Internet of things

The Internet of things (IoT) is the network of devices, vehicles, and home appliances that contain electronics, software, actuators, and connectivity which allows these things to connect, interact and exchange data.

IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally dumb or non-internet-enabled physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled.

## History

The definition of the Internet of things has evolved due to convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things.

The concept of a network of smart devices was discussed as early as 1982, with a modified Coke machine at Carnegie Mellon University becoming the first Internet-connected appliance, able to report its inventory and whether newly loaded drinks were cold. Mark Weiser's 1991 paper on ubiquitous computing, "The Computer of the 21st Century", as well as academic venues such as UbiComp and PerCom produced the contemporary vision of IoT. In 1994, Reza Raji described the concept in IEEE Spectrum as "[moving] small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories".Between 1993 and 1997, several companies proposed solutions like Microsoft's at Work or Novell's NEST. The field gained momentum when Bill Joy envisioned Device to Device (D2D) communication as a part of his "Six Webs" framework, presented at the World Economic Forum at Davos in 1999.

The term "Internet of things" was likely coined by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID Center, in 1999, though he prefers the phrase "Internet for things".At that point, he viewed Radio-frequency identification (RFID) as essential to the Internet of things, which would allow computers to manage all individual things.

A research article mentioning the Internet of things was submitted to the conference for Nordic Researchers in Logistics, Norway, in June 2002, which was preceded by an article published in Finnish in January 2002. The implementation described there was developed by Kary Främling and his team at Helsinki University of Technology and more closely matches the modern one, i.e. an information system infrastructure for implementing smart, connected objects.

## Applications

The extensive set of applications for IoT devices is often divided into consumer, commercial, industrial, and infrastructure spaces.

**Consumer applications**

A growing portion of IoT devices are created for consumer use, including connected vehicles, home automation, wearable technology, connected health, and appliances with remote monitoring capabilities.

Smart home

IoT devices are a part of the larger concept of home automation, which can include lighting, heating and air conditioning, media and security systems. Long term benefits could include energy savings by automatically ensuring lights and electronics are turned off.

A smart home or automated home could be based on a platform or hubs that control smart devices and appliances. For instance, using Apple's HomeKit, manufacturers can get their home products and accessories be controlled by an application in iOS devices such as the iPhone and the Apple Watch. This could be a dedicated app or iOS native applications such as Siri. This can be demonstrated in the case of Lenovo's Smart Home Essentials, which is a line of smart home devices that are controlled through Apple's Home app or Siri without the need for a Wi-Fi bridge. There are also dedicated smart home hubs that are offered as standalone platforms to connect different smart home products and these include the Amazon Echo, Apple's HomePod, and Samsung's SmartThings Hub.

Elder care

One key application of smart home is to provide assistance for those with disabilities and elderly individuals. These home systems use assistive technology to accommodate an owner's specific disabilities. Voice control can assist users with sight and mobility limitations while alert systems can be connected directly to cochlear implants worn by hearing impaired users. They can also be equipped with additional safety features. These features can include sensors that monitor for medical emergencies such as falls or seizures. Smart home technology applied in this way can provide users with more freedom and a higher quality of life.

The term "Enterprise IoT" refers to devices used in business and corporate settings. By 2019, it is estimated that EIoT will account for 9.1 billion devices.

Defining the Internet of things as "simply the point in time when more 'things or objects' were connected to the Internet than people", Cisco Systems estimated that IoT was "born" between 2008 and 2009, with the things/people ratio growing from 0.08 in 2003 to 1.84 in 2010.

### Commercial applications

Medical and healthcare

The Internet of Medical Things (also called the internet of health things) is an application of the IoT for medical and health related purposes, data collection and analysis for research, and monitoring. This 'Smart Healthcare', as it can also be called, led to the creation of a digitized healthcare system, connecting available medical resources and healthcare services.

IoT devices can be used to enable remote health monitoring and emergency notification systems. These health monitoring devices can range from blood pressure and heart rate monitors to advanced devices capable of monitoring specialized implants, such as pacemakers, Fitbit electronic wristbands, or advanced hearing aids. Some hospitals have begun implementing "smart beds" that can detect when they are occupied and when a patient is attempting to get up. It can also adjust itself to ensure appropriate pressure and support is applied to the patient without the manual interaction of nurses.

A 2015 Goldman Sachs report indicated that healthcare IoT devices "can save the United States more than $300 billion in annual healthcare expenditures by increasing revenue and decreasing cost." Moreover, the use of mobile devices to support medical follow-up led to the creation of 'm-health', used "to analyze, capture, transmit and store health statistics from multiple resources, including sensors and other biomedical acquisition systems".

Specialized sensors can also be equipped within living spaces to monitor the health and general well-being of senior citizens, while also ensuring that proper treatment is being administered and assisting people regain lost mobility via therapy as well. These sensors create a network of intelligent sensors that are able to collect, process, transfer and analyse valuable information in different environments, such as connecting in-home monitoring devices to hospital-based systems. Other consumer devices to encourage healthy living, such as connected scales or wearable heart monitors, are also a possibility with the IoT. End-to-end health monitoring IoT platforms are also available for antenatal and chronic patients, helping one manage health vitals and recurring medication requirements.

Advances in plastic and fabric electronics fabrication methods have enabled ultra-low cost, use-and-throw IoMT sensors. These sensors, along with the required RFID electronics, can be fabricated on paper or e-textiles for wirelessly powered disposable sensing devices. Applications have been established for point-of-care medical diagnostics, where portability and low system-complexity is essential.

As of 2018 IoMT was not only being applied in the clinical laboratory industry, but also in the healthcare and health insurance industries. IoMT in the healthcare industry is now permitting doctors, patients and others involved (i.e. guardians of patients, nurses, families, etc.) to be part of a system, where patient records are saved in a database, allowing doctors and the rest of the medical staff to have access to the patient's information. Moreover, IoT-based systems are patient-centered, which involves being flexible to the patient's medical conditions. IoMT in the insurance industry provides access to better and new types of dynamic information. This includes sensor-based solutions such as biosensors, wearables, connected health devices and mobile apps to track customer behaviour. This can lead to more accurate underwriting and new pricing models.

The application of IOT in healthcare plays a fundamental role in managing chronic diseases and in disease prevention and control. Remote monitoring is made possible through the connection of powerful wireless solutions. The connectivity enables health practitioners to capture patient’s data and applying complex algorithms in health data analysis.

Transportation

The IoT can assist in the integration of communications, control, and information processing across various transportation systems. Application of the IoT extends to all aspects of transportation systems (i.e. the vehicle, the infrastructure, and the driver or user). Dynamic interaction between these components of a transport system enables inter and intra vehicular communication, smart traffic control, smart parking, electronic toll collection systems, logistic and fleet management, vehicle control, and safety and road assistance. In Logistics and Fleet Management for example, The IoT platform can continuously monitor the location and conditions of cargo and assets via wireless sensors and send specific alerts when management exceptions occur (delays, damages, thefts, etc.). If combined with Machine Learning then it also helps in reducing traffic accidents by introducing drowsiness alerts to drivers and providing self driven cars too.

Building and home automation

IoT devices can be used to monitor and control the mechanical, electrical and electronic systems used in various types of buildings (e.g., public and private, industrial, institutions, or residential) in home automation and building automation systems. In this context, three main areas are being covered in literature:

The integration of the Internet with building energy management systems in order to create energy efficient and IOT driven "smart buildings".

The possible means of real-time monitoring for reducing energy consumption and monitoring occupant behaviors.

The integration of smart devices in the built environment and how they might to know who to be used in future applications.

### Industrial applications

Manufacturing

The IoT can realize the seamless integration of various manufacturing devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities. Based on such a highly integrated smart cyberphysical space, it opens the door to create whole new business and market opportunities for manufacturing. Network control and management of manufacturing equipment, asset and situation management, or manufacturing process control bring the IoT within the realm of industrial applications and smart manufacturing as well. The IoT intelligent systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing production and supply chain networks, by networking machinery, sensors and control systems together.

Digital control systems to automate process controls, operator tools and service information systems to optimize plant safety and security are within the purview of the IoT. But it also extends itself to asset management via predictive maintenance, statistical evaluation, and measurements to maximize reliability. Smart industrial management systems can also be integrated with the Smart Grid, thereby enabling real-time energy optimization. Measurements, automated controls, plant optimization, health and safety management, and other functions are provided by a large number of networked sensors.

The term industrial Internet of things (IIoT) is often encountered in the manufacturing industries, referring to the industrial subset of the IoT. IIoT in manufacturing could generate so much business value that it will eventually lead to the fourth industrial revolution, so the so-called Industry 4.0. It is estimated that in the future, successful companies will be able to increase their revenue through Internet of things by creating new business models and improve productivity, exploit analytics for innovation, and transform workforce. The potential of growth by implementing IIoT may generate $12 trillion of global GDP by 2030.

While connectivity and data acquisition are imperative for IIoT, they should not be the purpose, rather the foundation and path to something bigger. Among all the technologies, predictive maintenance is probably a relatively "easier win" since it is applicable to existing assets and management systems. The objective of intelligent maintenance systems is to reduce unexpected downtime and increase productivity. And to realize that alone would generate around up to 30% over the total maintenance costs. Industrial big data analytics will play a vital role in manufacturing asset predictive maintenance, although that is not the only capability of industrial big data. Cyber-physical systems (CPS) is the core technology of industrial big data and it will be an interface between human and the cyber world. Cyber-physical systems can be designed by following the 5C (connection, conversion, cyber, cognition, configuration) architecture, and it will transform the collected data into actionable information, and eventually interfere with the physical assets to optimize processes.

An IoT-enabled intelligent system of such cases was proposed in 2001 and later demonstrated in 2014 by the National Science Foundation Industry/University Collaborative Research Center for Intelligent Maintenance Systems (IMS) at the University of Cincinnati on a bandsaw machine in IMTS 2014 in Chicago. Bandsaw machines are not necessarily expensive, but the bandsaw belt expenses are enormous since they degrade much faster. However, without sensing and intelligent analytics, it can be only determined by experience when the band saw belt will actually break. The developed prognostics system will be able to recognize and monitor the degradation of band saw belts even if the condition is changing, advising users when is the best time to replace the belt. This will significantly improve user experience and operator safety and ultimately save on costs.

Agriculture

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. This data can be used to automate farming techniques, take informed decisions to improve quality and quantity, minimize risk and waste, and reduce effort required to manage crops. For example, farmers can now monitor soil temperature and moisture from afar, and even apply IoT-acquired data to precision fertilization programs.

In August 2018, Toyota Tsusho began a partnership with Microsoft to create fish farming tools using the Microsoft Azure application suite for IoT technologies related to water management. Developed in part by researchers from Kindai University, the water pump mechanisms use artificial intelligence to count the number of fish on a conveyor belt, analyze the number of fish, and deduce the effectiveness of water flow from the data the fish provide. The specific computer programs used in the process fall under the Azure Machine Learning and the Azure IoT Hub platforms.

### Infrastructure applications

Monitoring and controlling operations of sustainable urban and rural infrastructures like bridges, railway tracks and on- and offshore wind-farms is a key application of the IoT. The IoT infrastructure can be used for monitoring any events or changes in structural conditions that can compromise safety and increase risk. IoT can benefit the construction industry by cost saving, time reduction, better quality workday, paperless workflow and increase in productivity. It can help in taking faster decisions and save money with Real-Time Data Analytics. It can also be used for scheduling repair and maintenance activities in an efficient manner, by coordinating tasks between different service providers and users of these facilities. IoT devices can also be used to control critical infrastructure like bridges to provide access to ships. Usage of IoT devices for monitoring and operating infrastructure is likely to improve incident management and emergency response coordination, and quality of service, up-times and reduce costs of operation in all infrastructure related areas. Even areas such as waste management can benefit from automation and optimization that could be brought in by the IoT.

Metropolitan scale deployments

There are several planned or ongoing large-scale deployments of the IoT, to enable better management of cities and systems. For example, Songdo, South Korea, the first of its kind fully equipped and wired smart city, is gradually being built, with approximately 70 percent of the business district completed as of June 2018. Much of the city is planned to be wired and automated, with little or no human intervention.

Another application is a currently undergoing project in Santander, Spain. For this deployment, two approaches have been adopted. This city of 180,000 inhabitants has already seen 18,000 downloads of its city smartphone app. The app is connected to 10,000 sensors that enable services like parking search, environmental monitoring, digital city agenda, and more. City context information is used in this deployment so as to benefit merchants through a spark deals mechanism based on city behavior that aims at maximizing the impact of each notification.

Other examples of large-scale deployments underway include the Sino-Singapore Guangzhou Knowledge City; work on improving air and water quality, reducing noise pollution, and increasing transportation efficiency in San Jose, California; and smart traffic management in western Singapore. French company, Sigfox, commenced building an ultra-narrowband wireless data network in the San Francisco Bay Area in 2014, the first business to achieve such a deployment in the U.S. It subsequently announced it would set up a total of 4000 base stations to cover a total of 30 cities in the U.S. by the end of 2016, making it the largest IoT network coverage provider in the country thus far. Cisco also participates in smart cities projects. Cisco has started deploying technologies for Smart Wi-Fi, Smart Safety & Security, Smart Lighting, Smart Parking, Smart Transports, Smart Bus Stops, Smart Kiosks, Remote Expert for Government Services (REGS) and Smart Education in the five km area in the city of Vijaywada.

Another example of a large deployment is the one completed by New York Waterways in New York City to connect all the city's vessels and be able to monitor them live 24/7. The network was designed and engineered by Fluidmesh Networks, a Chicago-based company developing wireless networks for critical applications. The NYWW network is currently providing coverage on the Hudson River, East River, and Upper New York Bay. With the wireless network in place, NY Waterway is able to take control of its fleet and passengers in a way that was not previously possible. New applications can include security, energy and fleet management, digital signage, public Wi-Fi, paperless ticketing and others.

Energy management

Significant numbers of energy-consuming devices (e.g. switches, power outlets, bulbs, televisions, etc.) already integrate Internet connectivity, which can allow them to communicate with utilities to balance power generation and energy usage and optimize energy consumption as a whole. These devices allow for remote control by users, or central management via a cloud-based interface, and enable functions like scheduling (e.g., remotely powering on or off heating systems, controlling ovens, changing lighting conditions etc.). The smart grid is a utility-side IoT application; systems gather and act on energy and power-related information to improve the efficiency of the production and distribution of electricity. Using advanced metering infrastructure (AMI) Internet-connected devices, electric utilities not only collect data from end-users, but also manage distribution automation devices like transformers.

Environmental monitoring

Environmental monitoring applications of the IoT typically use sensors to assist in environmental protection by monitoring air or water quality, atmospheric or soil conditions, and can even include areas like monitoring the movements of wildlife and their habitats. Development of resource-constrained devices connected to the Internet also means that other applications like earthquake or tsunami early-warning systems can also be used by emergency services to provide more effective aid. IoT devices in this application typically span a large geographic area and can also be mobile. It has been argued that the standardization IoT brings to wireless sensing will revolutionize this area.

Living Lab

Another example of integrating IoT is Living Lab which integrates and combines research and innovation process, establishing within a public-private-people-partnership. There are currently 320 Living Labs that use IoT to collaborate and share knowledge between stakeholders to co-create innovative and technological products. For companies to implement and develop IoT services for smart cities, they need to have incentives. The governments play key roles in smart cities projects as changes in policies will help cities to implement IoT which provides effectiveness, efficiency, and accuracy of the resources that are being used. For instance, the government provides tax incentives and cheap rent, improves public transports, and offers an environment where start-up companies, creative industries, and multinationals may co-create, share common infrastructure and labor markets, and take advantages of locally embedded technologies, production process, and transaction costs. The relationship between the technology developers and governments who manage city's assets, is key to provide open access of resources to users in an efficient way.