies the management of blockchain systems, and SG3 mainly studies the application of DLT to solve financial-related problems. Each of the two groups has two standards under development, and no standard has been published yet.

SG17 has published the most standards, with a total of 10 items. X.1400: *Terms and definitions for distributed ledger technology* was published in October [40–44], which provides terms and definitions for DLT, of which the definition of blockchain is: A distributed ledger consisting of digitally recorded data arranged into chains of continuously growing blocks, each cryptographically linked and hardened against tampering and modification. Some terms and definitions in the standard refer to the standard ISO 22739:2020 *Blockchain and distributed ledger technologies—Vocabulary* [45] issued by ISO, and the definitions of some terms are slightly different from ISO. Other standards in the X.1400 series specify DLT and its security in digital identity, digital payment, and data sharing [46].

Published standards in SG17 as shown in Table 3.

**Table 3:** Published Standards in SG17

| Standard encoding | Standard name |
|---|---|
| X.1252 | Baseline identity management terms and definitions |
| X.1400 | Terms and definitions for distributed ledger technology |
| X.1401 | Security threats of distributed ledger technology |
| X.1402 | Security framework for distributed ledger technology |
| X.1403 | Security guidelines for using DLT for decentralized identity management |
| X.1404 | Security assurance for distributed ledger technology |
| X.1405 | Security threats and requirements for digital payment services based on distributed ledger technology |
| X.1406 | Security threats to online voting system using distributed ledger technology |
| X.1407 | Security requirements for digital integrity proofing service based on distributed ledger technology |
| X.1408 | Security threats and requirements for data access and sharing based on the distributed ledger technology |

SG16 has the most standards under development, and the types of standards are rich, covering basic technologies, information security, processes and methods, trustworthiness and interoperability, business and application types. The F.751.2 Reference framework for distributed ledger technologies published by SG16 gives the high-level conceptual architecture of DLT [47]. The architecture is a private chain and non-blockchain distributed ledger system represented by Hyperledger Fabric, given by F.751.2 Architecture includes resource and infrastructure functions, protocol or governance and compliance functions, application functions, operations and maintenance, external interaction management functions, and extension functions [48].

Published standards in SG16 as shown in Table 4.

**Table 4:** Published standards in SG16

| Standard encoding | Standard name |
|---|---|
| F.747.10 | Requirements of distributed ledger systems for secure human factor services |
| F.751.0 | Requirements for distributed ledger systems |
| F.751.1 | Assessment criteria for distributed ledger technology (DLT) platforms |
| F.751.2 | Reference framework for distributed ledger technologies |
| F.751.3 | Requirements for change management in distributed ledger technology (DLT)-based decentralized applications |
| F.751.4 | General framework of DLT-based invoices |
| F.751.5 | Requirements for distributed ledger technology-based power grid data management |
| F.751.6 | Performance assessment methods for distributed ledger technology platforms |
| F.751.7 | Functional assessment methods for distributed ledger technology platforms |

(Continued)

**Table 4 (continued)**

| Standard encoding | Standard name |
|---|---|
| F. Sup4 | Overview of convergence of artificial intelligence and blockchain |
| HSTP.DLT-RF | Distributed ledger technology: Regulatory framework |
| HSTP.DLT-UC | Distributed ledger technologies: Use cases |

SG13 mainly studies the requirements, functional framework and applications of blockchain and DLT in future networks, cloud computing, IoT networks, mobile telecommunications and other networks.

Published standards in SG13 as shown in Table 5.

**Table 5:** Published standards in SG13

| Standard encoding | Standard name |
|---|---|
| Y.2342 | Scenarios and capability requirements of blockchain in next generation network evolution |
| Y.3550 | Cloud computing–Functional requirements for blockchain as a service |

SG20 mainly studies the application of blockchain technology in the Internet of Things and smart cities, including vocabulary, network infrastructure, etc.

Published standards in SG20 as shown in Table 6.

**Table 6:** Published standards in SG20

| Standard encoding | Standard name |
|---|---|
| Y.4464 | Framework of blockchain of things as decentralized service platform |
| Y.4560 | Blockchain-based data exchange and sharing for supporting internet of things and smart cities and communities |
| Y.4561 | Blockchain-based data management for supporting internet of things and smart cities and communities |
| Y.4476 | OID-based resolution framework for transaction of distributed ledger assigned to IoT resources |
| Y.4907 | Reference architecture of blockchain-based unified KPI data management for smart sustainable cities |
| Y.Suppl.62 | Overview of blockchain for supporting Internet of Things and smart cities and communities in data processing and management aspects |

SG5 mainly studies issues related to blockchain energy consumption. It has published a standard L.1317: *Guidelines on energy efficient blockchain systems*, and a standard L.Energy_Crypto_currency: *Energy consumption of crypto currency* under development.

### *3.3 Current Situation of IEEE*

At present, IEEE has published 12 blockchain standards, mainly focusing on encrypted currency, electronic bill business, data management and supply chain financial applications. The published IEEE blockchain international standards are shown in Table 7.

**Table 7:** Statistics of published IEEE blockchain international standards

| Project number | Project title | Standards committee |
|---|---|---|
| 2140.1–2020 | Standard for general requirements for cryptocurrency exchanges | CTS/BSC |
| 2140.2–2021 | Recommended practice for E-invoice business using blockchain technology | CTS/BSC |
| 2140.5–2020 | Standard for custodian framework of cryptocurrency | CTS/BSC |
| 2142.1–2021 | Recommended practice for E-invoice business using blockchain technology | CTS/BSC |
| 2143.1–2020 | Standard for general process of cryptocurrency payment | CTS/BSC |
| 2144.1–2020 | Standard for framework of blockchain-based internet of things (IOT) data management | CTS/BSC |
| 2146.1–2022 | Approved draft standard for entity-based risk mutual assistance model through blockchain technology | CTS/BSC |
| 2418.2–2020 | Standard for data format for blockchain systems | C/BDL |
| 2418.7–2021 | Standard for the use of blockchain in supply chain finance | C/BDL |
| 2418.10–2022 | Standard for blockchain based digital asset management | CTS/BSC |
| 3801–2022 | Standard for blockchain-based electronic contracts | CTS/DFESC |
| 3802–2022 | Standard for application technical specification of blockchain-based E-commerce transaction evidence collecting | CTS/DFESC |

At the same time, there are 78 blockchain standards currently under development by IEEE, mainly focusing on basic, application, asset, technology, service, etc. At this stage, these standards are mainly under the control of the following three standards committees, namely C/BDL, CTS/BSC [5] and CTS/ DFESC. They have 27, 24 and 20 blockchain-related standards under development, accounting for 91.02% of the total standards under development. The remaining 7 blockchain standards under development are under the Standards Activities Board (C/SAB), Intelligent Transportation Systems (VT/ITS), Smart Buildings, Loads and Customer Systems (PE/SBLC), Com Standards Committee (EMB/Stds Com), Industrial Electronics Society Standards Committee (IES/IES), and Business Advisory Group (BOG/CAG).

CTS/BSC mainly focuses on standards for blockchain applications and service. The blockchain international standards under development in CTS/BSC are shown in Table 8.

**Table 8:** Statistics of CTS/BSC blockchain international standards under development

| Project number | Project title |
|---|---|
| P2140.3 | Standard for user identification and anti-money laundering on cryptocurrency exchanges |
| P2140.4 | Standard for distributed/decentralized exchange framework using DLT (distributed ledger technology) |
| P2141.1 | Standard for the use of blockchain in anti-corruption applications for centralized organizations |
| P2141.2 | Standard for transforming enterprise information systems from centralized architecture into blockchain-based decentralized architecture |
| P2141.3 | Standard for transforming enterprise information systems from distributed architecture into blockchain-based decentralized architecture |
| P2143.2 | Standard for cryptocurrency payment performance metrics |
| P2143.3 | Standard for risk control requirements for cryptocurrency payment |
| P2144.2 | Standard for functional requirements in blockchain-based internet of things (IoT) data management |
| P2144.3 | Standard for assessment of blockchain-based internet of things (IoT) data management |
| P2145 | Standard for framework and definitions for blockchain governance |
| P2146.2 | Standard for external data retrieval of blockchain for risk mutual assistance model |
| P2418.1 | Standard for the framework of blockchain use in internet of things (IoT) |
| P2418.8 | Standard for blockchain applications in governments |
| P2418.9 | Standard for cryptocurrency based security tokens |
| P2677.1 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Overarching framework |
| P2677.10 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Access to personal data |
| P2677.11 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Access to telecommunications data |
| P2677.12 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Access to transportation data |
| P2677.20 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Requirements for blockchain infrastructure |
| P2677.21 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Requirements for peer-to-peer storage infrastructure |
| P2677.22 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Requirements for grid computing infrastructure |
| P2677.30 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Personal application programming interface |
| P2677.31 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Healthcare application programming interface |
| P2677.32 | Standard for blockchain-based omnidirectional pandemic/epidemic surveillance: Government application programming interface |

C/BDL mainly focuses on standards for blockchain foundation, technology and applications. The blockchain international standards under development in C/BDL are shown in Table 9.

**Table 9:** Statistics of C/BDL blockchain international standards under development

| Project number | Project title |
|---|---|
| P3201 | Standard for blockchain access control |
| P3202 | Standard for capability evaluation requirements of blockchain practitioners |
| P3203 | Standard for blockchain interoperability naming protocol |
| P3204 | Standard for blockchain interoperability-cross chain transaction consistency protocol |
| P3205 | Standard for blockchain interoperability-data authentication and communication protocol |
| P3206 | Standard for blockchain-based digital asset classification |
| P3207 | Standard for blockchain-based digital asset identification |
| P3208 | Standard for blockchain-based digital asset exchange model |
| P3209 | Standard for blockchain identity key management |
| P3210 | Standard for blockchain-based digital identity system framework |
| P3211 | Standard for blockchain-based electronic evidence interface specification |
| P3212 | Standard for blockchain system governance specification |
| P3214 | Standard for testing specification of blockchain systems |
| P3216 | Standard for blockchain service capability evaluation |
| P3217 | Standard for application interface specification for blockchain systems |
| P3218 | Standard for using blockchain for carbon trading applications |
| P3219 | Standard for blockchain-based zero-trust framework for internet of things (IoT) |
| P3220 | Guide for the application of non-fungible token (NFT) based digital asset |
| P3221 | Standard for technical requirements of digital collection services based on blockchain technologies |
| P3222 | Standard for the reference architecture of blockchain as a service |
| P3223 | Standard for the reference architecture of blockchain fusion server |
| P3224 | Standard for blockchain-based green power identification application |
| P3225 | Standard for using blockchain in low carbon zones evaluation |
| P3226 | Standard for trusted data circulation based on blockchain and distributed ledger technologies (DLT) |
| P3227 | Standard for a reference framework of data security circulation system based on blockchain and federated computation |
| P3229 | Guide for industrial software application based on blockchain |
| P3230 | Standard for blockchain based power system demand response technical specification |

CTS/DFESC mainly focuses on standards for blockchain technology and asset. The blockchain international standards under development in CTS/DFESC are shown in Table 10.

**Table 10:** Statistics of CTS/DFESC blockchain international standards under development

| Project number | Project title |
|---|---|
| P3800 | Standard for a data-trading system: Overview, terminology and reference model |
| P3803 | Standard for household appliance customer data assetization and commercialization requirements |
| P3806 | Standard for blockchain-based hepatobiliary disease data extraction and exchange |
| P3809 | Standard for technical specification of blockchain-based electronic bidding |
| P3810 | Standard for framework of energy market simulation |
| P3812.1 | Standard for general requirements for identity framework for metaverse |
| P3812.2 | Standard for data access management for identity relationships |
| P3813 | Standard for general framework and technical requirements for an industrial digital asset trading platform |
| P3814 | Standard for carbon asset trading mechanism and technical requirements |
| P3815 | IEEE standard for layer 2 framework for blockchain and distributed ledger technologies (DLT) |
| P3816 | Standard for internet of rights (IOR): Overview and architecture |
| P3816.1 | Standard for internet of rights (IOR)–specific requirements part 2: contract and income sharing |
| P3816.2 | Standard for internet of rights (IOR)–specific requirements part 3: role and permission |
| P3816.3 | Standard for internet of rights (IOR)–specific requirements part 4: delegated storage |
| P3817 | Standard for natural gas market knowledge graphs |

The remaining 7 blockchain standards under development are mainly related to agriculture, IoT and medical fields. The blockchain international standards under development in other committees are shown in Table 11.

**Table 11:** Statistics of other committees blockchain international standards under development

| Project number | Project title | Standards committee |
|---|---|---|
| P2418.3 | Standard for the framework of distributed ledger technology (DLT) use in agriculture | C/SAB |
| P2418.4 | Standard for the framework of distributed ledger technology (DLT) use in connected and autonomous vehicles (CAVs) | VT/ITS |
| P2418.5 | Standard for blockchain in energy | PE/SBLC |
| P2418.6 | Standard for the framework of distributed ledger technology (DLT) use in healthcare and the life and social sciences | EMB/Stds Com |

(Continued)

**Table 11 (continued)**

| Project number | Project title | Standards committee |
|---|---|---|
| P2418.11 | Framework for use of distributed ledger technology in security of electronic voting (e-Voting) systems | IES/IES |
| P2958 | Standard for a decentralized identity and access management framework for internet of things | BOG/CAG |
| P2963 | Data formats for smart legal contracts | C/SAB |

## 4 Analysis of International Blockchain and DLT Standards

The organizations that formulate blockchain and DLT standards are diversified, and they have gathered many experts with professional skills and knowledge from all over the world to work on the formulation of standards, which leads to the problem of fragmentation in the field of standards. Focusing on technology and data foundation, security, and privacy, it has also made progress in Internet of Things and cryptocurrency, but it is still less involved in technical subdivisions and specific applications such as smart contracts, cross-chain, and sharding. The whole is in the basic construction stage of the blockchain and DLT standard system, and there is still a lot of room for development. In July 2018, China divided the blockchain standards into the following five categories in the "*Announcement of the National Blockchain and Distributed Accounting Technology Standardization Technical Committee Preparation Plan"*: basic standards, information security standards, trustworthy and interoperable standards, process and method standards, business and application standards [49–54].

At present, the main blockchain international standard-setting organizations are ITU-T, ISO, IEEE, and many other countries and industry organizations are involved in the work of blockchain-related standards. The following mainly analyzes all the blockchain standards currently published by ISO, ITU-T and IEEE according to the above classification methods.

### *4.1 Blockchain and DLT Standard Classification Statistics in ISO*

In the current statistics of ISO's published blockchain and DLT related standards, they mainly focus on terminology, classification and ontology, smart contracts, digital assets, privacy, and personal information protection, etc. In terms of blockchain standards under research, it mainly focuses on reference architecture, cross-chain interoperability, distributed digital identity, use cases, etc. It should be noted that the standards researched and formulated by ISO/TC 307 are more focused on the blockchain and DLT itself, and do not involve standards in a certain segment (such as finance, energy, medical care, etc.), but also need to pay attention to, ISO blockchain-related standards are still in the development period, lacking standards such as consensus mechanisms, oracles, on-chain and off-chain data specifications, etc., and there are phenomena such as incomplete standard coverage and unexplored technical fields.

As shown in Fig. 5, from the perspective of standard classification, basic standards account for the largest number, reaching 7 items, accounting for nearly half of the overall number, followed by information security standards and business and application standards. The number is 3, and ISO also has standard project research in other standard fields.

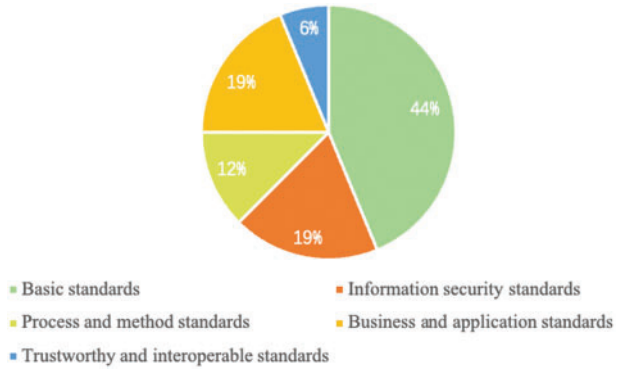


**Figure 5:** Statistics of ISO blockchain standard types

ISO has made great efforts in basic standards and has a layout for the terms and infrastructure of blockchain and DLT. The layout of standards and application standards is still in its infancy. The standards have great potential for development, a wide range of coverage, and a deep degree of expansion. It is foreseeable that ISO/TC 307 will have more standards development and input into these standard classifications.

### *4.2 Blockchain and DLT Standard Classification Statistics in ITU-T*

With the continuous development and improvement of blockchain technology, the development of blockchain-related standards has gradually shown an upward trend [55]. As shown in Fig. 6, all ITU-T blockchain and DLT related standards are based on this basic standard and information security standard. trusted and interoperable standards, process and method standards, business and application standards for statistics. As can be seen from the figure, there are many basic technology and application standards, accounting for 60% of the total, followed by security standards. The number of trusted and interoperable standards is small, and there are no new technology-related standards such as cross-chain, NFT, and Metaverse [56].

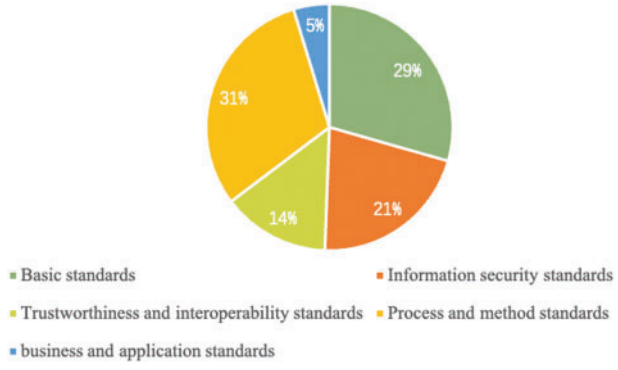


**Figure 6:** Statistics of ITU-T blockchain standard types

### *4.3 Blockchain and DLT Standard Classification Statistics in IEEE*

At present, IEEE has published 12 blockchain standards. Similarly, all IEEE's published blockchain and DLT related standards are based on this basic standard, information security standard,

trustworthiness and interoperability standard, process and method standard, business and apply standard 5 categories for statistics [57–60]. As shown in Fig. 7, there is little difference in the number of various technical standards. Among them, the number of process method, business and application standards is the largest, reaching 6, accounting for 50%, followed by basic technology, interoperability and information security. The standard of each category is 2 items, each accounting for 25% of the total. The number of process method standards is the least, with 2 standards, accounting for 16.7% of the total number of technical standards. The number base of various technical standards is not large, and both technical standards and industry application standards account for the IEEE area. 50% of the total number of blockchain standards. This data shows that the development of blockchain standards is balanced in terms of technical standards, there is no centralized development of standards in one aspect, and few standards in other aspects.

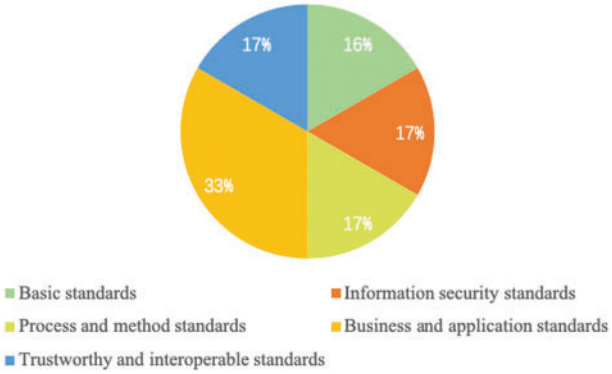


**Figure 7:** Statistics of IEEE blockchain standard types

### *4.4 Comprehensive Analysis*

As of December 2022, the three major international standardization organizations, ITU, ISO and IEEE, have issued a total of 40 standards related to blockchain and DLT. ISO has published 9 international standards, focusing on the technical foundation and security fields. Four working groups related to ITU-T blockchain have published a total of 31 international standards related to blockchain technology, mainly focusing on technology and data foundation, security, supervision, artificial intelligence, Internet of Things, smart cities and other fields.

From the published international blockchain standard data in Fig. 8, the number of IEEE's published blockchain and DLT standards is less than ITU-T. There is a lag, but from 2020 to 2022, the IEEE blockchain standard formulation has achieved fruitful results. As of December 2022, IEEE has published 10 international blockchain standards, of which 6 will be officially published in 2020 and 2 will be officially published in 2021, 2 items will be officially published before March 2022. ISO has published a small number of standards, and ITU and IEEE published standards are mainly distributed in basic standards, business and application standards. Including application fields such as cryptocurrencies, IoT data management, supply chain finance, and electronic invoices, the published standard data in the field of trustworthiness and interoperability is 0, and they are currently under research.

According to statistics, there are currently 11 blockchain and DLT related standards under research by ISO, mainly focusing on identity management, smart contracts, interoperability, governance, etc. There are 54 blockchain and DLT related standards under research by ITU and IEEE.

There are more than 60 blockchain standards under research, covering smart contracts, cross-chain, identity, security, asset management, etc. As can be seen from Fig. 9, the international blockchain standards under research, IEEE blockchain standards are currently focused on fundamental technology, business and application areas, and the number of processes and methods is increasing. The sudden increase in the number of IEEE blockchain standards under research reflects the recognition and enthusiasm of experts in the global blockchain field for the IEEE blockchain and DLT standards, and also shows that the influence of IEEE blockchain and DLT standards has gradually grown, and it has also enriched It expands the coverage of the international blockchain standard system, promotes the speed of formulation of international blockchain and DLT standards, and provides important reference value for the formulation of international blockchain and DLT standards.

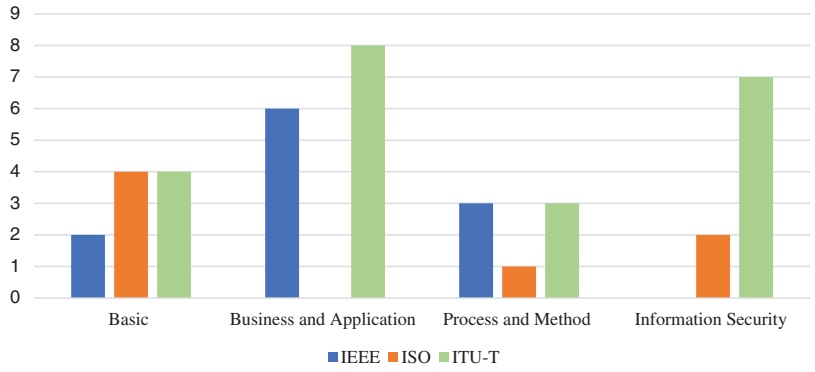


**Figure 8:** Published international blockchain standards

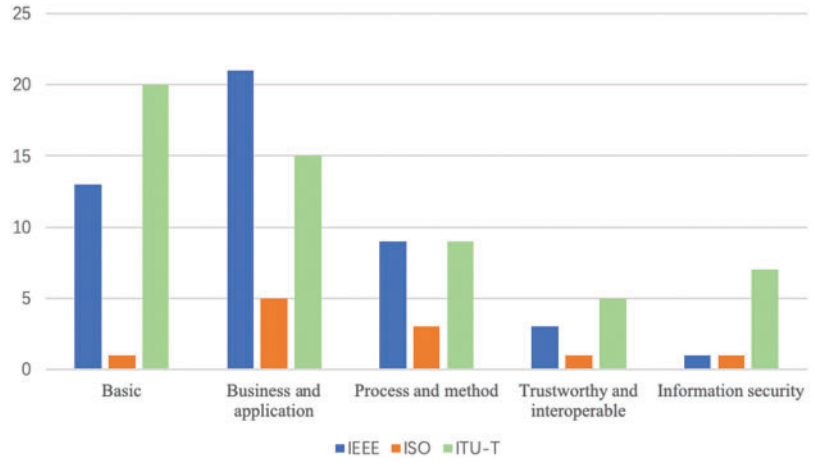


**Figure 9:** International blockchain and DLT standards under development

## 5 Overlaps, Gaps and Conflicts in the Field of International Blockchain and DLT Standards

### *5.1 Overlaps in the Field of Standards Development*

At present, there are many international standards development organizations, and they are all carrying out standard development work in the field of blockchain, including blockchain technical standards, blockchain industry application standards, and standards for the integration of blockchain technology and other technologies (such as IoT, big data, AI, etc.) [61–65]. These standards

development organizations have different participants and different technical fields of concern, so some fields have high attention. Standards in this area have sprung up with the development of technology, so there is a phenomenon that the scope of standard development in some fields overlaps. while some areas have received less attention or have not been explored, and there are few or no standards in this area. Through the analysis of the statistical data of international standards, it is found that there are overlaps in the standard development of the following five areas [66].

#### *5.1.1 Terminology*

Since terminology is a fundamental part of all standard development processes, it is the basis for standard development, and the basis for the activity of standard development. Therefore, different standards development organizations have carried out the development of terminology standards [67]. However, due to the different organizations that develop standards, different entities involved in the development of standards, and experts or editors involved in the development of standards with different depths of understanding of blockchain and DLT, the definition of blockchain and DLT and the standards of the reference architecture will overlap or difference. At present, ITU-T has published the term-related standard "X.1400: *Terms and definitions for distributed ledger technology"*, and ISO has published the term-related standard "22739:2020 *Blockchain and distributed ledger technologies—Vocabulary*".

#### *5.1.2 Security*

Security issues have always been a field of high concern around the world, and cyber security is a top priority. As countries pay more attention to blockchain and DLT, the development of blockchain and DLT security standards is also the focus field of international standards development organizations. Although the blockchain and DLT was created by innovating on the shoulders of giants, with the continuous development of blockchain technology and the continuous improvement of the blockchain ecosystem, in addition to traditional network security issues, the blockchain and DLT field has also emerged in addition to the unique network attack methods and methods of many blockchain and DLT systems, consensus protocols and licenses will also affect the formulation of blockchain and DLT security standards [68–74]. Therefore, accelerating the development of blockchain security standardization has become the consensus of many practitioners in the industry. According to statistics, ISO, IEEE, ITU-T and SAC have more than a dozen standards related to blockchain security. For example, ISO has published safety-related standards ISO/TR 23244:2020 and ISO/TR 23576:2020, ITU-T has published ITU-T SG17 X.1401, ITU-T SG17 X.1402, ITU-T SG17 X.1403, ITU-T SG17 X.1404, etc., China is developing national security-related standards in SAC/TC260, *Information security technology–Security specification for information service of blockchain*, *Information security technology–Security framework for blockchain technology* [75].

#### *5.1.3 IoT*

With the continuous development of the times and modern technologies, to better serve the society and meet new needs, more and more new technologies, new models and new platforms are emerging. Blockchain technology and IoT technology are the two most prominent. The combination of blockchain and the IoT can solve some problems existing on the IoT, also bring the perfect applications of the blockchain to the IoT. Assessing the convergence of emerging technologies is critical for forward-looking standardization efforts. Therefore, the International Standardization Organizations pay high attention to the standardization of the integration of blockchain technology and IoT technology [75–80]. For example, ITU-T and IEEE have formulated several standards for the integration of blockchain

technology and IoT technology. For example, IEEE published the IoT-related blockchain standard 2144.1–2020 *Standard for Framework of Blockchain-Based Internet of Things (IoT) Data Management*. In addition, IEEE also has several IoT-related blockchain standards under development: P2144.2 *Standard for Functional Requirements in Blockchain-Based Internet of Things (IoT) Data Management*, P2144.3 *Standard for Assessment of Blockchain-Based Internet of Things (IoT) Data Management*, P2418.1 *Standard for the Framework of Blockchain Use in Internet of Things (IoT)*, etc.

### *5.1.4 Decentralized Identifiers, DID*

Digital identity can be regarded as the cornerstone of digitization in various fields, whether government governance, public services, or medical care, telecommunications, finance, etc. With the full awakening of the awareness of "data sovereignty", blockchain-based digital identity is accelerating the "scenario" layout. Throughout the world, many participants, including governments, banks, Internet giants, and startups, are making various attempts in the field of digital identity, and some typical fields have already achieved preliminary results [81]. At the same time, the basic principles of digital identity, the generation and management of secret keys, protocol specifications, signature authentication, data formats, etc. are the core focus of standards formulation by various standard-setting agencies. W3C, ISO, IEEE and China Standardization Organization have developed several DID-related standards. For example, DID-related standards published by W3C Decentralized Identifiers (DIDs) Core architecture, data model, and representations (https://www.w3.org/TR/did-core/#abstract). DID-related standards published by ISO 24165-1: 2021 *Digital token identifier (DTI)–Registration, assignment and structure*, the DID-related standard P3210 *Standard for Blockchain-based Digital Identity System Framework* under development by IEEE [82–88].

### *5.1.5 Technical Requirements*

For operating a blockchain and DLT system, it is necessary to consider its software requirements and hardware requirements. Therefore, the technical requirements of the blockchain and DLT are also the focus of the current standard-setting bodies. At present, there are many blockchain-related requirements and standards in the world, such as the technical requirements or specifications of the underlying platform of the blockchain, the requirements of smart contracts, the requirements of consensus mechanisms, the technical requirements of cross-chain, etc., as well as storage, network, computational requirements, in addition, there are some standards that include functional requirements, security requirements, performance requirements, reliability requirements, scalability requirements, interoperability requirements and compliance requirements. For example, 3801–2022 *Standard for Blockchain-Based Electronic Contracts* and 3802–2022 *Standard for application technical specification of blockchain-based E-commerce transaction evidence collecting* have been published by IEEE [89]. The underlying blockchain platform, smart contract, consensus mechanism of contracts and E-commerce transaction evidence collecting put forward corresponding requirements. For example, the standard F.751.5 (ex F.DLT-DMPG): *Requirements for DLT-Based Data Management for Power Grid*, which is published by ITU-T, also puts forward corresponding technical requirements for power grid data management in the vertical application field of blockchain, including: Compliance, Security, Permission Grading, Scalability, Business high availability, Traceable, etc. Blockchain requirements also have specific requirements according to different scenarios, which need to be based on national conditions and other aspects [90–92]. For example, different countries have different governance policies for the blockchain, and the specific governance requirements are also different; different countries have different regulatory policies for the blockchain and DLT, and the specific regulatory requirements are also different.

### *5.2 Gaps in the Field of Standards Development*

Although the current international standards development organizations have paid a lot of attention to certain aspects of the blockchain and DLT, despite this, due to the immaturity of the technology, the complexity of the application scope and the differences in the basic concepts of the technology, there are still some differences. The following four gaps are listed:

#### *5.2.1 Decisions on the Applications of Blockchain and DLT*

Blockchain and DLT are the innovative technologies because of its potential to create a secure real-time communication network that can support and enhance capabilities from supply chains, payment systems, and medical data sharing, among others [93]. However, supply chain systems, payment systems, medical systems, etc. may not necessarily use blockchain and DLT, and some scenarios and businesses need to evaluate and judge the necessity of using blockchain and DLT. Most institutions can draw from the core technical elements of the blockchain and DLT, the performance indicators of DLT and the evaluation guidance in the relevant vertical fields whether it is suitable to use the blockchain and DLT, and thus obtain specific application reference frame standards.

#### *5.2.2 Development of Core Technologies*

Based on the continuous development of blockchain and DLT, such as consensus algorithms, interoperability, and integration and innovation with other digital technologies, it is also largely related to the construction of knowledge reserves of industry participants and the continuous evolution of technology. The development of technology is restricted by formalization and standardization, and the development of technology will drive the formulation of new standards, but the previous standards also have reference value.

#### *5.2.3 Testing of Blockchain and DLT*

The testing of blockchain and DLT is very different from traditional software testing, which is mainly reflected in fuzzy system boundaries, complex failure types, and different types of blockchains and DLT. Develop different test plans according to the test requirements and test scenarios. IEEE established a blockchain performance testing standard IEEE P3214 *Standard for Testing Specification of Blockchain Systems*, which defines the definition, types, testing specifications, testing methods, and testing procedures of blockchain systems. The standard also defines a test architecture for blockchain systems, including but not limited to functional testing, performance testing, security testing, stability testing, and compliance testing.

#### *5.2.4 Applications in Related Vertical Fields*

As mentioned above, standard setting organizations have begun to explore applications in different vertical fields. At present, blockchain and DLT have been widely used in vertical industries such as trade, logistics, finance, government affairs, intellectual property, agriculture, energy, education, and medical care. Applications are under development in vertical industries such as entertainment, social public services, social networking, daily consumption, and industry [94]. However, there are still unexplored areas. Since the expert members in different standards development organizations come from different countries in the world, the specific applications in vertical fields will be different. The same expert may participate in multiple different international standardization organizations or may only participate in one. The corresponding standards will also be different, and there are inevitably some gaps.

### *5.3 Conflicts in the Field of Standards Development*

#### *5.3.1 The Entities that Set the Standards Are Different*

Today, many standards development activities are based in Europe, North America and China. While some agencies have deliberately attempted to incorporate global voices into their standard development activities through local channels, many groups or regional representatives do not have a clear mandate for geographic representation. For example, of ISO's 11 working groups, only one (the DLT Audit Guidelines Ad Hoc Group) has a convener that is not from Europe, North America, or Australia [95]. Because of this representativeness, or the lack of opportunities for other countries to submit feedback, standards may not be compatible with infrastructure, regulatory and/or operational realities in certain regions. In addition, core thematic elements of standards-setting efforts such as privacy contain a great deal of cultural interpretation and context. There are cultural differences in the world, so there is a possibility of conflict in the formulation of privacy standards.

#### *5.3.2 The Implementation of the Standard Is Not Perfect*

Some argue that standard payments defeat the purpose of blockchain and DLT, however, open-source projects face their own set of considerations and constraints. The current state of decentralization and blockchain also means that there is no dedicated entity responsible for issuing standards and overseeing their implementation. Therefore, the implementation of the standard is largely determined at the organizational and ecosystem level. Many people need to pay to become members to participate in the development of blockchain and DLT standards, so the upper organizational structure will inform the organizational standards strategy [96–98].

In addition, many companies now measure the number of standards they developed, but ignore the organization and implementation of standards and implementation supervision perfect. There are still problems such as "emphasis on preparation and neglect of implementation", "non-compliance with standards and lax implementation of standards". Moreover, many standards are excerpted from each other, there are few innovative contents, few actual compiling personnel, and limited review experts. The quality of formulation and revision is poor, and the effect of standard implementation is poor.

#### *5.3.3 Complex and Diverse Expertise and Diverse Consumer Representation*

Given that blockchain and DLT involves software, cryptography, and economics, diverse expertise is required during the standard development process. Consumer engagement also varies. Some standards development organizations have partnered with consumer-facing groups [99]. For example, ISO works closely with Consumers International, and in the case of open-source, protocol-oriented standards, the contributors are usually the consumers of the product. At the very least, the standard process is transparent and accessible via GitHub. However, transparency may not be the main concern in the standards development process, and a transparent standards process may have consumer protection concerns.

#### *5.3.4 Intellectual Property Considerations Remain Unclear*

A well-functioning standards body creates a standard that is easy to implement, and furthermore, there should be no patent issues, or, if there are, it should be clearly stated. However, it is important to note that there may be trade-offs between openness and intellectual property ownership. For example, the open processes used by Bitcoin and Ethereum, because participation is completely public and without any transfer of intellectual property rights, has the potential to create standards that infringe the patents owned by the participants. While this has not emerged as a substantial issue, it could be a

risk in the future. Conversely, other standards bodies run processes that are arguably more ”closed,” as participants in these conversations may need to agree to license any proprietary IP, they hold that is covered by those standards.

## 6 Suggestions for International Blockchain and DLT Standardization

From the current situation, ITU-T has several SGs which develop blockchain and DLT standards. The secretariat of ISO/TC 307 is set up in the SA, which mainly develops and discusses the development of international standards related to blockchain and DLT, focuses on the formulation of basic standards for blockchain and DLT. In addition, ISO/TC 307 is responsible for cooperating with other international standards organizations to study standardization issues related to this field [100]. The formulation of IEEE blockchain standards is mainly concentrated in Europe, North America, and China. At present, in addition to the formulation of basic standards for blockchain and DLT, more and more industry application standards have been published, and at the same time, blockchain and other technologies have begun to be deployed fusion application class standard.

From the perspective of the international development environment, the characteristics presented by the development of international standards in the blockchain and DLT field in 2022 will continue in the future. The development of international standards for blockchain and DLT will be mainly reflected in the following aspects in the future.

### *6.1 International Standardization Organizations*

#### *6.1.1 Ensure Further Coordination and Cooperation among Standardization Organizations*

As mentioned in the previous analysis, there are both overlaps and gaps in current blockchain-related international standards. This situation can be mitigated by increasing cross-entity collaboration, for example, through exchanges or consultations between committee or working group leaders of standards development organizations [101]. This promotes standard consistency, including harmonizing terminology and working definitions, standardizing the order in which standards are developed, minimizing redundancy, and maximizing interoperability.

#### *6.1.2 Ensure that Discussions on Standardization May Be Premature*

Certain technical aspects of blockchain and DLT may not be mature enough for standardization activities. Premature setting of standards may stifle innovation or lead to some degree of tilt or adverse measures. Therefore, setting the scope of the standard is crucial. It is important to carefully define these aspects, and activities related to technology development and corresponding standards development can be carried out simultaneously in determining the basic technology development path [102]. As technology evolves, standards development organizations may opt for a principles-based approach: first high-level principles are defined, then relevant guidance is issued, and eventually, when the technical aspects have reached sufficient maturity, further standards can be specified and developed.

#### *6.1.3 Diversified Development and Promotion of Standards*

Currently, most standards development organizations support public review of drafted standards and represent a broad spectrum of countries and organizations when developing blockchain standards. Ensuring diverse representation is critical to maintaining the integrity and coverage of standards, creating a process for designing standards that do not image a particular product, idea, or geopolitical interests [103]. Given that the headquarters of standards development organizations are mainly located

in Europe and North America, the views of experts from other countries around the world need to be considered.

### *6.2 Entities Involved in Standards Developement*

#### *6.2.1 Early Participation in Standards Development Activities*

Entities should identify their participation (or non-participation) in relevant standard developement activities as early as possible. Among these activities, this may include, but is not limited to, identifying areas or topics of engagement, joining specific industry standardization action groups or appointing technical experts to work groups at an early stage, however, it is recommended that entities continue keep an eye on ongoing standards development activities to at least understand the progress and changing landscape of standards development [104].

#### *6.2.2 Diversity Collaborates to Develop Standards*

As the entire paper demonstrates, the development of blockchain and DLT standards is a mixture of industry-specific demands and responses. Therefore, organizations can benefit from joining or learning from industry alliances. The collaborative approach used by industry consortia to identify influence gaps in the industry sector and observe suitable entities or individuals for setting standards can help minimize redundant and redundant activities.

#### *6.2.3 Active Adoption of Existing Standards*

At present, China's standards at all levels (national standards, industry standards, group standards, local standards, and enterprise standards) adopt international corresponding standards when they are published. The Chinese standardization system is compatible with international standards, absorbs international experience and understands international consensus. Based on actively adopting existing international standards, we should also actively lead or participate in the formulation of more international standards.

## 7 Conclusion

The professional and global nature of the International Standardization Organizations provides an international professional platform for the development of blockchain and DLT standards. More and more blockchain and DLT experts around the world are actively participating in the development of blockchain and DLT standards. The number of blockchain and DLT standards has exploded. The blockchain technology and application systems are constantly developing and improving with the promotion of policies and laws, and the relevant blockchain and DLT standards are also constantly brewing and developing. At the same time, the International Standardization Organizations, like ISO, ITU-T, IEEE, etc., have also made efforts in the field of blockchain and DLT standards and have deployed in various fields of blockchain technology and blockchain applications. This paper analyzes the standardization and the layout of technical standards in mainstream international standardization institutions in blockchain and DLT filed, comparative analysis of the technical scope and fields of IEEE, ITU-T, and ISO blockchain and DLT standards, and put forward corresponding suggestions and prospects for global standardization institutions and entities involved in standardization. In the next few years, more and more international blockchain and DLT standards will be published, and blockchain and DLT standards will be more internationalized to promote the development of the blockchain industry.

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