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Industrie 4.0/Intelligent Manufacturing SME Test Bed Program Proposal

Sino-German Industrie 4.0/Intelligent Manufacturing Standardization Sub-Working Group

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FORWORD

The Industry 4.0/Intelligent Manufacturing SME Test Bed Program and the related standardisation activities can contribute to sustainable economic activities between China and German Small-Medium-Enterprises (SME – Mittelstand).

Even though, in the last years, the increasing number of I4.0 test beds, platforms and industry-research alliances and consortia still affects the challenges for digital transformation, new value chains and key technologies, such as: AI, Cloud/ Edge Computing, 5G, etc., especially small and medium-sized enterprises face the problem of mastering these challenges and tasks in addition to their day-to-day business.

Therefore, the SME Test Bed Program, provides a unique way for interested China and German small and medium-sized companies, that have fewer resources available to work and active participating on test bed projects, ensuring that not only large companies but also SMEs are directly involved in establishing new eco-systems, technology-cooperation and new bidirectional China-German business relationships.

To bring together, German Industry 4.0 and Integration of Industrialisation and Informatisation (III) of China, even though there are different models and methods, the SME Test Bed Program helps to develop and demonstrate the following key targets:

- Align Germany's Industry 4.0 and Integration of Industrialisation and Informatisation (III) of China models and methods to achieve a balanced and harmonized reference architecture.
- Develop Industry 4.0 digitalization roadmaps for suitable cooperation models and bi-national co-operation projects to show digital-supply-chain-value.
- Build a strong relationship between German SMEs and industry partners in China for best practice sharing.
- Define clear conditions, process models and KPI's for all Test Bed projects and activities.
- Describe standardisation requirements from the "Voice of the Industry" in specific areas of high-interest such as AI, Cyber Security, Data Privacy, Edge/Cloud Computing, etc.
- Empower knowledge transfer from China and German SME's to explore opportunities for an innovation partnership.
- Establish a strong education and training exchange between the Test beds and existing innovation diffusion initiatives by using the existing Smart Manufacturing network in both countries (e.g. Sino-German AGU Working Groups, e.g. Training and Qualification WG).
- Strengthen the standardisation process and dialogue of all involved standardisation bodies. This includes direct feedback to existing or new standards and specifications. Please note that the test bed program has no intention to perform conformity assessment and/or to establish certification processes. However, the new or extended standards may be the basis for testing and verification.

A focus on SMEs and the manufacturing-supply-industry in particular can play a major role of Sino-German Industry 4.0 cooperation.

This approach - to set up and initial, SME Test Bed Program and joint projects between German SMEs and industry partners in China - to achieve the goal of entering into an innovation partnership and to develop exploring opportunities, cooperation potential and align standardisation, could at least act as a catalyst for the Sino - German SME-Industry 4.0 business boost to growth.

Additionally, the proposed SME Test Bed Program will also encourage the German SMEs and industry partners in China to provide feedback on the quality of the used standards within their projects and report interoperability flaws between different standards, as well between standards and open source. Their feedback will be used to further encourage the development of new Sino-German standards as well to improve the consistency between existing standards developed within different standard and open source organisations.

1 INTRODUCTION

The Intelligent Manufacturing / Industry 4.0 are national initiatives to drive the digital transformation within the manufacturing industry. An important aspect of these initiatives is the convergence between Information Communication Technologies (ICT) and the Operational Technologies (OT). This convergence of ICT/OT enables a number of the required use cases that provide new services while introducing a more cost efficient and higher quality production capabilities towards the manufacturing industry.

The Intelligent Manufacturing / Industry 4.0 has noticed already a substantial number of initiatives in the domain of necessary standards, specifications, test beds, field trials, white papers and so on. These initiatives are driven by the larger industries who has the strategic resources (human and financial) and the academics (national or regional funded) to drive the progress of the new concepts within the mentioned Intelligent / Industry 4.0 programs. The integration of several communication technologies such as 5G, Edge Computing, Internet of Things, Artificial Intelligence, and Cyber Security are a few things that are expected to bring new experiences to the industrial automation. However, the manufacturing Small and Medium Enterprises (SMEs) are unfortunately not very well involved in these activities due to their limited resources they are able to spend to these strategic activities. As a result, most of the Intelligent Manufacturing / Industry 4.0 field trail activities fail to be transformed into successful commercial deployment within the manufacturing industry.

It is clear that the SME input and involvement within the mentioned initiatives are critical to transform the field trail projects into commercial deployments. Beyond the consideration of technical innovation aspects this requires a careful analysis and planning of scalability of the solutions and its commercial production. In addition, the financial context of the solutions shall be considered, e.g. transitioning from trial and training licenses to full-price licenses. Their feedback will contribute to the customer demands which will strengthen the specification of requirements and use cases. In addition, the direct involvement in the current activities will distribute the Intelligent Manufacturing / Industry 4.0 knowledge among the manufacturing SME and will ease the adoption of the digital transformation by the manufacturing industries. Furthermore, their direct feedback will also address the understanding of the migration steps from current industrial automation process towards the expected Intelligent Manufacturing / Industry 4.0.

2 SCOPE

This report describes a proposal for an SME Test Bed Program that shall enable the Manufacturing SMEs to be directly involved into the Intelligent Manufacturing / Industry 4.0 initiatives. It shall provide critical additional resources in domain of education, system integration and human/financial support.

The report will describe the current ICT Technology and Market Trends (chapter 3), the details of the proposed Manufacturing SME Test Bed program (chapter 4), the involved parties in SME Test Bed program (chapter 5), the application process to be followed to acquire the resources from this program (chapter 6), the incentives of this program to the Manufacturing SME applicants, as well the incentives to the industry (chapter 7), provided competence centers and lab facilities (chapter 8) and will conclude with recommendation towards decision makers on such proposed program, (chapter 9).

3 ICT TECHNOLOGY AND MARKET TRENDS

3.1 Introduction

The following technology and market trends are extracted from the IEC SEG8 Deliverables on Technology and Market Trends of Communication technologies. The documents are expected to be made public in short term.

3.2 ICT Technology Trends

This section documents new ICT technology trends related to communication technologies. It evaluates the impact of these trends in particular on systems-related standardisation activities.

For the new technology trends, the following trends are presented:

- **Fifth Generation Mobile Networks (5G)**
  The first 5G release (3GPP Release 15) still focuses on Enhanced Mobile Broadband services the other two services (i.e. URLCC and mMTC) will be supported in the next releases. With network slicing 5G can support virtual private networks that provide network Service Level Agreement (SLA) assurance, service isolation and on-demand network function customisation.

- **IoT Technologies**
  There are many IoT Technologies that are specified in several organisations. This report summarises two examples of IoT standards from networking and application interworking perspectives, such as oneM2M and W3C WoT.

- **Single-pair Ethernet (SPE)**
  SPE provides Ethernet communication at 10, 100 and 1000 Gbit/s over single twisted pair cabling. It can be used over existing wiring and specifically targets constrained devices.

- **Deterministic Networking / Time-Sensitive Networking** (DetNet, TSN)
  Deterministic networking enables achieving real time communications on a wired or wireless communication network. Their main properties are bounds on latency, loss, packet delay variation (jitter), and high reliability. Real-time traffic and normal IT traffic (best effort and QoS managed traffic) shall cohabit on the same network without impacting the real-time flows.

- **Software Defined Networking (SDN)**
  SDN separates the control functions from the data forwarding function of a network. Network control like routing becomes directly programmable by users and applications. Network resources and traffic flows can be configured and secured depending on the application and traffic needs. Standardised interfaces decouple the data forwarding, control and application layer.

- **Low-Power Wide-Area Networks (LPWAN)**
  LPWAN allows to connect a vast number of objects, often battery operated, over a large area and are optimized for low power consumption of the end devices. LPWAN usually provide bit rates in the range of 10s of bits to 100ks of bits per second and usually each node transmits a few bytes up to a few hundred bytes per day.

- **Virtualisation**
  Virtualisation allows to run multiple software entities, usually operating systems, concurrently and in isolation on a single computing hardware platform. These isolated entities are called virtual machines (VM).

- **Autonomic Networks**
  Autonomic Networking (AN) aims to dramatically simplify the management and operation of a network. Instead of relying on management decisions to be taken by a system external to the network, components within the autonomic network take decisions without external intervention, thereby eliminating management tasks in the process.

- **eSIM**
  The eSIM is a software-based solution providing secure reconfigured and updated of the SIM information from remote. It can be used in pull fashion, where a mobile phone user can for example switch to a new service provider by downloading the subscription information, or in a push fashion where an IoT service provider can push new subscription information on all of its IoT devices.

- **MulteFire**
  3GPP mobile networks are so far designed for the use in public networks with dedicated spectrum. MulteFire enables the use of LTE and next generation mobile cellular technology standalone in enterprise networks which use unlicensed/shared spectrum or special dedicated spectrum.

3.3 Market Trends

This section documents new market trends, and analyses new business models related to communication technologies. It evaluates the impact of these trends in particular on systems-related standardisation activities.

For the new market trends, the following trends are presented:

- **Internet of Things**
  IoT represents a huge market opportunity for both consumer- and vertical-specific business devices through globally interconnected and networked things.

- **Digital Twin**
  Digital twin refers to a digital replica of physical assets (physical twin), processes and systems that can be used for various purposes. It is applied to numerous domains, from energy generation and transportation to industrial process automation, mainly to decrease the cost of the maintenance of complex equipment and processes.

- **Smart Manufacturing**
  Smart Manufacturing represents a trend that goes beyond the automation of foreseeable tasks with reproducible algorithms but also focuses on individual customer requests requiring more flexibility of the production process.

- **Evolving Workforce**
  Evolving workforce refers to the shift in the trend of workforce brought about not only by talent or age- and experience-related changes, but also due to technology changes such as collaborative robots and transformative user interface platforms, which will change how actual work will be performed.

- **Digital Transformation**
  Digital transformation refers to the digitisation process that is experienced by every domain to decrease cost, improve productivity and enable new services.

- **IT/OT Convergence**
  IT/OT Convergence refer to the effort to converge two distinct technologies: IT, which is the study or use of systems (especially computers and telecommunications) for storing, retrieving, and sending information; and OT, which is hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes, and events in the enterprise.

- **Artificial Intelligence**
  AI refers to the trend where machines mimic cognitive functions that humans associate with other human minds, such as pattern matching, learning and problem solving.

For the new business models, the following models are presented, i.e. data driven, service driven and platform driven business models. These three business models are just for illustration purposes and there is no judgment which one is preferred. However, please note that the different business models will drive the necessity of supporting information communication capabilities.

There is no suggestion to standardize business models but rather highlight the correlation between innovative business models and ICT technologies. It is important that this correlation is understood when addressing new ICT technologies.

4 MANUFACTURING SME TEST BED PROGRAM

The main objective of the Manufacturing SME Test Bed Program is to promote the test bed projects within the manufacturing SME community between China and Germany to stimulate the transition from the legacy manufacturing solutions towards the Intelligent Manufacturing / Industry 4.0 solutions. The manufacturing SME would benefit from support in sense of::

1. **Training** to ensure knowledge about the value propositions, business benefits and the concepts.

2. **Integration support** to ensure interoperable migration from current manufacturing solutions towards the new smart manufacturing solutions.

3. **"German – China expert pool"** to ensure an efficient and efficient project execution for test bed projects in the field of Intelligent Manufacturing / Industry 4.0

4. **Financial support** to empower SMEs on the way of the digital transformation from current manufacturing solutions towards the new smart manufacturing solutions with important need for standardisation. The aim is to create new supply-chain-value between German and Chinese manufacturing companies. This financial support should be aligned with existing infrastructures, such as the German Mittelstand – Digital platform and platform concepts

When all the conditions are provided (i.e. knowledge, migration, resources, finance and time constraints) then the manufacturing test beds can be deployed effectively and efficiently. It will be critical to create a commercial opportunity from the test beds to have the experts pool engaged. Today, too many test bed projects are successfully executed but do not result into commercial deployment of the smart manufacturing concepts within the SMEs. This Program offers the critical services to complement a successful test bed project and support the transition of the test bed project into a commercial project. Note that the program will take no responsibility for both the test bed projects as well as the commercial projects. These projects will be under the responsibility of the Manufacturer and its project stake holders.

4.1 Education

The knowledge about the end-user benefits, supported use cases, the reference architecture and deployment options need to be distributed towards the manufacturing SMEs. This knowledge can be distributed via reports, such as Guidelines, Best Practice and White Papers. Another channel is to have public presentations and exhibitions during public industry and private events. Round Table or Panel discussions can be used to engage the Manufacturing SMEs to the Intelligent Manufacturing / Industry 4.0

The Program may also provide commercial consultancy and training services using a pool of "committed" industry experts. Training certificates will illustrate the different expertise levels of the trainers.

4.2 Digitising Industry Center (DIC)

The Program shall also provide critical support to the Manufacturing SMEs to transform their current industrial automation deployments into stepwise integration of Intelligent Manufacturing / Industry 4.0 concepts. The integration shall not only take the technical aspects into account but also the non-technical factors are equally important.

Non-technical aspects, such as staff training, organisational changes and company culture may need to have change management support as well. The introduction of Intelligent Manufacturing / Industry 4.0 will require a smooth man-machine interaction and therefore the non-technical aspects are critical as well for the successful implementation of the digital transformation.

Another aspect is that additional guidance is required to be provided to adopt the Intelligent Manufacturing / Industry 4.0 concepts within the supply chain. The Digital Transformation may introduce new business models and new services that are traditionally not within the manufacturing scope.

4.3 Resource Support

The Manufacturing SMEs will very likely lack sufficient human and financial resources to conduct the necessary investments into the deployment of Intelligent Manufacturing / Industry 4.0 solutions. However, the competitiveness of the manufacturing industry is under stress and the necessary manufacturing innovations will be fundamental to improve the economics of the manufacturing industry. Furthermore, introduction of Intelligent Manufacturing / Industry 4.0 solutions will also introduce a risk since it will require a digital transformation by all players in the value chain, i.e. suppliers, business partners, distributors and even customers.

The risks of deploying Intelligent Manufacturing / Industry 4.0 require to be mitigated to ensure a successful market deployment. It will be critical aspects to drive the transition from Industry 3.0 towards Industry 4.0. Therefore, financial support will be required in addition to the Intelligent Manufacturing / Industry 4.0 SME Program. The Manufacturing SMEs will require to comply with the program conditions, which need further study to identify these conditions.

5 THE ROLE OF INVOLVED PARTIES

5.1 The government

The Government will play an important role in the program and its most significant functions are organisation and policy guidance. In order to fully use the test bed, the government can organise all involved parties to join the program. The government can also stimulate the deployment of specific technologies within the Smart Manufacturing test beds. The government can enact some policies to promote the usability of test bed, such as government subsidies, it also can encourage the smart manufacturing industry to provide test bed services for the Manufacturing SME.

Note that the term Government refers to any government and is not intended to a single Government. In this specific context, it refers to both the Chinese and German Governments.

5.2 The Smart Manufacturing industry

The manufacturing industry stakeholders can be large enterprises, scientific research institution, colleges and universities or industry association. Generally, the industry establishes the test bed for academic research, technical identification or scheme demonstration. The industry stakeholders can provide services for SME or set a typical example for SMEs.

5.3 The Manufacturing SMEs

There are many test bed users (e.g. SMEs, standardization, certification, and research projects) and SME is one of them which can use the test bed according to its own scheme. In the report, we only discuss the SMEs and not the other test bed users.

6 APPLICATION PROCESS

The SME Test Bed Program shall manage the deliverables from the test bed projects and ensure that these are publicly available. Therefore, the program shall evaluate the proposed test beds if these test beds comply towards the objectives, requirements, and conditions of the SME Test Bed Program. In order to perform this evaluation, the SME Test Bed Program shall introduce such a Program application process.

The "Test Bed Project" representative is responsible to register the project within the SME Test Bed Program. The "Test Bed Project" shall address a number of requirements that are relevant to receive support from the SME Test Bed Program.

The Application Form will be made available online on a dedicated nominated website assigned by the Test Bed Program. The SME Test Bed Program will meet regularly in order to evaluate if the "Test Bed Project" proposal fulfils all requirements. The SME Test Bed Program will arrange a meeting with the "Test Bed Project" requirements to provide feedback to their proposal, offers appropriate experts consultancy and necessary supportive resources to ensure successful completion of the SME Test Bed Project.

The SME Test Bed Project, if desired, can be hosted by one of the Smart Manufacturing industry, for example some Lab Facilities, which are linked to the SME Test Bed Program, and it will remain under the responsibility of the original project members but will be required to produce feedback on the used standards and on any gaps of standards needed for their Test Bed. The SME Test Bed Program will evaluate the provided feedback and will address the necessary standardisation needs, such as new standardisation projects, corrections to existing standards and/or adjust the Industry 4.0 Standards Roadmap.

7 PROGRAM INCENTIVES

7.1 Manufacturing SMEs

In order to encourage the SME to take advantage of new technologies and solutions to build a sustainable digital business infrastructure, in its own shop floor and to interact seamless within the hole supply-chain to all its business partners, to achieve higher efficiency and productivity and to create new digital business opportunities, the test bed is an effective and rapid way for SME to adapt new technologies and new services.

The SME Test Bed initiative should focus on the cooperation, joint refinement of use cases, showcasing, testing and validating of innovative technologies, development of prototype implementations, and international networking, while the knowledge diffusion and the contact to SMEs are to be made via existing structures (e.g. ZIM, Mittelstand-Digital, Plattform Industrie 4.0, and Public Service Platforms).

The government should make some policies to encourage SME to positively use all kinds of social resources which include test bed, such as usage fee subsidy or exemption. These will stimulate SME to be willing to use the test bed in the long term. It is worthy to note that the Chinese test bed infrastructure is based on a longer-term vision and driven top-down, while the German test bed infrastructure relies on industrial initiatives and is driven bottom-up.

The Manufacturing SMEs can safely experience the necessary production innovations that may optimize their production processes and/or introduces new sources of the revenue streams. The SME exposure towards these innovations are critical to introduce the disruptive digital transformation of the current manufacturing technology into the new Industry 4.0 / Intelligent Manufacturing technologies.

The Manufacturing SMEs will also benefit of the accessibility towards the existing structures to exchange strategic and business visions with industry experts to prepare the transition of the product-oriented economy towards the service and/or data driven economy. The provided consultancy by independent industry consultants will enable further evolution of the manufacturer's strategic and business visions to address the digital transformation within their domain.

The provided resource support will enable the Manufacturing SME to perform innovation projects with higher efficiency (e.g. lower number of high qualified engineers, reduced financial means, and easier access to test bed facilities). This support will lower the barrier to engage actively within innovation projects that will provide the Manufacturing SMEs the insight how to migrate towards the Industry 4.0 / Intelligent Manufacturing operational technology.

The registered SME Test Bed Projects will be listed and marked as key SME projects that contributed towards the development of the Smart Manufacturing technologies. The most successful ones will be exposed by means of presentations on their learnings from the SME Test Bed Projects, e.g. test bed awards.

7.2 Industry Incentives

The direct involvement of the Manufacturing SMEs will lower the barrier for the SME to migrate towards the smart manufacturing. It will make the dedicated knowledge and competence easier accessible towards the Manufacturing SMEs. The engagement with the Manufacturing SMEs will enable direct access towards the understanding of the SME perceived challenges but also their opportunities.

The involvement of the industry experts within the SME Test Bed Program, DIC, will also be a platform to exchange non-competitive information and alignment on the key concepts within the Smart Manufacturing. The acquired feedback from the SME Test Bed projects may be the basis for further evolution of these concepts in the context of new introduced technologies such as AI, 5G, Digital Twin and Data Privacy.

The DIC of the SME Test Bed Program may have the opportunities to grow into Smart Manufacturing Think Tanks where the industry viewpoints can be formed and published on the Smart Manufacturing challenges for the industry, standardisation, cross border alignments and regulations.

Intensive collaboration between these Digitising Industry Centres will be beneficial to align the different national programs into a single end-2-end Smart Manufacturing technology that is globally accessible. It will be critical to the success of the introduction of Smart Manufacturing is not impeded by national protective measurements.

7.3 Standardisation Incentives

The current standardisation on Smart Manufacturing is industry driven and addresses a wide range of new concepts within the Operational Technology (OT) as well the Information and Communication Technology (ICT). Many Smart Manufacturing requirements are driven by the convergence of these OT and ICT technologies driven by the era of digital transformation. The standardisation community has its problems to involve and to engage the end-user community, in sufficient number, which is essential when smart manufacturing standards and specifications are introducing disruptive but necessary changes. This proposed SME Test Bed Program may be a channel for the end-user feedback on these current set of Smart Manufacturing standards in general.

As mentioned above, many Smart Manufacturing (SM) requirements are addressed by the convergence of ICT and OT technologies, which has resulted that the SM specifications are distributed across many different standardisation organisations.

Therefore, interoperability within Smart Manufacturing is not easy to be addressed by a single organisation. Addressing interoperability by a federation of different organisations will not be only very complex but also very time intensive. The SME Test Bed Program will accelerate the understanding the cross-domain interoperability issues and will provide the opportunity to address them timely.

Note that Open Source is commonly used within the ICT domain and are driven based on coding projects. However, the convergence of ICT and OT technologies is driving the usage of open source components within Smart Manufacturing as well. The interoperability between the open source and standards will be an important aspect to be secured. Open source solutions from ICT and OT may be deployed or extended as part of testbed projects.

Direct feedback on the "quality" of the standards by the end-users will be basis to improve the specifications and may also highlight the improvements towards the standardisation processes within the standardisation organisations. This will help to make the standardisation more effective, efficient and higher performance in perspective of quality of the specifications.

8 PROGRAM FACILITIES

8.1 Digitising Industry Centre (DIC)

The formation of Digitising Industry Centre (DIC) will centralise the different industry experts with difference competence backgrounds, allowing the end-2-end consultancy where all competences may be included. The DIC may be distributed towards different regions but efficient alignment shall be secured by networking these experience centres (DIC) so that knowledge and competence can be shared. The DIC shall involve with existing German and Chinese test bed infrastructures via networking with these initiatives and to provide training, publications etc.

The main purpose of the experience center is to act as a point of contact for the SMEs to acquire knowledge and support on Smart Manufacturing. However, the DIC may also be a platform to further evolve the visions on Smart Manufacturing and make these visions public as white papers or short reports to the relevant bodies in Germany and China.

8.2 Lab Facilities

The SME Test Bed Program shall benefit of the existing lab facilities and/or industry initiatives created for Smart Manufacturing but may have some dedicated requirements to these lab facilities. It will also be useful to have Smart Manufacturing Experience Centre where Manufacturing SMEs can see the Smart Manufacturing opportunities to their business. This can be performed in an existing infrastructure and/or a new DIC.

9 CONCLUSION

To intensify Sino-German standardisation cooperation in terms of the digital transformation in Manufacturing for Small-Medium-Companies, and other industry verticals such as smart energy, etc. the new SME test bed program should work as a catalyser to define a structured process, create a huge number of projects short-and-mid-term and produce a deep-insight for critical factors to be considered for planning and executing further standardisation activities. In addition, the convergence challenges between OT and ICT especially in the domain of the manufacturing industry can be better managed with a close collaboration of end users in joint test beds to derive standards.

In particular, when the existing infrastructure in China and Germany used for the digitisation of the industry are closely linked to the new SME test bed program. The SME Test Bed Program gets an important role ascribed to the complex process of convergence of OT and IT and the progressive collaboration between industry verticals, supply-chain integration, data exchange and further automation of production processes, e.g. by means of AI, Robotic, 3D Printing, etc.
In accordance with the key-facts for the proposed new SME Test Bed Program, described in this paper, based on the expert group discussions and the exchange with existing Industry 4.0 programs, the following conclusions can be drawn:

a) The Sino-German SME test bed program focuses on typical test bed activities to empower the standardisation work while using, as much as possible, existing infrastructure and where it make sense, in specific centres with a unique focus.
b) To empower the participation of SMEs on both sides, an Incentive catalogue with clear benefits for the companies needs to be defined and supported with the necessary financial and know-how resources.
c) A small group of experts, from China and Germany, should be appointed and established, to define and describe all further details about the SME test bed program in the short term.
d) To get future potential standardisation contribution out of the new test bed program, a close cooperation with all relevant and existing organizations is a key requirement and should have the full support from the Chinese and German government. The Test Bed Program may also result into new standardisation activities within the Sino-German standardisation collaboration.
e) The SME Test Bed Program stimulates harmonisation of smart manufacturing standards between different standards and industry organisations. This will drive the need of the Sino-German standardisation collaboration to collaborate with a wider range of standardisation organisations and industry associations, such as ITU, IEEE, 5GACIA, 3GPP.

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