IoT Standardization: An Overview of Organizations and Standards

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***Abstract*—The Internet of Things is becoming more and more part of our lives. The growth in economic investment in IoT makes it a good subject for standardization. This article highlights the different international standardization efforts with special attention to the standardization efforts in Russia. An overview of the standard development organizations is presented with a glance at their structure, history, and standards.**

Keywords—IoT, IIoT, standardization, ITU, ISO, IEC, IEEE SA, IETF, IRTF, 3GPP, ETSI, W3C, oneM2M, OGC, OASIS, TC 194, Rosstandart, RVC, IOTAS

I. INTRODUCTION

The internet of things is a large field of technology that combines a variety of other fields, mainly information and communication technologies (ICT). Further integration leads to new application domains. For example, ICT combined with robotics, control, and production engineering opens doors for smart manufacturing, and ICT combined with transport telematics, traffic engineering, power engineering, and the automotive industry has led to intelligent transport systems [1]. IoT enables the smart part of the previous technologies. IoT extends Internet usage to a new category of standalone devices that operate with or without the intervention of humans, like sensors, switches, and gadgets. However, conventional internet protocols have not been set for such constraints as low power consumption, limited processing capability, or low bandwidth. A new set of protocols and standards have been developed for IoT for different functionalities such as communication, identification, discovery, and semantics. Hence, the developer has the freedom to choose after careful study and consideration of the requirements. This diversity, driven by the rapid industrial and technological revolution, and the growing demand for solutions to connect and automate every aspect of our lives has led to a bulk of technical solutions that may not be fully compatible with each other, or are vendor-specific, which has negative effects on competitiveness and flexibility in today's markets, because it causes the customer to be dependent on one manufacturer, reduces competition and increases the costs. It is obvious that IoT may benefit from standards in other areas, especially wireless technology, in addition to its own standards that provide means for operation under low power and other constraints. Standards allow information and communication systems to be interoperable and work flawlessly together, which leads to more competition, innovations, and lower costs. Furthermore, standards reduce system development time and allow the developer, regulator, and user to easily understand each other [2] by suggesting IoT reference architectures, defining vocabulary, developing security protocols, outlining privacy and authentication requirements, and imposing restrictions on using the available spectrum. Since standards are set after thorough investigations, discussions, and meetings, they are more reliable in many aspects than proprietary solutions. They are sometimes used to make new technologies compatible with the characteristics of society by adapting international standards to meet national requirements. Coordinating the different standardization activities in IoT has a very high importance in avoiding setting equivalent and competing standards, which will decrease interoperability, fragment the market, and increase costs [1]. Different mechanisms have been developed for organizing standardization efforts. These mechanisms can take the form of formalized high-level regulatory documents to informal coordination done by individuals working in multiple Standard Setting Organizations (SSOs) [1].

II. INTERNATIONAL STANDARDIZATION EFFORTS IN THE FIELD OF IOT

A. IoT Standardization Efforts in ITU

The International Telecommunication Union (ITU) was founded in 1865 to regulate and standardize telegraph networks. It was originally called the International Telegraph Union. Then its name changed to the International Telecommunication Union in 1932, and in 1947 it became a UN agency [3]. ITU consists of three core sectors: the Radiocommunication Sector (ITU-R), whose main purpose is the regulation of the radio spectrum and satellite orbits on a worldwide level, the Telecommunication Development Sector (ITU-D), which aims at maintaining international cooperation on ICT, spreading telecommunication and ICT, and addressing global issues like disaster management and climate change using telecommunications and ICT. The third sector is the Telecommunication Standardization Sector (ITU-T), where most of the work related to IoT happens. The standardization is carried out by study groups (SGs), which are created and managed by the quadrennial conference "World Telecommunication Standardization Assembly" or WTSA. In the beginning, standardization of IoT was a common task for several study groups such as SG2, SG3, and SG17. Besides, the Internet of Things Global Standards Initiative (IoT-GSI) was created in 2011 to harmonize efforts with other SDOs. IoT-GSI was dissolved in July 2015 after the establishment of Study Group 20 (SG20) at ITU-T. SG20 includes two working parties (WP):

- WP1: Internet of things (IoT)
- WP2: Smart Cities and Communities (SC&C).

The workload is currently divided into seven questions (from Q1/20 to Q7/20) that address different issues or interests. For example, Q1/20 holds the name "Interoperability and interworking of IoT and SC&C applications and services" and addresses use cases for internetworking, the requirements to provide interoperability, especially data and semantic interoperability. An answer to a question or part of it takes the form of a recommendation. SG20 released a set of recommendations related to IoT, especially the Y-series.

B. IoT Standardization Efforts in ISO and IEC

The International Organization for Standardization (ISO) is an independent, non-governmental international organization with a membership of 167 national standards bodies [4]. The organization was created in the 1920s under the name "the International Federation of the National Standardizing Associations". The International Electrotechnical Commission (IEC) is an international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies. IEC began its activities on 26 June 1906 [5]. ISO and IEC formed a joint committee (ISO/IEC JTC 1) for developing standards in the field of information and communication technologies. The subcommittee SC41 is responsible for putting standards in the field of IoT and digital twin. SC41 contains working groups (WGs) and joint working groups (JWGs). For example, the working group WG3 is concerned with IoT foundational standards like vocabulary and architectures, while WG4 specializes in interoperability. ISO/IEC JTC 1/SC41 published a large set of standards on different areas of interest like ISO/IEC 30141, ISO/IEC 20924, ISO/IEC 30149, ISO/IEC TS 30168, ISO/IEC 21823-3, ISO/IEC 21823-4, ISO/IEC 30178, ISO/IEC 30161-2, ISO/IEC 30162, ISO/IEC 30169, ISO/IEC TR 30174 and others [6].

C. IoT Standardization Efforts in IEEE SA

The Institute of Electrical and Electronics Engineers Standards Association (IEEE SA) is a member of the IEEE family that develops global standards in a lot of sectors. IEEE came into being in 1963 after the merger between the American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE) [7]. It is not a formal or governmental organization, but more like a community. A lot of standards have been produced for physical and medium access control layers in connectivity applications like the 802.3 series of standards on Ethernet; the 802.11 series of standards on wireless local area networks; and the 802.15 series of standards on wireless personal area networks. The latter three standards play an important role in a lot of IoT technologies. IEEE SA defines a set of standards that specialize in the field of IoT. These standards cover a lot of aspects of IoT, like security and interoperability as defined in IEEE 1451-99 and IoT architecture and domains as defined in IEEE P2413-2019 and quality of data sensor parameters in IoT environment as defined in IEEE 2510.

D. IoT Standardization Efforts in IETF and IRTF

The Internet Engineering Task Force (IETF) is a leading open standards organization that develops Internet standards. It originally started its activities as a quarterly meeting in 1986 [8]. It is considered a complementing organization to IEEE, 3GPP, and ITU. Furthermore, it consists of several working groups (WGs) and a steering group. Internet Research Task Force (IRTF) is an organization that works in parallel with IETF, but unlike IETF, which focuses on short-term issues, IRTF focuses on Internet-related long-term issues [9]. It consists of many research groups (RGs). IETF working groups and IRTF research groups have developed and are still working on several standards in different focus areas such as connectivity (6LoWPAN, 6TiSCH, 6Lo, LPWAN), routing (ROLL), application (CoRE, CBOR, T2TRG), security (DICE, ACE, SUIT, TEEP, COSE, LAKE, RATS), infrastructures use cases and experimentation (IPWAVE, HOMENET, LWIG, ICNRG, DINRG) [9].

E. IoT Standardization Efforts in 3GPP

The 3rd Generation Partnership Project (3GPP) aggregates the efforts of seven standard development organizations (SDOs) called "the organizational partners", in a convenient environment to define technologies by publishing reports and specifications. 3GPP was set up in December 1998 when the European Telecommunications Standards Institute (ETSI) joined forces with other SDOs from around the globe to develop new technologies in the field of communication and radio technology [10]. 3GPP consists of several technical specification groups (TSGs) and working groups (WGs). 3GPP contributed to the world of IoT by putting standards on several low-power wide-area network technologies (LPWANs) like LTE-M, NB-IoT, and EC-GSM-IoT in addition to 5G [11], which offers better capabilities regarding capacity (up to a million devices per square kilometer) and speed (response delay as little as 1ms).

F. IoT Standardization Efforts in ETSI

The European Telecommunications Standards Institute (ETSI) was established in 1988 by the European Conference of Postal and Telecommunications Administrations (CEPT) after suggestions from the European Commission [12]. ETSI contributes to IoT standardization activities in 3GPP at the radio layer (LTE-M, NB-IoT, and EC-GSM-IoT) and in oneM2M at the service layer [13]. ETSI promotes semantic interoperability by introducing SAREF (SAREF or Smart Applications REFerence ontology), and context management by introducing the NGSI-LD API that defines an information model, a set of architectures, data representations, properties, and querying languages.

G. IoT Standardization Efforts in W3C

The World Wide Web Consortium dates to 1994 [14] and is the main international standards organization for the World Wide Web. It developed the Web of Things (WoT) architecture that enables interoperability by describing an abstract architecture, building blocks, application domains, and use cases. Another contribution is the Web of Things (WoT) Thing Description (TD) that specifies metadata and abstracts physical and virtual things of entities in the world of IoT.

H. IoT Standardization Efforts in oneM2M

The oneM2M is a global standards initiative established in 2012 [15] by a group of world-leading SDOs. The

oneM2M structure is composed of a steering group that provides long term direction and management, a technical plenary that is in charge of organizing technical activities, and 3 types of working groups (WGs): requirements and domain models (RDM), system design and security (SDS), and finally the testing and developers ecosystem (TDE) [16]. oneM2M defines an architecture with a focus on the software service layer that resides between M2M applications and communication hardware and software, providing a set of common service functions like data management and repository, registration, and security. oneM2M takes the approach of collaborating and making different standards work together instead of defining new ones [17].

I. IoT Standardization Efforts in OGC

The Open Geospatial Consortium (OGC) dates to 1994 [18] and has more than 500 members collaborating in a voluntary consensus process to develop open standards for different areas, among which is IoT. OGC in its structure contains a technical committee (TC), a planning committee (PC), an architecture board (OAB) and a strategic member advisory committee (SMAC). OGC contributes to the standardization of IoT by introducing the OGC SensorThings API, which enables over-the-web connections for IoT devices, applications and data in an open geospatial-enabled and unified way using a two-part technology: the sensing part and the tasking part. It provides syntactic and semantic interoperability [19].

J. IoT Standardization Efforts in OASIS

The Organization for the Advancement of Structured Information Standards (OASIS) was set up in 1993 [20] with the initial goal of promoting interoperability using Standard Generalized Markup Language (SGML); so it was called SGML Open at first. The OASIS MQTT Technical Committee is responsible for developing and maintaining the well-known MQTT standard. MQTT is a messaging transport protocol that is open, simple, and easy to implement. It uses the client-server architecture and publish/subscribe model for messaging [21]. MQTT-SN is a variant of MQTT, that is modified to address some issues in wireless communication environments like low bandwidth, high link failures, short message length, etc. It is also well suited for implementation on low-cost, battery-powered devices that have limited processing power and storage space [22].

K. IoT Standardization Efforts in OCF

Open Connectivity Foundation (OCF) formerly known as Open Interconnect Consortium (OIC) was founded in September 2014. After that, Universal Plug and Play (UPnP) forum merged with OIC. This merger was very important since UPnP defines a set of networking protocols that enable automatic discovery of devices on the network without the need for manual configuration or human intervention and establish services like media streaming. In 2016, OIC was renamed OCF and the AllSeen Alliance (a big competitor to OIC) joined the organization [23]. The AllSeen alliance maintains the AllJoyn protocol, which is an open-source protocol initially promoted by Qualcomm, then its trademark was transferred to The Linux Foundation in 2013 [24]. AllJoyn enables interoperability with a special focus on home automation and Wi-Fi networks. Windows has built-in support for AllJoyn. The IoTivity project is another open-source project maintained by OCF. It is considered an implementation of the OCF Secure IP Device Framework which enables Device-to-Device and Device-to-Cloud communications over IP.

L. IoT Standardization Efforts in IIC

The Industrial Internet Consortium (IIC) was established in 2014 [25]. IIC released the Industrial Internet Reference Architecture (IIRA) which presents an architectural template to define system requirements for the Industrial Internet of Things (IIoT) and provides concrete architectures to address these requirements [26]. IIC also released frameworks and reports like the Industrial Internet Connectivity Framework, the Industrial IoT Analytics Framework, the Industrial IoT Networking Framework, and the Industrial Internet Vocabulary Technical Report [27] in addition to white papers like Distributed Ledgers in IIoT [28].

M. IoT Standardization Efforts in OPC

The Open Platform Communications (OPC) foundation was set up in 1995 by a group of automation vendors as a task force, whose job was to create a standard for data access based on Microsoft's COM and DCOM technologies. It behaves like a device driver to enable PLC controllers to issue alarms and transmit live and historical data [29][30]. OPC-UA is the state-of-the-art OPC technology, that addresses a broad range of modern communication requirements and is maintained by the Unified Architecture Working Group within the OPC foundation.

III. IoT Standardization in Russia

In 2021, the number of connected IoT and machine-to-machine communication (M2M) devices in Russia increased by 16% compared to 2020 and reached 29.6 million devices, and the volume of this market increased to 93.5 billion rubles [31]. These numbers are expected to continue their growth as the Russian economy and industry continue to benefit from and appreciate the advantages of IoT. According to the IoT index published by Megaphone, which is a major telecommunication and IoT company in Russia, clients saw 41% cost reductions, 41% effectiveness increase in data collection and resource usage, 40% increase in optimization of labor resources, 33% increase in customer loyalty, 20% increase in competitiveness, 22% increase in income [32]. These numbers are a result of a survey held in 2020 in association with Kantar Group, in which 780 companies were surveyed. Such large adoption of IoT in Russia has led to the dedication of great efforts in the field of IoT standardization. In the Russian Federation, the Federal Agency for Technical Regulation and Metrology (Rosstandart) is the federal executive body of Russia responsible for the provision of public services and state property management in the field of technical regulation and metrology. Since 2004, Rosstandart has been under the jurisdiction of the Ministry of Industry and Trade of the Russian Federation. The instruments of Rosstandart activities are technical committees for standardization. Activities in the field of digital technologies, machine-to-machine interaction, Internet of Things, sensor networks,

industrial internet, etc. are entrusted to Technical Committee TC 194 (Cyber-Physical Systems), which was created on the initiative of the Russian Venture Company (RVC) in 2017. It has more than 100 organizations that unify their standardization efforts in six working groups: the Internet of Things (WG1), smart cities (WG2), big data (WG3), smart manufacturing (WG4), artificial intelligence (WG5), and smart energy (WG6) [33]. NB-Fi and LoRAWAN protocols were approved as national standards in the field of IoT and sensor networks [34]. A lot of preliminary national standards projects are currently under discussion. They are adapted mainly from ISO/IEC standards to easily integrate foreign technologies into the Russian market and to enable direct exportation of Russian technologies. These preliminary standards after their final approval as national standards will encourage the development of the digital market in Russia. Additionally, other Russian organizations contribute to the standardization of IoT. For example, Kaspersky lab takes part in developing IoT security-related standards, and Rostelecom initiated the development of the first internationally approved Russian standard in the field of the Industrial Internet of Things (IIoT) in 2022 [34]. Rostelecom also maintains a Russian IoT platform. Another Russian player in the field of IoT is the IoT association (IOTAS), which is a member of IIC and TC194. This association was established in 2016 and has six working groups on NB-FI, NB-IoT, LORAWAN, smart cities, metering of municipal services, science and education [35].

IV. Conclusion

The field of IoT will continue to grow and a lot of investments will be made in this technology. Thus, new challenges will appear, and standardization efforts will be needed. This form of harmonization in technology is inevitably necessary. However, it can be clearly seen that despite the collaboration and standardization work that has been done over the past few years, these efforts have not converged yet. One standard for IoT seems like a good goal to achieve, but a hard one. It looks that the good approach is to provide interoperability techniques between existing standards and improve them in areas where enough standardization efforts have been made and suggest new standards in areas where no work has been done yet. This can help solve the dilemma of standardization, when the need to solve interoperability between standards leads to creating even more standards. Standardization in IoT can also benefit from the existing coordination and collaboration mechanisms, that were designed for industry fields much older that IoT. In Russia, IoT and IoT standards are at the center of attention with wide acceptance into the market. Great efforts have been made to develop national standards compatible with the international ones, and to contribute to the process of worldwide IoT standardization.

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