Chapter 11
Industry Organizations and Standards Landscape

11.1 Overview

The IoT industry landscape is crowded with different standard bodies and organizations chipping away at various aspects of the technology. As is typically the case early on in the technology cycle, some of the organizations are tackling the same problem, and hence a subset of the standards that they are proposing are overlapping and competing for mainstream adoption. This creates confusion in a vast and multifaceted industry and inevitably slows down product development, as vendors do not want to take bets on standards that may never take off in the market (think Betamax vs. VHS in the early video format war days).

Some of the industry organizations focus their efforts on a specific IoT vertical, whereas others are involved in defining crosscutting technologies that apply across various IoT applications and verticals. Furthermore, not all organizations are actively defining their own standards; rather some are promoting harmony and alignment among others, which define and ratify standards.

What is common across all these standards is that they are all being based on (or migrating to) a common normalization layer, the IP network layer, which guarantees system interoperability while accommodating a multitude of link layer technologies, in addition to a plethora of application protocols. IP constitutes the thin waist of the proverbial hourglass that is the IoT's protocol stack (refer to Fig. 11.1). The diversity in physical and link layer standards is a manifestation of the IoT challenges and requirements that impact that layer of the protocol stack, as was discussed in Chap. 5 (Sect. 5.1.1). By the same token, the large number of application layer standards is a reflection of the many industry verticals and applications (as discussed in Chap. 9) that IoT enables.

In this chapter, we will provide an overview of the key IoT standards defining organizations and the various protocols that they have been defining or promoting.

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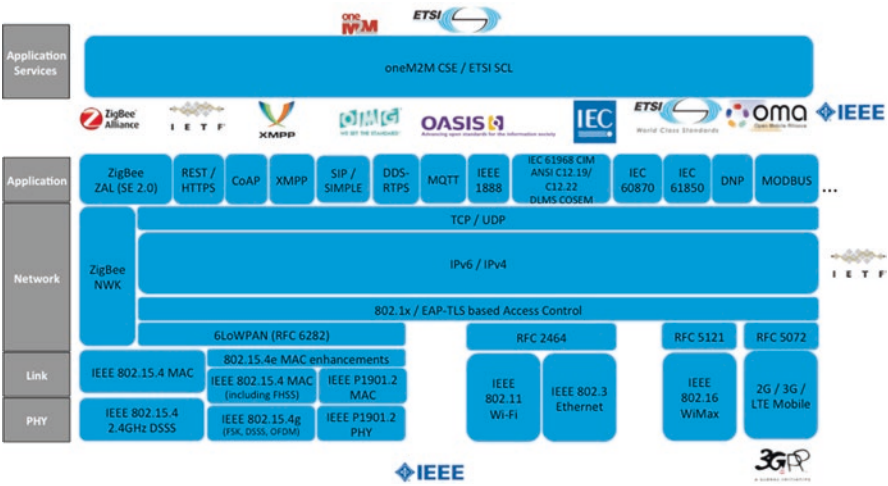

Fig. 11.1 IoT standards landscape

Our focus will be on standards operating at the physical, data link, network, and transport layers of the OSI model presented in Chap. 2. We will also touch upon a select subset of standards efforts operating at the application layer of the model. As can be seen in Fig. 11.1 above, such efforts are numerous, industry vertical specific and require expert domain knowledge in the associated industry or application (e.g., IEC 61968, ANSI C12.19/C12.22, DLMS/COSEM are smart grid standards).

11.2 IEEE (Institute of Electrical and Electronics Engineers)

IEEE is a well-established technology standard body, which, among other things, had defined the standards for Ethernet and wireless local area networks (LANs). Given its legacy and expertise in physical and link layer network technologies, the IEEE embarked on defining a number of physical and link layer standards for IoT. These include the 802.15.4 family of low-power wireless protocols, which were discussed in Sect. 5.1.2.1, the 802.11ah long-range Wi-Fi standard discussed in Sect. 5.1.2.3, as well as the 1901 power line communications standards. The latter define technologies for carrying network data, in addition to alternating current (AC), over conventional electric wiring.

Beyond the efforts on standardizing physical and link layer technologies, IEEE kicked off the IoT initiative as a platform for the technical community to collaborate on technologies that advance the IoT. Adjunct to this initiative, many IoT-related standards activities had been completed or are underway. We will go through an overview of these activities next.

11.2.1 IEEE 1451 Series

The IEEE 1451 series addresses smart transducers, which are defined as devices that convert a physical measurement into an electrical signal, or vice versa. Transducers include sensors or actuators that we discussed in Chap. 3. The standards define communication interfaces for interconnecting smart transducers to networks or external systems via either wired or wireless mechanisms. Among the main elements of these standards is the definition of the Transducer Electronic Data Sheets (TEDS). The TEDS is associated with every smart transducer. It provides relevant technical data pertaining to the transducer in a standard format. Such data includes the device identity, type, accuracy, calibration, or other manufacturer-related information, etc. The standards define common mechanisms by which a transducer can communicate its associated TEDS to the connected network or system. TEDS may be implemented in one of two ways. They can be embedded onboard within the transducer itself, typically on some memory component such as EEPROM. Alternatively, a virtual TEDS can be implemented as an off-board data file that is stored in some component separate from the transducer albeit accessible to the instrument or system connected to the transducer. Virtual TEDS allow the extension of the TEDS standard to legacy sensors and devices where onboard or embedded memory may not exist.

11.2.2 IEEE 1547 Series

The IEEE 1547 series addresses smart grid and in particular handling distributed resources in electric power systems. The standard defines technical requirements for interconnecting distributed generators and energy storage systems to electric power systems. Examples of such generators include fuel cells, photovoltaic, microturbine, reciprocating engines, wind generators, large turbines, and other local generators. The technology helps utilities tap into surplus electricity from alternative and renewable energy sources. Furthermore, the IEEE 1547 series deals with various facets of renewable energy, including micro-grids (IEEE 1547.4) and secondary networks for distributed resources (IEEE 1547.6).

11.2.3 IEEE 1609 Series

The IEEE 1609 series addresses intelligent transportation systems (ITS) and focuses on Wireless Access in Vehicular Environments (WAVE). The series defines the architecture, services, and interfaces to enable secure vehicle-to-vehicle and vehicle-to-roadside infrastructure wireless communication. The standard enables applications that include vehicle safety, enhanced navigation, traffic management, automated tolling, and more. The IEEE 1609 series specifies standards for communication security (IEEE 1609.2), WAVE connection management (IEEE 1609.3), and Layer 3 through Layer 7 operation across multiple channels on top of IEEE 802.11p.

11.2.4 IEEE 1888 Series

The IEEE 1888 series focuses on ubiquitous green community control networks. It describes remote control architecture for buildings, digital communities, and metropolitan networks. The standard defines the data formats between systems and the data exchange protocol that interconnects various components, including gateways, storage systems, and application units over an IP network. This network provides open interfaces for public administration/service, property management, and individual service. The interfaces enable central management, remote surveillance, and collaboration.

11.2.5 IEEE 1900 Series

The IEEE 1900 series focuses on dynamic spectrum access radio systems and networks. One of the main goals of this series is to improve spectrum utilization. To that effect, the standard explores architectures and interfaces for dynamic spectrum access in the TV whitespace frequency bands, as well as management systems for optimization of radio resource usage, spectrum access control, and compliance with regional regulations aimed at protecting broadcast systems. The standard also defines policy language and architectures for managing dynamic spectrum access among distributed heterogeneous devices.

11.2.6 IEEE 2030 Series

The IEEE 2030 series focuses on the smart grid, including electric vehicle infrastructure. It defines a reference model for smart grid interoperability including the three pillars of energy, information, and communications technologies. The standard addresses applications for electric vehicles and associated support infrastructure used for personal and mass transit. Furthermore, the standard covers energy storage systems that are integrated with the electric power infrastructure and relevant test procedures for these systems.

11.2.7 IEEE 2040 Series

The IEEE 2040 series focuses on connected, automated and intelligent vehicles. The series defines an overview and architectural framework (IEEE 2040), taxonomy and definitions (IEEE 2040.1), as well as testing and verification (IEEE 2040.2) standards. The series leverages existing standards where applicable.

11.2.8 IEEE 11073 Series

The IEEE 11073 series of standards focuses on point-of-care medical device communication and personal health device communication. The standard enables interoperability between medical devices and external computer systems. It defines information models to guarantee semantic interoperability between communicating medical devices. It also specifies a tree hierarchy for modeling the device and its relevant information: measurements, physiological and technical alerts, as well as contextual data.

11.2.9 IEEE 2413 Series

The IEEE 2413 series defines an architectural framework for the IoT, including descriptions of various IoT verticals, definitions of their associated abstractions, and identification of commonalities across those verticals. The standard establishes a reference model for IoT domain verticals and an architecture that defines the building blocks and common elements.

11.3 IETF

The IETF has been instrumental in defining and standardizing the Internet technologies, including IPv4 and IPv6 as well as numerous routing protocols (e.g., OSPF, RIP, PIM, BGP), application protocols (e.g., HTTP, LDAP, SMTP), and security protocols (e.g., TLS, IPSec, IKE). In 2006, work started in the IETF on a number of IoT standards. The initial scope centered on enabling IP on top of IEEE 802.15.4 wireless networks but has expanded beyond that over time. Currently, there are five IETF working groups focusing on IoT-related technologies. We will discuss their work next.

11.3.1 ROLL

The Routing over Low-Power and Lossy networks (ROLL) working group focuses on routing issues for Low-Power and Lossy Networks (LLNs). LLNs typically comprise of embedded devices with limited power, memory, and processing resources that are interconnected by a variety of link technologies. LLNs cover a multitude of applications such as building automation, smart homes, smart healthcare, industrial monitoring, environmental monitoring, asset tracking, smart grid, etc. The ROLL working group is concerned with defining routing requirements for a subset of the aforementioned applications: industrial (RFC 5673), connected home (RFC 5826), building automation (RFC 5867), and urban sensor networks (RFC 5548). The working group is approaching these requirements by defining an IPv6 architecture that enables scalable networks of constraint devices to communicate with high reliability. Routing security and manageability (e.g., autonomic configuration) are among the key issues that ROLL is looking into.

ROLL analyzed the particular routing protocol requirements of LLNs, starting with the constraints that these protocols must adhere to. The following constraints were identified, which stem from the constrained nature of the nodes in LLNs:

- Protocols need to operate with minimal amount of state.
- Protocols must be optimized for efficiency, i.e. saving energy, memory, and processing power.
- Protocols must support unicast and multicast application traffic patterns.
- Protocols must be very efficient in encoding information to operate with very small link layer maximum transfer unit (MTU) size.

The ROLL working group evaluated existing routing protocols to examine whether they could operate within the confines of the above constraints. The following protocols were analyzed: OSPF (RFC2328), IS-IS (RFC1142), RIP (RFC2453), OLSR (RFC3626), TBRPF (RFC3684), AODV (RFC3561), DSR (RFC4728), DYMO, and OLSv2 (RFC7181). Based on this analysis, the working group determined that none of the existing protocols meet the requirements of LLNs. As a result, the working group defined a new protocol, RPL, which was discussed in Sect. 5.2.2.2.

11.3.2 CORE

The Constrained RESTful Environments (CORE) working group focuses on defining a framework for RESTful applications running over constrained IP networks. These applications include applications to monitor simple sensors (e.g., temperature sensors or power meters), to control actuators (e.g., valves or light switches), and to remotely manage devices. Such applications are typical of several IoT verticals such as home and building automation and smart grid. The applications are forced to operate under the same set of constraints that define LLNs, namely, limitations on memory, processing power and energy, as well as high loss rates and small packet sizes. In addition, the applications must deal with the fact that nodes are typically powered off and wake up for a short period of time.

The framework defined by the working group assumes a general operating paradigm for applications where network nodes run embedded web services and are responsible for resources (e.g., sensors or actuators) that can be queried or manipulated by remote nodes. Furthermore, nodes may publish local resource changes to remote nodes that have subscribed to receive notifications. The CORE has defined the CoAP protocol, which was discussed in Sect. 5.3.5.1, to support this application framework.

One of the key challenges to applications running in these constrained environments is security. The working group's scope includes selecting viable approaches for security bootstrapping to handle secure service discovery, distribution of security credentials, and application-specific node configuration.

11.3.3 6LowPAN

The IPv6 over Low-Power Wireless Personal Area Networks (6LowPAN) working group focused on enabling IPv6 over IEEE 802.15.4 networks. The group started its work in 2005 and concluded in 2014 after working through the following goals:

First, defining a fragmentation and reassembly layer to allow adaptation of IPv6 to IEEE 802.15.4 links. This is because the link protocol data units may be as small as 81 bytes, which is much smaller than the minimum IPv6 packet size of 1280 bytes.

Second, introduce an IPv6 header compression mechanism to avoid excessive fragmentation and reassembly, since the IPv6 header alone is 40 bytes long, without optional headers.

Third, specify methods for IPv6 address stateless auto configuration to reduce the provisioning overhead on the end nodes.

Fourth, examine mesh routing protocol suitability to 802.15.4 networks, especially in light of the packet size constraints.

Finally, investigate the suitability of existing network management protocols and mechanisms in terms of meeting the requirements for minimal configuration and self-healing as well as meeting the constraints in processing power, memory, and packet size.

The working group produced six standards: 6LowPAN problem statement document (RFC4919), IPv6 adaptation layer and header format specification (RFC4944), IPv6 header compression specification (RFC6282), 6LowPAN use cases and applications document (RFC6568), IPv6 routing requirements document (RFC6606), and IPv6 neighbor discovery optimization specification (RFC6775).

11.3.4 6TisCH

This working group is chartered with enabling IPv6 over the Time-Slotted Channel Hopping (TSCH) mode of IEEE 802.15.4e. The target network comprises of Low-Power and Lossy Networks (LLNs) connected through a common backbone via LLN Border Routers (LBRs). The focus of the working group is on defining an architecture that describes the design of 6TiSCH networks in terms of the component building blocks and protocol signaling flows. The working group will also produce an information model that describes the management requirements of 6TiSCH network nodes, together with a data model mapping for an existing protocol, such as Concise Binary Object Representation (CBOR) over the Constrained Application Protocol (CoAP). In addition, the working group will define a minimal and a best practice 6TiSCH configuration that provides guidance on how to construct a 6TiSCH network using the Routing Protocol for LLNs (RPL) and static TSCH schedule. Finally, the working group may produce implementation and coexistence guides to help accelerate the industry.

11.3.5 ACE

The Authentication and Authorization for Constrained Environments (ACE) working group is tasked with producing use cases and requirements for authentication and authorization in IoT, as well as defining protocol mechanisms that can address these requirements and are capable of running on constrained IoT devices. The scope of the work is limited to RESTful architectures running the Constrained Application Protocol (CoAP) over Datagram Transport Layer Security (DTLS). Hence, the working group is looking to provide a standardized solution for authentication and authorization to enable a client's authorized access to REST resources hosted on a server. Both client and server are assumed to be constrained devices. The access will be facilitated by a non-constrained authorization server. The working group will evaluate the existing protocol mechanisms for suitability and applicability to constrained environments and will advise on any required restrictions, changes, or gaps.

11.4 ITU

The International Telecommunication Union (ITU) is the United Nations (UN) specialized agency with over 190 member states and over 700 industry members in addition to universities as well as research and development institutes. It has been heavily involved in the definition and development of telecommunication standards.

The ITU published one of the first reports on "the Internet of Things" in 2005 and has been involve in IoT since then, producing multiple standards documents in this space, as discussed next.

Recommendation ITU-T Y.2060, *Overview of the Internet of Things,* provides a definition of IoT, terming it: "A global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies." It describes the concept and scope of IoT, discussing its fundamental characteristics and high-level requirements and providing a detailed overview of the IoT reference model. Additionally, the standard discusses the IoT ecosystem and accompanying business models.

Recommendation ITU-T Y.2061, *Requirements for support of machine-oriented communication applications in the NGN environment,* offers a description of machine-oriented communication applications in next-generation network (NGN) environments, covering the NGN extensions, additions, and device capabilities required to support MOC applications.

Recommendation ITU-T Y.2062, *Framework of object-to-object communication for ubiquitous networking in an NGN environment,* discusses the concept and high-level architectural model of such communication and provides a mechanism to identify objects and enable communications between them.

Recommendation ITU-T Y.2063, *Framework of Web of Things*, specifies the functional architecture including conceptual and deployment models for the Web of Things. The standard also provides an overview of service information flows and use cases in home control.

Recommendation ITU-T Y.2069, *Terms and definitions for Internet of Things*, specifies the terms and definitions relevant to the Internet of things (IoT) from an ITU-T perspective, in order to clarify the Internet of Things and IoT-related activities.

The ITU has multiple study groups looking into various aspects of IoT: Study Group 11 started activity in July 2014 and is looking into application programmatic interfaces and protocols for IoT as well as IoT testing. Study Group 13 focuses on the networking aspects of IoT. Study Group 15 looks at smart grid and home networks. Study Group 16 focuses on IoT applications including e-Health. Study Group 17 is looking at the security and privacy protection aspects of IoT. In addition, there are multiple focus groups looking at topics including smart cities, water management, and connected cars.

11.5 IPSO Alliance

The "Internet Protocol for Smart Objects" (IPSO) Alliance is an open nonprofit special interest group that promotes the use of the IP protocol to connect smart objects (i.e., *Things*) to the network. It was formed in 2008 and includes members from technology and communication companies in addition to industry vertical companies (e.g., energy). The alliance complements the work of other standards defining bodies, such as the IETF, IEEE, and ETSI, by promoting IoT technologies through publishing whitepapers and hosting webinars, interoperability events, and challenges.

The interoperability events have helped in advancing IP technologies for IoT by providing a vendor-neutral forum to test evolving IoT technologies and providing feedback to the standards bodies defining them in order to fix potential issues that affect interoperability. For instance, in one of the interoperability events held in conjunction with the IETF, a number of issues related to early versions of RPL were communicated back to the Routing over Low-Power and Lossy Networks (ROLL) working group in order to improve the developing drafts.

IPSO has published the IPSO Application Framework, which defines a representational state transfer RESTful design for use in IP smart objects for machine-to-machine applications. It specifies a set of REST interfaces that may be used by a Thing to represent its available resources and to interact with other Things and remote applications. The framework was extended to cover a wide range of use cases and to more precisely describe the parameters of smart objects during an interoperability event held during IETF 84 in Vancouver, Canada.

11.6 OCF

The Open Connectivity Foundation (OCF) is an industry group that focuses on developing standards and certification for IoT devices based on the IETF CoAP protocol. It was formed in July 2014 by Intel, Broadcom, and Samsung Electronics under the name of the Open Interconnect Consortium. The consortium changed its name to OCF in February 2016. It currently has more than 80 member companies including General Electric, Cisco Systems, Microsoft, and Qualcomm. The OCF is defining a framework for easy device discovery and trusted connectivity between things. In September 2015, it released the first version of the specification of this framework. OCF is also working on open source reference implementation of the specification, which is called "IoTivity."

11.7 IIC

The Industrial Internet Consortium is a nonprofit organization that aims to accelerate the development and adoption of interconnected machines and devices, intelligent analytics, and people at work. It was founded by AT&T, Cisco, General Electric, IBM, and Intel in March 2014. IIC does not develop standards for IoT; rather, it provides requirements to other standards defining organizations. IIC focuses on creating use cases, reference architectures, frameworks, and test beds for real IoT applications across varying industrial environments. IIC also states among its goals to facilitate open forums for sharing and exchanging real-world ideas, practices, and insights, in addition to building confidence around new and innovative approaches to security. The work of the IIC does not include consumer IoT; rather it is targeted at business verticals such as energy, healthcare, transportation, and manufacturing.

11.8 ETSI

The European Telecommunication Standards Institute (ETSI) is an independent nonprofit standards defining organization. ETSI was among the very first organizations to develop a set of standards that define a complete horizontal service layer for M2M communications.

The ETSI M2M standards specify architectural components for IoT including devices (things), gateways with associated interfaces, applications, access technologies, as well as the M2M Service Capabilities Layer (middleware). They also include security, traffic scheduling, device discovery, and lifecycle management features. These standards, which were released in 2012, include:

- Requirements in ETSI TS 102689
- Functional architecture in ETSI TS 102690
- Interface definitions in ETSI TS 102921

ETSI is also looking into various applications of M2M technologies, including smart appliances, smart metering, smart cities, smart grid, eHealth, intelligent transportation systems, and wireless industrial automation.

11.9 oneM2M

In July 2012, seven standards development organizations (TIA and ATSI from the USA, ARIB and TTC from Japan, CCSA from China, ETSI from Europe, and TTA from Korea) launched a global organization to jointly define and standardize the common horizontal functions of the IoT Application Services layer under the umbrella of the oneM2M Partnership Project (http://www.onem2m.org). The founders agreed to transfer and stop their own overlapping IoT Application Service layer work. The partnership has grown to include, in addition to the seven standards bodies, five global information and communications technology forums and more than 200 companies. oneM2M states among its objectives the development of the following:

- Use cases and requirements for a common set of Application Services capabilities

- Service architecture and Protocols/APIs/standard objects based on this architecture (open interfaces and protocols)
- Security and privacy aspects (authentication, encryption, integrity verification)
- Reachability and discovery of applications
- Interoperability, including test and conformance specifications
- Collection of data for accounting (to be used for billing and statistical purposes)
- Identification and naming of devices and applications
- Information models and data management (including store and publish/subscribe functionality)
- Management aspects (including remote management of entities)

Among the work items being undertaken by oneM2M, the effort on Abstractions and Semantics Enablement will be key to achieving application level interoperability for IoT, as was discussed in Chap. 4. This area of semantics remains a major gap in the overall IoT standardization journey.

11.10 AllSeen Alliance

The AllSeen Alliance was formed in December 2013 as a Linux Foundation Collaboration Project.

It is an open nonprofit consortium that aims to promote the IoT based on the AllJoyn open source project. AllJoyn is an open, secure, and programmable software framework for connectivity and services. It enables devices to discover, connect, and interact directly with other AllJoyn-enabled products. The project was originally created by Qualcomm and released into the open source domain.

It consists of an open source software development kit (SDK) and code base of service frameworks that enable basic IoT functions such as discovery, onboarding, connection management, message routing, and security, thereby ensuring interoperability among systems.

11.11 Thread Group

The Thread working group was formed in July 2014 and included Google's Nest subsidiary, Samsung, ARM Holdings, Freescale, Silicon Labs, Big Ass Fans, and the lock company Yale. The purpose of the group is to promote Thread as the protocol for the connected home and certify products that support this protocol. The Thread protocol is a closed-documentation royalty-free protocol that runs on top of IEEE 802.15.4 and 6LowPAN. It adds functions such as security, routing, setup, and device wakeup to maximize battery life. Thread competes with other protocols already in this space such as Bluetooth Smart, Z-Wave, and ZigBee.

11.12 ZigBee Alliance

The ZigBee Alliance was formed in 2002 by Motorola, Philips, Invensys, Honeywell, and Mitsubishi to develop, maintain, and publish the ZigBee standard. Since then, the alliance has grown to include over 170 participant members and over 230 adopter companies, including ABB, Fujitsu, British Telecom, Huawei, Cisco, etc. The alliance publishes "application profiles" that enable vendors to create interoperable products. The initial ZigBee specification focused on home automation but the scope has since expanded to include large building automation, retail applications, and health monitoring.

Most of the protocol specifications are based on the IEEE 802.15.4 radio, even though the more recent Smart Energy specifications are no longer tied to 802.15.4.

The initial protocols standardized by the alliance were based on the standard IEEE 802.15.4 MAC/PHY but defined a ZigBee specific stack that includes the networking and services layer, through the full application layer. Since those beginnings, the ZigBee Alliance has undertaken a constant effort to increase the interoperability with the Internet Protocol suite, which renders ZigBee as one of the protocols that are capable of adapting to different market segments. In 2013, the ZigBee Alliance released ZigBee IP, an IoT solution based on IPv6, RPL, and 6LowPAN.

11.13 TIA

The Telecommunications Industry Association (TIA) develops industry standards for information and communication technologies and represents over 400 companies in this domain. The TIA TR-50 engineering committee was launched in 2009 to develop application programmatic interface (API) standards for the monitoring and bi-directional communication between smart devices and other devices, applications, or networks. The committee includes many industry players, including Alcatel Lucent, AT&T, CenturyLink, Cisco, Ericsson, ILS Technology, Intel, LG, Nokia Siemens Networks, Numerex, Qualcomm, Sprint, Verizon, and Wyless. Even pre-dating TR-50, TIA was involved in M2M standards, with several of its engineering committees having worked on smart device communications, including TR-45 (Mobile and Personal Communications Systems Standards), TR-48 (Vehicular Telematics), TR-49 (Healthcare ICT), and through its work on the Third Generation Partnership Project 2 (3GPP2).

11.14 Z-Wave Alliance

The Z-Wave Alliance is an industry consortium of over 300 companies creating IoT products and service over the Z-Wave protocol. Z-Wave is a short-range wireless protocol, initially developed by a small Danish company called Zensys. Z-Wave is a vertically integrated protocol, which runs over its own radio. Z-Wave's physical and media access layers were ratified by the International Telecommunication Union (ITU) as the international standard G.9959. Z-Wave is often considered to be the main competitor to ZigBee, but unlike ZigBee, it only focuses on home environment applications.

11.15 OASIS

OASIS is a nonprofit consortium that drives the development, convergence, and adoption of open standards for the global information society. OASIS produces standards for security, Internet of Things, cloud computing, energy, content technologies, emergency management, and other areas.

There are three technical committees in OASIS involved in defining IoT technologies.

The Advanced Message Queuing Protocol (AMQP) technical committee is standardizing the AMQP protocol, a secure, reliable, and open Internet protocol for handling business messaging.

The Message Queuing Telemetry Transport (MQTT) technical committee is standardizing the MQTT protocol, a lightweight publish/subscribe reliable messaging transport protocol suitable for communication in M2M/IoT contexts where a small code footprint is required and/or network bandwidth is at a premium.

The Open Building Information Exchange (oBIX) technical committee is defining technologies to enable mechanical and electrical control systems in buildings to communicate with enterprise applications.

11.16 LoRa Alliance

The LoRa Alliance is an open, nonprofit association to standardize Low-Power Wide Area Networks (LPWAN) using the LoRa protocol (LoRaWAN). The alliance was announced in January 2015, and initial members include IoT solution providers Actility, Cisco, Eolane, IBM, Kerlink, IMST, MultiTech, Sagemcom, Semtech, and Microchip Technology, as well as telecom operators: Bouygues Telecom, KPN, SingTel, Proximus, Swisscom, and FastNet (part of Telkom South Africa). The LoRA protocol provides long-range wireless connectivity for devices at low bit rates (from 0.3 kbps to 50 kbps) with low power consumption for battery-powered devices. LoRaWAN transceivers can communicate over distances of more than 100 km (62 miles) in favorable environments, 15 km (9 miles) in typical semi-rural environments and more than 2 km (1.2 miles) in dense urban environments.

The LoRa alliance claims that the scope of applications where LPWANs are applicable is endless but indicates that the main applications driving current network deployments are intelligent building, supply chain, Smart City, and agriculture.

11.17 Gaps and Standards Progress Scorecard

The road to a standards-based IoT is well underway. The industry has made significant strides toward converging on the IP network protocol as the common basis for IoT communication protocols. Multiple Physical and Link layer standards have been defined to address the requirements of constrained devices, which are limited in both compute capacity as well as available power. Some work remains at these layers, particularly with regard to adding support for determinism and time-sensitive applications. At the Network layer, the gaps are relatively limited and manifest in the need to add support for routing over Time Slotted Channel Hopping (TCSH) link technologies. The lion's share of the gaps exists at the Application Protocols and Application Services layers. The former is currently characterized by a multitude of competing and largely functionally overlapping standards. No clear winner has emerged; especially as the industry adoption remains highly fragmented. The latter is currently in a state where the industry has more or less rallied around a common forum, namely, oneM2M, and an initial standard has been released, which defines the Common Services Entities and Common Services Functions. However, at the time of this writing, the market acceptance and adoption of the standard remains unknown. In addition, the released standard is only a first step toward standardization as the area of semantics remains largely unchartered territory. Figure 11.2 below summarizes the progress scorecard for IoT industry standards.

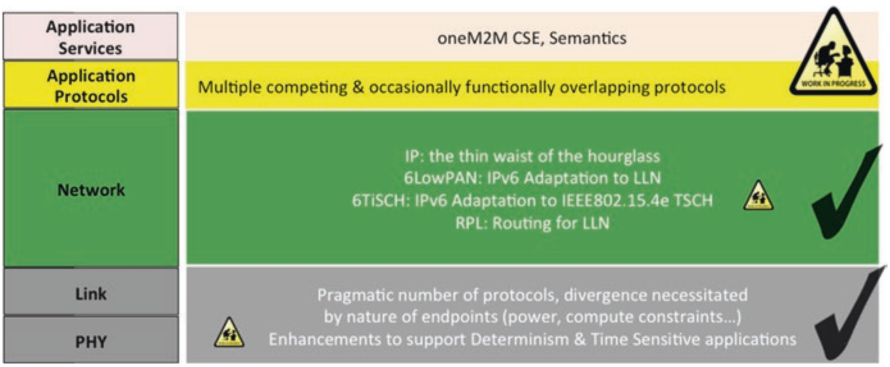

Fig. 11.2 IoT standards progress scorecard

11.18 Summary

In this chapter, we started with an overview of the IoT standardization landscape and then provided an overview of the main standards defining organizations involved in IoT and a snapshot of the projects that they are undertaking. We covered the following industry organizations: IEEE, IETF, ITU, IPSO Alliance, OCF, IIC, ETSI, oneM2M, AllSeen Alliance, Thread Group, ZigBee Alliance, TIA, Z-Wave Alliance, OASIS, and LoRa Alliance. Finally, we presented a summary of the standards gaps and provided a scorecard of the progress to the time of this writing.

Problems and Exercises

1. Name three established networking standards bodies involved in defining technology standards for IoT?
2. Which devices does IEEE 1451 series address? What does it specifically define? What does TEDS provide for IEEE 1451 devices? Provide specific examples.
3. What are the two mays to implement TEDS?
4. What does the IEEE 1888 standard define?
5. What constraints should routing protocols adhere to in order to meet the requirements of LLNs, as analyzed by the IETF ROLL workgroup?
6. Which RESTful protocol, defined by the IETF CORE workgroup, extends RESTful architectures to constrained devices? Why is REST applicable here?
7. What is the role of the IPSO Alliance among IoT standards organizations?
8. What two standards bodies are developing competing wireless technologies for home automation?
9. What is the scope of the standards being developed by oneM2M?
10. What IoT verticals does the work of the IIC encompass?
11. The LoRA Alliance standardizes the LoRA protocol. Describe the data rate and range characteristics of the technology?
12. Is the IoT standards landscape well defined? What is the net result of this on the industry?
13. Where does the industry stand on the road to a standards-based IoT? State the gaps per protocol layer.
14. Name two IoT Application Protocols that are being standardized by OASIS. Describe what function does each protocol serve.
15. Is the ZigBee stack based on the Internet Protocol? Explain.

References

1. D. Wobschall, IEEE 1451 – A Universal Transducer Protocol Standard. https://eesensors.com/media/wysiwyg/docs-pdfs/ESP16_Atest.pdf

2. B. Li et al., Wireless access for vehicular environments. http://www.mehrpouyan.info/Projects/Group%205.pdf
3. A. Khattab et al., An overview of IEEE standardization efforts for cognitive radio networks, IEEE International Symposium on Circuits and Systems (ISCAS), Lisbon, Portugal, May 2015
4. M. Kasparick et al., New IEEE 11073 standards for interoperable, networked Point-of-Care medical devices, 37th annual international conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, Italy, August 2015
5. O. Logvinov, Standard for an architectural framework for the Internet of Things (IoT). http://grouper.ieee.org/groups/2413/Intro-to-IEEE-P2413.pdf
6. IETF, ROLL Working Group charter. https://datatracker.ietf.org/wg/roll/charter/
7. J.P. Vasseur, Terms used in routing for low-power and Lossy networks, RFC 7102, Jan 2014
8. P. Levis et al., Overview of Existing Routing Protocols for Low-Power and Lossy Networks, draft-IETF-roll-protocols-survey-07, work in progress, Apr 2009
9. IETF, CORE Working Group charter. https://datatracker.ietf.org/wg/core/charter/
10. N. Kushalnagar et al., IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): overview, assumptions, problem statement, and goals, RFC4919, Aug 2007
11. G. Montenegro et al., Transmission of IPv6 Packets over IEEE 802.15.4 Networks, RFC4944, Sept 2007
12. J. Hui et al., Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks, RFC6282, Sept 2011
13. E. Kim et al., Design and application spaces for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs), RFC6568, Apr 2012
14. E. Kim et al., Problem statement and requirements for IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) Routing, RFC6606, May 2012
15. Z. Shelby et al., Neighbor discovery optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs), RFC6775, November 2012
16. IETF, 6TiSCH Working Group Charter. https://datatracker.ietf.org/wg/6tisch/charter/
17. IETF, ACE Working Group Charter. https://datatracker.ietf.org/wg/ace/charter/
18. C. Zavazava, ITU Work on the Internet of Things, Presentation at ICTP Workshop, Mar 2015
19. IPSO Alliance. http://www.ipso-alliance.org/
20. IETF, IPSO alliance successfully demonstrates Internet of Things interoperability, IETF Journal, Oct 2012
21. Open Connectivity Foundation. http://openconnectivity.org/
22. ETSI IoT. http://www.etsi.org/technologies-clusters/technologies/internet-of-things
23. oneM2M. http://www.onem2m.org/about-onem2m/why-onem2m
24. Thread Group. http://www.threadgroup.org/
25. O. Mazhelis et al., Internet of Things Market, Value Networks, and Business Models: State of the Art Report, 2013
26. Z-Wave Alliance. http://z-wavealliance.org/
27. TIA TR-50. http://www.tiaonline.org/all-standards/committees/tr-50
28. OASIS. https://www.oasis-open.org/committees/tc_cat.php?cat=iot
29. IBM LoRaWAN Press Release. https://www03.ibm.com/press/us/en/pressrelease/46287.wss
30. LoRa Alliance. https://www.lora-alliance.org/