



AN INTRODUCTION TO THE INTERNET OF THINGS



The concept of the “Internet of Things” (IoT) is no longer the stuff of science fiction but an essential part of the reality of our everyday lives. Today, there are more than 13 billion interconnected digital and electronic devices in operation globally, the equivalent of nearly 2 devices for every human on earth. Although the most common examples of the IoT consist of so-called “smart home” devices such as programmable thermostats and remote controlled appliances, the largest share of future growth of the IoT is likely to come from applications of the technology in virtually every sector of the economy, from commercial and industrial environments to healthcare and public safety.

In this UL white paper, we’ll provide readers with a general introduction to the technologies and standards that are expected to support the continued widespread deployment of the IoT. Beginning with an overview of current and future IoT applications, the paper will then discuss the specific technologies that make the IoT possible, and provide details on current standards development activities in progress. The white paper will conclude with a preview of the future standards and regulatory landscape.

The Promise of the Internet of Things

The “Internet of Things” (sometimes also referred to as the “Internet of Everything,” or IoE) generally refers to the multiple networks of devices or technology platforms (“things”) that communicate with each other via wireless protocols and without direct human interaction. Connections made through IoT-enabled devices facilitate the rapid and efficient transfer of data needed to support a wide range of activities and operations. In this way, the application of IoT technologies can lead to significant operational improvements, such as increased efficiency, better performance and enhanced safety.

Many think of the IoT as a single global network. But the IoT actually encompasses a multitude of independent but complementary networks in various service sectors, such as those supporting efficient energy distribution and usage (so-called smart grids), home automation

systems, vehicular traffic management and healthcare services. Indeed, technology research and consulting firm Beecham Research has identified nine different IoT service sectors and 29 separate applications for current and potential IoT development or expansion.

The potential in this broad applicability of IoT technologies is reflected in projections of future IoT market revenue and growth. IDC Research estimates that the global market value for IoT products and devices, currently about \$655 billion (USD), will increase to \$1.7 trillion by the year 2020, a compound annual growth rate (CAGR) of 16.9 percent. A separate projection from ABI Research indicates that the number of IoT-connected devices will increase from around 16 billion in 2014 to nearly 41 billion by 2020. Clearly, leveraging the growth potential of the IoT is likely to be an essential element of the strategy of technology companies in the years to come.





The IoT Landscape: Current and Potential Applications

Today's IoT is already bringing advanced technological capabilities to multiple consumer, commercial and industrial market segments. Some examples of current and potential applications for IoT technologies include:

- **Consumer and residential**—IoT applications in these market sectors include domestic and home automation tools, such as remote monitoring and control of appliances, lighting, heating and air conditioning, water usage, entertainment systems and premises security. Also included in this category are wearable consumer devices, such as smart watches and smart eyeglasses, and clothing with embedded technologies.
- **Health and healthcare**—These markets include personal health and fitness devices that monitor physical activity, such as wrist bands and other wearable devices. They also include m-Health technologies that monitor and record vital patient data in real time, or that enable healthcare professionals to retrieve and update patient medical records from any location. And m-Health technologies will enable baby-boomer generation adults with the ability to age in place, helping to reduce their overall impact on healthcare costs.
- **Transportation**—IoT applications in the transportation sector include smart cars and smart roadways that can help manage the flow of traffic and minimize congestion, and applications that identify vacant parking spaces. IoT

transportation applications are also being applied to public transportation systems, helping to balance capacity with anticipated ridership in real time, and providing riders with accurate scheduling information.

- **Energy infrastructure and distribution**—Smart grid technologies are transforming the way in which energy is produced and distributed, enabling utility operators to more accurately estimate usage and to source energy from the most cost-effective suppliers. IoT smart grid applications can also enable energy users to more effectively monitor and control their energy usage, thereby reducing consumption as well as the need for added infrastructure.
- **Public safety**—Cities and towns are quickly adopting IoT technologies to improve public safety and services. In some cases, these efforts leverage the transportation applications noted previously to help reduce city congestion. Other examples include smart phone apps for paying parking meter fees, or for reporting potholes or non-working traffic lights. Still others can help city officials monitor crime activity, allowing for the effective allocation of limited law enforcement resources.
- **Industrial and manufacturing**—IoT technologies, such as so-called machine-to-machine (M2M) applications, are being widely adopted in support of industrial automation to increase productive efficiency and flexibility. IoT sensors can also be used to monitor manufacturing equipment to determine when maintenance is

required. And IoT technologies can monitor inventory levels and raw material usage, helping to optimize inventory investment.

- **The environment**—Finally, IoT technologies are being used to monitor environmental conditions that could affect human, animal or plant life. IoT-equipped sensors can be used to detect rising water levels in rivers and streams that could lead to flooding, increases in air pollution levels due to automobiles or industrial activity, localized atmospheric conditions that could portend an increased risk of forest fires, and even vibration patterns that could signal risk of an earthquake, landslide or avalanche.

These examples represent just a small sampling of the myriad of current IoT applications, and illustrate some of the many potential benefits that can come from the continued growth and deployment of IoT technologies.

Enabling Technologies That Will Drive IoT Growth

The deployment of the IoT is based on a handful of enabling technologies. These include communications networks and protocols, hardware devices and components such as sensors, wireless charging technologies and software.

Communications Networks

An IoT network can be defined by the total area within which IoT devices are expected to operate. A local area network (LAN) usually covers an area the size of an office or home, within which devices are directly connected either by wire, such as twisted-pair or coax cable, or wirelessly

using a wireless communications protocol. Smart home IoT technologies typically operate in a LAN environment.

A wide area network (WAN) covers a much larger area, such as a group of buildings or remote locations. Connections are made with either fiber optic cable or wirelessly using microwave or satellite transmissions. A WAN may also consist of a series of interconnected networks, such as the Internet or an intranet. Most IoT technology applications, other consumer or residential applications, operate within a WAN environment.

At the other end of the spectrum are personal area networks (PANs), which typically cover a small area, such as a room. PAN-based IoTs enable the wireless connection of computers with printers and other peripherals, entertainment systems with headsets and remote controls. And body area networks (BANS) provide connectivity between a variety of wearable technologies and smart clothes, and even implanted devices.

Wireless Communications Protocols

Most IoT applications require the use of wireless communications protocols to enable the transmission of data between devices. There are a number of wireless communications protocols that are currently used to support IoT technologies. Some of the more widely used communications protocols include:

- **Wi-Fi**—A protocol for LAN-based IoT applications, Wi-Fi is based on the IEEE 802.11 series of standards. Wi-Fi works within the 2.4-5GHz frequency band to connect wireless devices to a network access point, and has an indoor range of about 20 meters.

- **Bluetooth and variants**—The Bluetooth protocol (based on IEEE 802.15.1) also operates in LAN-based environments at distances typically up to 10 meters, although some Bluetooth-enabled devices will work at distances of up to 100 meters. Bluetooth's principle advantages are its low rate of power consumption, the capacity to handle multiple devices simultaneously, and its ability to transmit wirelessly without visual line of sight contact. A Bluetooth variant, Bluetooth LE (also known as Bluetooth Smart) offers all of Bluetooth's communications advantages at significantly reduced power consumption rates.
- **Near Field Communications**—Near field communications is intended for use in PANs between devices that are within close proximity to each other, typically less than 20 centimeters (about eight inches). The limitations in their effective operating range help to make NFC-enabled devices inherently

more secure than those utilizing other communications protocols. Further NFC devices transmit data at relatively low rates, resulting in reduced energy consumption.

- **Zigbee**—Based on IEEE 802.15.4, Zigbee is designed for use in IoT applications operating in PAN environments that require secure networking and long battery life (at least two years) but that are not data transmission intensive. Zigbee-based IoT devices can communicate via line of sight at distances between 10 and 100 meters.
- **ZWave**—Zwave is a LAN environment communications protocol specifically designed for use with compatible home automation controls. It operates in frequency bands below 1 GHz, thereby avoiding interference from devices that work on other wireless communications protocols.

The appropriate wireless protocol for a given IoT device is usually prescribed



by a number of factors, including the type of communications network with which the device is intended to operate, anticipated data rate requirements, the availability of energy needed to support communications transmissions, and any application-specific requirements regarding security.

Sensors

Sensors are low-powered, wireless microelectronic devices that are designed to monitor a specific physical, electrical or chemical element and to transmit data on changes in that element over time. A sensor can be a simple, single-function device designed for a specific application, or integrated into a computing device such as a smart phone. But, regardless of the form that they take, sensors are an essential technology in the IoT universe since they enable the efficient collection and transfer of data.

Charging Technologies

To support the power requirements of IoT devices and components, wireless charging technologies are becoming increasingly important. Inductive charging uses electromagnetic fields to transfer power between devices such as a smart phone and a charging mat or pad that are in direct contact with each other, while resonance charging uses magnetic fields to transfer power between devices. In addition to eliminating the need for power cords or cables, both charging technologies allow IoT devices to be constructed without openings or sockets for power cords, making them less susceptible to damage from exposure to water and other liquids.

Software

Finally, like most technology platforms, the IoT depends on multiple types of software. These include IoT platforms and protocols, embedded operating systems and dedicated IoT applications. Certain software tools are intended for use with specific IoT applications, such as those intended to support smart home devices. In addition, some software is proprietary and may be subject to certain commercial restrictions, while other software is open source and freely available for use.

Key IoT Standards Development Activities

Numerous efforts are currently underway to develop standards and protocols that will help to guide future IoT technology development. Key development activities include:

- **IEEE**—The IEEE Standards Association is working on multiple fronts to create a standards-based framework to support the future development of the IoT. Most notable is the development of IEEE P2413, Draft Standard for an Architectural Framework for the Internet of Things (IoT), which is intended to define common architectural elements for IoT technologies, and the relationships among various IoT vertical market applications. The framework and concepts presented in P2413 is expected to significantly influence other standards development efforts.
- **Open Interconnect Consortium**—The Open Interconnect Consortium (OIC) consists of more than 50 companies from diverse markets working to

develop open source specifications to support interoperability between various types of IoT technologies. The OIC's lead standards development project is IoTivity, an open source software framework that will enable seamless connectivity between IoT devices operating across multiple operating systems and network protocols.

- **Industrial Interconnect Consortium**—Founded in March 2014, the Industrial Interconnect Consortium (IIC) is comprised of representatives from industry, government and academia working to develop an open framework architecture, standard specifications and security requirements for IoT technologies. In June 2015, the IIC released its Industrial Internet Reference Architecture technical paper, a blueprint for industrial IoT technologies that outlines a standard-based, open architecture. The IIC and OIC signed a strategic liaison agreement in February 2015 to foster collaboration between the two groups.
- **Thread Group**—The Thread Group is dedicated to promoting the interoperability of IoT technologies and devices intended for use in the home. The Thread wireless network protocol is intended to support a robust, self-healing mesh network to support the connection of appliances, access and climate controls, energy management, lighting safety and security. In conjunction with UL, the Thread Group has recently launched a certification program for products utilizing the Thread protocol.

- **NFC Forum**—The NFC Forum has been in the forefront of developing NFC technical specifications for more than a decade. Originally formed in 2004, the NFC Forum includes hundreds of member companies and organizations from around the world committed to expanding the deployment of NFC technology by developing and promoting interoperability specifications for most NFC devices and applications. There are currently 20 adopted specifications that have been developed by the NFC Forum. In addition, the Forum sponsors a voluntary certification program for NFC-enabled devices and applications.



- **AllSeen Alliance**—The AllSeen Alliance consists of more than 185 technology companies from a variety of industries with the goal of improving device and software interoperability in support of the IoT. The Alliance’s AllJoyn® Framework enables developers to create interoperability applications for the IoT that run on most platforms and operating systems.
- **AirFuel Alliance**—The result of the 2015 merger between the Power Matters Alliance (PMA) and the Alliance for Wireless Power (A4WP), the AirFuel Alliance includes nearly 200 companies and is focused on the development of standards to support inductive (formerly addressed by the PMA) and resonant (formerly the focus of the A4WP) wireless charging technologies. The AirFuel Alliance has recently announced a global certification program for wireless charging devices and components.

The Road Ahead for Standards Development

As this list of some of the current standards development efforts illustrates, industry has played an important role to date in the development of standards applicable to IoT technologies, as part of the larger effort to support interoperability between IoT devices and applications. The merger of the PMA and the A4WP is a clear signal that some current standards development efforts may unnecessarily duplicate those of other groups. But industry’s involvement in IoT standards development is expected to continue and even increase to support the future expanded deployment of IoT technologies in various industry sectors.

At the same time, the IEEE Standards Association reports that it has more than 110 new IoT-related standards in various stages of development, and an additional 40 current IoT-related standards under revision. Separately, development efforts

by independent standards bodies such as the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) are beginning to gain traction as well. Indeed, the availability of ISO and IEC standards for IoT technologies would help to establish harmonized requirements for the deployment of IoT technologies around the world.

In the short term at least, the plethora of current and anticipated IoT-related standards is likely to generate more questions than answers for companies seeking to take advantage of the market opportunities afforded by the anticipated growth of the IoT ecosystem. However, these opportunities are also likely to foster increased collaboration in future standards development efforts, and the consolidation of current standards development activities that share complementary objectives. These developments will eventually provide IoT



participants with greater clarity regarding technical requirements applicable to their specific products, thereby easing the path for market acceptance.

Summary and Conclusion

The IoT has the potential to dramatically increase the availability of information, and is likely to transform companies and organizations in virtually every industry around the world. As such, finding ways to leverage the power of the IoT is expected to factor into the strategic objectives of most technology companies, regardless of their industry focus. The number of different technologies required to support the deployment and further growth of the IoT places a premium on interoperability, and has resulted in widespread efforts to develop standards and technical specifications that support seamless communication between IoT devices and components. Collaboration between various standards development groups and consolidation of some current efforts will eventually result in greater clarity for IoT technology companies.

UL is committed to the continued development and widespread deployment of technologies in support of the IoT ecosystem. UL senior technical experts serve in key leadership positions in many of the current standards development efforts, including the OIC, the Thread Group, the NFC Forum, and the Air Fuel Alliance. UL is also just one of two NFC Forum-authorized testing laboratories in North America, and is the exclusive testing partner for the Thread Group's recently announced certification program. UL has extensive experience in IoT technologies, and can conduct testing at locations throughout North America, the European Union and Asia.

For more information about UL's IoT technology-related testing and certification services, contact Mick Conley at Mick.Conley@ul.com.

References

- [1] “Internet of Things’ Connected Devices to Almost Triple to Over 38 Billion Units by 2020,” Juniper Research, 28 July 2015. Web. 24 October 2015. <http://www.juniperresearch.com/press/press-releases/iot-connected-devices-to-triple-to-38-bn-by-2020>.
- [2] “M2M World of Connected Services: The Internet of Things,” an infographic prepared by Beecham Research. Web. 4 November 2015. <http://www.beechamresearch.com/download.aspx?id=18>.
- [3] “Explosive Internet of Things Spending to Reach \$1.7 Trillion in 2020, According to IDC,” press release, IDC Research, Inc., 2 June 2015. Web. 4 November 2015. <http://www.idc.com/getdoc.jsp?containerId=prUS25658015>.
- [4] “The Internet of Things Will Drive Wireless Connected Devices to 40.9 Billion in 2020,” ABI Research, August 20, 2014. Web. 4 November 2015. <https://www.abiresearch.com/press/the-internet-of-things-will-drive-wireless-connect/>.
- [5] Additional information about IEEE P2413 and its development is available at the website of the IEEE Standards Association, <http://grouper.ieee.org/groups/2413/> (as of 4 November 2015).
- [6] Additional information about the OIC’s IoTivity project is available at <https://www.iotivity.org/> (as of 4 November 2015).
- [7] “The Industrial Internet Reference Architecture Technical Paper,” prepared by the Industrial Internet Consortium, June 2015. Available for download at <http://www.iiconsortium.org/IIRA.htm> (as of 4 November 2015).
- [8] “Open Interconnect Consortium Forms Liaison with the Industrial Internet Consortium to Accelerate IoT Standard,” OIC News Release, February 26, 2015. Web. 4 November 2015. <http://openinterconnect.org/oic-news-releases/open-interconnect-consortium-forms-liaison-with-the-industrial-internet-consortium-to-accelerate-iot-standards/>.
- [9] Additional information about the Thread Group and the Thread protocol is available at <http://threadgroup.org> (as of 4 November 2015).
- [10] Additional information about the AllSeen Alliance’s AllJoyn Framework is available at <https://allseenalliance.org/framework> (as of 4 November 2015).
- [11] Additional information about the AirFuel Alliance is available at www.airfuel.org (as of 4 November 2015).
- [12] “IEEE-SA Internet of Things Ecosystem Study,” IEEE Standards Association, 2015. Available for download at <http://standards.ieee.org/innovate/iot/study.html> (as of 5 November 2015).