

Construction and Implementation Path for Industrial Internet Standards System in China

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Abstract: Industrial Internet links new-generation information technology and advanced industries; therefore, standardization of the industrial Internet is crucial for both the innovative development thereof and for establishing effective connections between all the links in the industrial chain. In this study, the foundation work conducted in China and abroad for the standardization of the industrial Internet in fields such as industrial networks, big data, platforms, and information security is reviewed, and the challenges associated with industrial Internet standardization are summarized. Moreover, a framework for the industrial Internet standards system is proposed, consisting of basic and common, network, data, platform, and security standards. An implementation path for industrial Internet standardization is proposed and demonstrated, focusing on common demands in key areas, such as reference architecture construction, interconnectivity in data circulation, processing and use, monitoring control and decision optimization, and network security. Advancing the industrial Internet standards system requires accelerating breakthroughs for key industrial Internet standards, strengthening the application and promotion of standards, and cultivating and improving the industrial ecology.

Keywords: industrial Internet; standardization; system framework; implementation path

1 Introduction

As a new type of network infrastructure, the industrial Internet is a link between new-generation information technology and advanced industries [1]. In recent years, China has been focusing on intelligent manufacturing, accelerating the innovation and development of the industrial Internet [2], and improving the level of digital, networked, and intelligent manufacturing in the manufacturing industry. During the fight against COVID-19, industrial Internet companies have built multiple material information docking platforms to efficiently aggregate information and data generated upstream and downstream of the industrial chain and achieve accurate matching of production information, such as that used in the production of medical materials [3].

With the rapid development of the industrial Internet, the standardization thereof is imminent. Recently, national competent authorities have issued several policy documents to actively promote the standardization of the industrial Internet. In March 2019, the *Guide for the Construction of Industrial Internet Comprehensive Standardization System* proposed a conceptual framework of industrial Internet standards [4], focusing on promoting standardization and supporting industry application, and it detailed key technologies, products, management, and application requirements of the industrial Internet. In January 2021, the *Industrial Internet Innovation Development Action Plan (2021–2023)* formulated the development goals and key tasks for the advancement of China's industrial Internet over the next three years [5].

The industrial Internet is closely related to and interacts with the Internet of things, big data, information

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technology, and network security. Establishing an industrial Internet standards system requires not only research into the industrial Internet technology system itself, but also into related directions, such as the Internet of things, big data, information technology, and network security. Based on the actual requirements of the industrial Internet standards system, this article defines the development status, summarizes the existing challenges, proposes a system framework, and demonstrates an implementation path thereof to provide a basic reference for the standardization and high-quality development of China's industrial Internet.

2 Analysis of the role and progress of industrial Internet standardization

2.1 Analysis of the role of industrial Internet standardization

China attaches great importance to Internet standardization and aims to promote high-tech innovation at high standards to bring about high-quality development [6]. Standardization is the basis for realizing mutual governance, promotion, and application of the industrial Internet [7], and it is also an effective means of promoting industrial innovation and development.

In recent years, a number of international standards for information technology have been published internationally, which have played an important role in promoting network construction and use, big data, network security, and compatibility between various industrial networks. For example, the ISO 7498 open system interconnection model is a series of standards developed by the International Organization for Standardization [8] to effectively guide communication between various smart devices.

Standards can solidify the experience and knowledge of experts in various fields [9], standardize enabling technologies, reference architectures, and interconnections in various fields, and aid in the guidance, promotion, integration, and development of related technologies and industries. For example, the *Information Technology—Big Data—Core Metadata for Industrial Product* (GB/T 38555—2020) gathers the experience and knowledge of experts in China from various fields in the industry, stipulates the representation method of industrial product core metadata, and promotes information exchange.

Standards represent a bridge connecting scientific research and production. They can accelerate the demonstration and promotion of key industrial Internet technologies and contribute to the large-scale application thereof, thereby promoting technological progress. For example, the *Information Security Technology—Implementation Guide to Risk Assessment of Industrial Control Systems* (GB/T 36466—2018) provides the necessary basics for testing agencies and suppliers to conduct industrial control system risk assessment and promote the network security construction of industrial control systems.

2.2 Foreign industrial Internet standardization efforts

Recently, the International Organization for Standardization has focused on the standardization of the Internet of things and industrial data, laying a solid foundation for the international standardization of the industrial Internet. The International Organization for Standardization/ International Electrotechnical Commission First Joint Technical Committee (ISO/IEC JTC1) has accomplished the development of global information and communication technology standards [10], and its subordinate organizations are conducting international standardization research in the field of the Internet of things and digital twin technologies. The International Organization for Standardization/ Automation System and Integration Technical Committee (ISO/TC184) is the core standardization organization in the field of industrial automation, focusing on standardization research regarding automation and control systems, information systems, and integration technologies. The International Electrotechnical Commission/ Industrial Process Measurement and Control Technical Committee (IEC/TC65) mainly focuses on international standards of systems and components for industrial process measurement and control in the field of continuous and batch control [11]. The International Electrotechnical Commission/ Industrial Network Subcommittee (IEC/SC 65C) is responsible for formulating international standards related to industrial networks, such as interoperability and performance evaluation.

Based on the needs of industrial development, the United States and Germany promote related standardization at multiple levels, such as industrial alliances and national policies. The Industrial Internet Alliance of the United States was initiated and established by several large information technology companies [12]. It is an important platform for the promotion and standardization of the industrial Internet; guided by the reference architecture, it organizes application exploration in vertical fields and establishes a test bed to provide the supporting conditions via application to cases independently established by the enterprise; it also cooperates with other standardization

organizations to promote industrial Internet application. Germany proposed the concept of Industry 4.0 through national industrial planning and released the *Industry 4.0 Standardization Roadmap* (Fourth Edition), which recommends that the current core standardization requirements should include real cases, reference architecture models, systems and their attributes, interoperability, integration, and communication. The cross-domain standardization requirements are divided into open source, industrial security, data protection/privacy, value-added network credibility, and functional security, among others.

2.3 China's industrial Internet standardization efforts

China has been actively promoting the standardization of the industrial Internet and has officially issued several policies, such as the *Industrial Internet Innovation and Development Action Plan (2021–2023)* and *Guide for the Construction of Industrial Internet Comprehensive Standardization System*. The *Guide for the Construction of Industrial Internet Comprehensive Standardization System* identified 320 industrial Internet standard projects, and it is estimated that by 2025, more than 100 standards will be formulated [5], focusing on supporting the application of standardization in industry. The industrial Internet standards system relies on industry-leading companies to achieve key breakthroughs in the application of standards in certain areas, such as identity resolution, factory intranet, network resource management, edge equipment, industrial big data, and other standards that are urgently needed for industrial development.

Industrial Internet standardization is inseparable from fields such as industrial networks, data, platforms, and network security. (1) In terms of industrial networks, China has established a well-developed foundation for the external network of factories, leading to the formation of international standards, such as the Ethernet for factory automation and wireless networks for industrial process automation. (2) In terms of data, relying on the Big Data Standards Working Group of the National Information Technology Standardization Technical Committee, China has focused on the application of big data technology in fields such as industrial product development, production, and service, as well as on industrial data management to perform standardization research, and published a framework for industrial big data standard systems [13]. (3) There are more than 50 industrial Internet platforms with industry and regional influence [14], and the *Industrial Internet Platform Standardization White Paper* has been released and updated, and suggestions on the standardization development direction and the construction of standardization ecology have been proposed. (4) In terms of network security, since 2010, research and formulation of information-security-related standards for industrial control systems have been conducted [15]. Based on the National Information Security Standardization Technical Committee, an industrial control system information security standard system has been proposed.

3 Industrial Internet standardization challenges in China

3.1 System layout of industrial Internet standards requires urgent optimization

With the expansion of industrial Internet technology research and industrial applications, an increasing number of enterprises, universities, and research institutes have participated in investigating industrial Internet standards, and various national, industry, and group standards are continually being released. However, there is no organization that coordinates relevant standards, and there is no reasonable arrangement of priorities and urgency among standards; hence, the existing standards are not systematically formulated, and a coordinated and unified industrial Internet standardization development approach is yet to be undertaken.

3.2 Coordination with existing standards in related fields has not yet been achieved

Currently, 294 national standards related to Internet security have been issued, while 416 are under formulation, and 949 national standards related to information technology have been issued, while 969 are under formulation. These standards provide the basis and reference for industrial Internet standardization, and some standards in the industrial Internet standard system can be used or modified. In the process of formulating the current industrial Internet standard system, the coordination and promotion mechanism using existing standards in related fields has not yet been defined, leading to possible duplicate developments.

3.3 The application of standards needs to be intensely promoted

Industrial Internet standards involve the integration of industry, information technology, and related new technology fields. However, in the actual development process, the application of standards is generally

insufficient. In particular, the implementation of key standards is not sufficient, such as the *Information Technology—General Data Import Interface* (GB/T 36345—2018), which aims to solve the challenges of data interconnection.

4 System framework and implementation path of industrial Internet standards

The core of the industrial Internet-related technology system is data processing. Based on network interconnection, through data collection, transmission, integration, screening, and use, both platform-based and application-oriented, the optimization of decision-making, analysis, and control of the manufacturing process are conducted, while paying attention to the security issues present in the entire data closed-loop process. Based on the *Guide for the Construction of Industrial Internet Comprehensive Standardization System*, this study proposes an industrial Internet standard system framework for industrial development needs (Fig. 1), and aims to fully characterize the information infrastructure of the industrial Internet. The main objectives of an industrial Internet standard system involve basic and common, network, data, platform, and security standards, crucial for building a framework of the industrial Internet standard system, and addressing the standardization problem in the data circulation process.

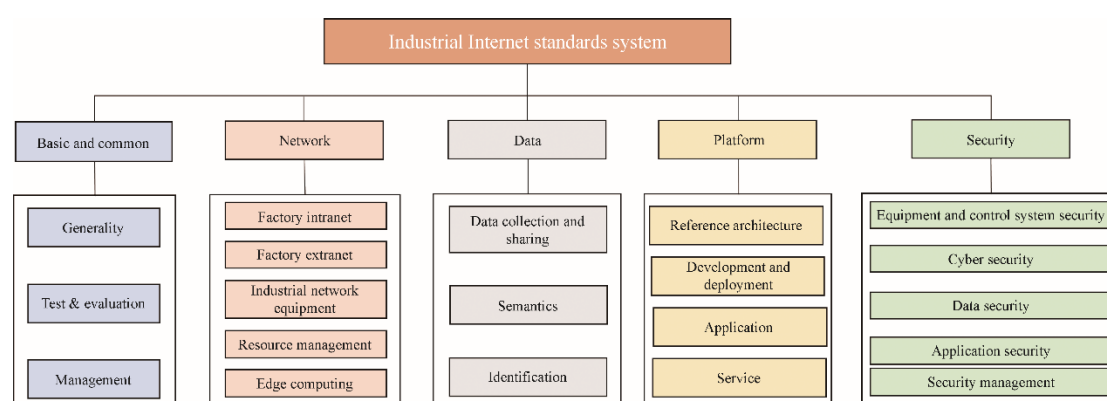


Fig. 1. Framework of the industrial Internet standard system.

Based on the system layout requirements and the framework of the industrial Internet standard system, this study proposes a roadmap for the formulation of industrial Internet standards (Fig. 2) whilst focusing on the challenges of industrial development, to define the main industry research tasks for the next five years. Based on the industrial Internet standards system and the developed roadmap, we can utilize trend research results and effectiveness evaluation tools to continue to iteratively optimize the system and roadmap, and promote the formation of a closed-loop work mechanism of “inspecting effectiveness to promote implementation and evaluating feedback to facilitate improvement.” This study is dedicated to elucidating and defining the interconnection and interoperability of equipment, production processes, and resource allocation within enterprises and group companies.

4.1 Basic and common standards

Considering the dividing methods of the basic and common standards in the *Guide for the Construction of Industrial Internet Comprehensive Standardization System* and the *Guidelines for the Construction of National Intelligent Manufacturing Standards System (2018 Edition)*, [16] it is recommended that the basic and common standards be divided into generality, test and evaluation, and management. Generality standards include definition, architecture, function, and reliability related to the industrial Internet. Test and evaluation standards include test methods, test indicators, and evaluation methods. Management standards include the management requirements for system construction, operation entities, and key elements. Basic and common standards are common standards in various fields of the industrial Internet, and they additionally form the basis for the formulation of standards in other fields.

As the foundation and principal part of the industrial Internet, the development of evaluation standards should be prioritized to promote the construction of the industrial Internet and provide effective tools for the accelerated innovation and development thereof. Standards related to “Basic & foundation—Test and Evaluation” in Fig. 1 are temporarily missing, and the research and formulation of relevant standards, such as *Industrial Internet Evaluation*

Index, Industrial APP Identification and Classification Evaluation Specification, Technical Testing and Evaluation Environment of Industrial Internet Network, and Industrial Internet Platform Application Capability and Performance Evaluation, should be promoted.

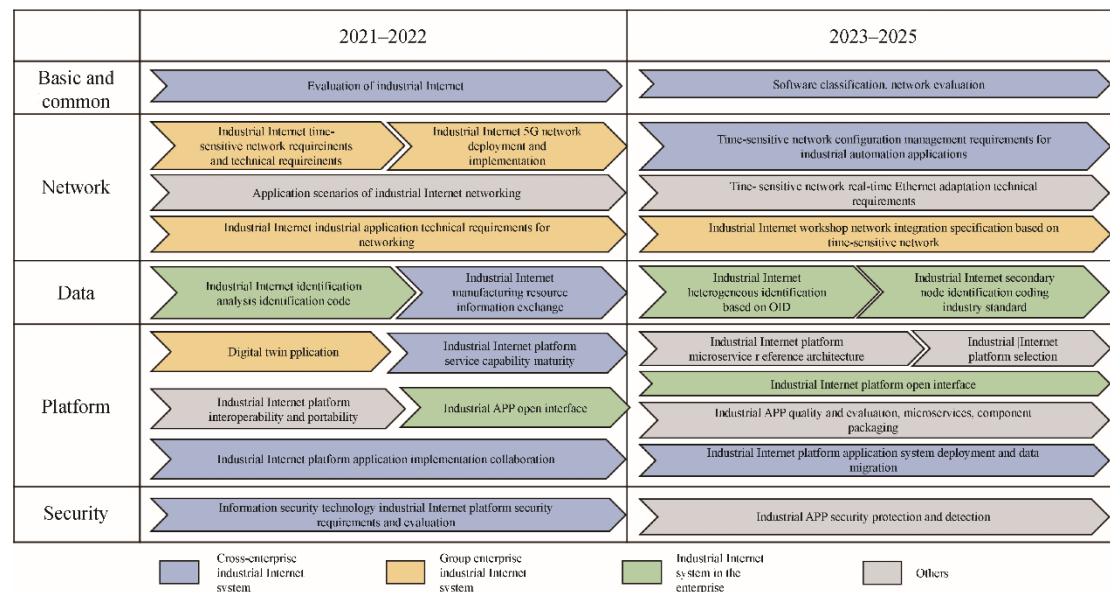


Fig. 2. Roadmap for the development of industrial Internet standards.

4.2 Network standards

Network standards should focus on the operation technology related to network interconnection, the information technology convergence network, and the backbone network [17]; these standards are divided into five parts: factory intranet, factory extranet, industrial network equipment, resource management, and edge computing. Industrial network equipment includes equipment/product networking, network equipment, and other low-level hardware standards, and network layer requirements should be highlighted. Resource management standards involve resource usage, such as addresses and the wireless spectrum, and network operation and management requirements. Edge computing is closely related to network layer standards. Internet standards are the key standards that regulate industrial Internet ontology and provide network connections and interconnection support for industrial Internet applications.

The *Guidelines for the Construction and Promotion of Industrial Internet Networks* released in 2018 clearly defines the goals for the development of industrial Internet network standards. To accelerate the promotion of the integration and application of new technologies and the Industrial Internet, research and formulation of Internet standards, such as *Industrial Internet—Time Sensitive Network Requirements and Scenarios*, *Industrial Internet—Industrial Application Scenarios Based on Software Defined Wide Area Network*, and *Industrial Internet—5G Deployment Implementation Guide*, are required for key industrial Internet technologies.

4.3 Data standards

Data is one of the three cores of the industrial Internet [18]. Data standards aim to address the problem of inconsistent data formats, representation, and interfaces involved in data collection, transmission, processing, analysis, and other links in the entire production process, and realize the digitization of physical entities, data interconnection, and interoperability; data standards consist of three parts: data collection and sharing, semantics, and identification.

Society is in the stage of big data and digital transformation. Data-driven strategies and their practical applications have become a consensus. Big data technology is beneficial for reducing production costs of manufacturing companies, which is essential for high-quality economic development. Research and formulation of data sharing standards under the industrial Internet scenario, such as the *Industrial Internet—Manufacturing Resource Information Exchange Specification*, should be studied and formulated.

4.4 Platform standards

Platform standards are divided into four parts: reference architecture, development and deployment, application, and service. The platform reference architecture standards specify the overall design requirements of the platform architecture. Platform development and deployment standards include the application interface deployed on the platform, interface standards among platforms, integration and adaptation standards between systems, and platform and environment standards development and expansion requirements. Platform application standards include industrial APP-related standards (encompassing design, development, testing, and application) and industrial application program interface (API)-related standards deployed on the platform. Platform service standards include standards related to microservices and resource pools that are transplanted onto the platform and platform operation standards.

In view of the lack of standards for industrial Internet platform development, deployment, and operation and maintenance, the *Industrial Internet Platform—Application System Deployment and Data Migration Specifications*, *Industrial Internet Platform—Open Interface Specifications*, and *Industrial APP Quality and Evaluation Specifications* should be studied and formulated. Research and formulation of the *Industrial Internet Platform—Reference Architecture* should be conducted to provide an industrial Internet platform framework based on common concepts to ameliorate implementation differences. Research and formulation of the *Industrial Internet Platform Service Capability Maturity Model* should be performed to improve the level of industrial Internet platform construction. Research and formulation of the *Industrial Internet Platform—Interoperability and Portability* is required to clarify the common normative terms and concepts of industrial Internet platform interoperability and portability, as well as the relationship between the two. Research and formulation of the *Industrial Internet Platform Selection Guide* is necessary to build the service support of the platform system, platform development ecology, and improve the platform service level.

4.5 Security standards

Security standards include equipment and control system, Internet, data, and application securities, as well as security management. There is a close dynamic relationship between equipment and control system safety, hence, they should not be considered separately. Internet security standards refer to the technical requirements for products, such as communication network security protection. Data security standards include data transmission security and data security management regulations. Application security standards include platform application security and application security. Security management standards refer to security management technology and service requirements related to the industrial Internet.

The “*Industrial Internet + Safe Production*” *Action Plan (2021–2023)* released in 2020 [19] proposes a defined plan for achieving a higher quality, more efficient, more sustainable, and safer development model. To strengthen network security protection and management of key technologies and important applications of the industrial Internet, related industrial Internet platform security standards such as the *Information Security Technology—Industrial Internet Platform Security Requirements and Evaluation Specifications* and other, and industrial APP network security related standards, such as *Industrial APP Security Protection Requirements*, *Industrial APP Security Detection Requirements*, and *Industrial Internet Industrial Security APP Technical Requirements*, should be studied and formulated.

5 Suggestions

5.1 Implement breakthroughs in key standards of industrial Internet

Focusing on the urgent needs of representative industries, such as the manufacturing industry, the key standards of the industrial Internet should be studied, and the Internet, data, platform, and security should be prioritized, reflecting the supporting role of new-generation information technology in the development of the manufacturing industry. Key issues present in critical links in the manufacturing industry should be resolved to accelerate breakthroughs in important industrial Internet standards, and forward-looking 5G layout, artificial intelligence, and other new technology innovation and integration application standards. In terms of basic shortcomings, such as in identification analysis and safety production, it is recommended to concentrate efforts on key technologies and standards to form a batch of advanced standards, and software and hardware products, and promote the development of iterative interaction between standardization and technological breakthroughs.

5.2 Focus on the application of standards

The plan for the application of industrial Internet standards in the manufacturing industry should be executed in its entirety, using existing relevant standards test and verification platforms and standardization resources to build a new industrial Internet standardization public service platform, and provide one-stop standardized comprehensive services for subdivided industries and small- and medium-sized enterprises. Industry demand orientation and the application and piloting of key industrial Internet standards should be strengthened, and the advancement, applicability, and effectiveness of the standards must be verified. It is important to steer key enterprises in the industrial Internet field to undertake or participate in the formulation and revision of international, national, and industry standards, and to promote the pilot application of key standards. Industry development trends should be prospectively studied and evaluated, and the industrial Internet standard system framework roadmap must be updated and optimized.

5.3 Cultivate and improve industrial ecology

Focusing on small- and medium-sized enterprises, industrial chain circulation should be leveled out, the cost of synergy in the industrial chain should be reduced by standardized means, the product lifecycle can be shortened, and a rapid response to market changes is required. The industrial chain coordination of key industries should be expanded and standards must take on a basic support and coordination role. Additionally, promoting regional, cross-regional, and cross-departmental collaboration are also important. Leading enterprises have a responsibility to demonstrate the application of standards; cross-industry business collaboration processes and service model innovation is required, and the overall coordination efficiency of the industrial chain should be improved. Focusing on the innovation and integration standards of industrial Internet and emerging technologies is important, as is the promotion and construction of new infrastructure in the industrial Internet field, as well as the realization of the close connection and coordinated operation of upstream and downstream supporting enterprises. A group of outstanding new industrial Internet supply chain platforms need to be selected and platform benchmarks built. Overall, a demonstrative and leading role should be adopted.

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