The Interconnecting of Everything

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Highlights

The Internet of Things is the Internet of the future, powering billions of integrated devices and processes across industries and global locations.

- The Internet of Things will combine technology and societal interests that bridge cultural differences and a wide range of user skills.
- The Internet of Things is the next giant leap in the Internet evolution, strengthening its ability to gather, analyze, and distribute data that becomes information and knowledge.
- The Internet of Things can use unique business offerings to the platform of anytime, anything, and any place connectivity.

The Internet of Things

The Internet of Things is a technological revolution in the future of computing and communication that is based on the concept of anytime, any place connectivity for anything.[1] Even in these early stages, the Internet of Things has transformed the way corporations and consumers interact with each other and the environment around them. Internet-of-Things technologies have impacted solution domains, such as Smart Grid, Supply Chain Management, Smart Cities, and Smart Home. The Internet of Things is a computing paradigm that will change business models, technology investments, consumer experiences, and everyday life.

The Internet of Things also represents a network of Internet-enabled, real-world objects, such as nanotechnology, consumer electronics, home appliances, sensors of all kinds, embedded systems, and personal mobile devices. It includes enabling network and communication technologies, such as IPv6, web services, RFID, and 4G networks. We are already applying Internet-of-Things solutions in practical ways by using mobile devices. For example, you can monitor your home security, lights, heating, and cooling from your smartphone. You can purchase a refrigerator that monitors its processes and sends reports to your smartphone.

The industry predicts that, by 2020, possibly 50 billion devices will be connected,[2] a number that is 10 times that of all current Internet hosts, including connected mobile phones[3]. This amazing number of connected devices, along with the required conditions for maintenance and effective operation, present intricate and complex challenges that affect Internet-of-Things adoption and growth.

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[1] ITU Internet Reports 2005: The Internet of Things: Executive Summary: http://www.itu.int/osg/spu/publications/internetofthings/InternetofThings_summary.pdf

[2] Dave Evans, *Internet of Things: How the Next Evolution of the Internet Is Changing Everything* (Cisco, April 2011)

[3] "CEO to shareholders: 50 billion connections 2020," Ericsson press release, April 2010: http://www.ericsson.com/thecompany/press/releases/2010/04/1403231

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Dimensions of the Internet of Things

The Internet of Things is based on three dimensions: components, building blocks, and system of systems as shown in Figure 1. Components deliver foundational capabilities. Building blocks encompass product technologies that emerge from integrating new Internet of Things components and traditional technology components. System of systems describes the unique ways that building block can be combined, integrated, and deployed across industries.

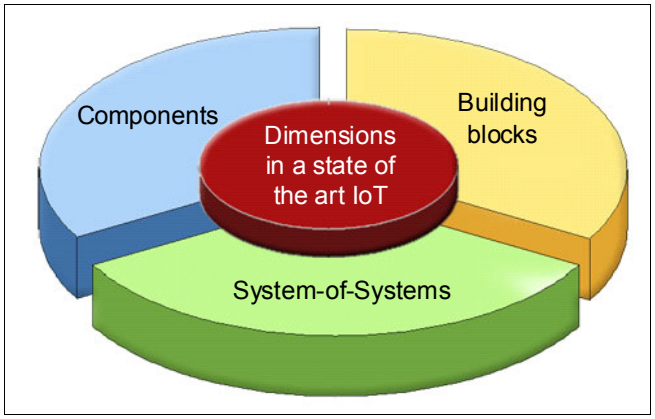

Figure 1 Dimensions of the Internet of Things

Components are specific to an application, meaning that they are specific to the solution. For example, a water system uses meters, pressure and flow sensors, and value control components. Building blocks are items that are common to many solutions but that are critical to success. Examples include communications, security, analytic engines, remote compute nodes, and update engines.

Building blocks are the backbone of many solutions and include communications, security, analytic engines, remote compute nodes, and update engines. Other examples of building blocks include software, household appliances, mobile devices, security and privacy technologies, and communication and network technologies. They also include consumer and business electronics; land, air and water-based vehicles; home automation technologies (including monitoring and metering); and Internet and network protocols (such as IPv6).

Building blocks are used to create systems, which are then combined to create a system of systems. The distinction in an Internet of Things world is defined by the operational scenario that is being supported.

For example, a car is a system that consists of multiple building blocks and components. In city traffic, the car and driver interact with the city traffic systems to navigate directions and traffic flow as a type of city-traffic system of systems. For an automobile manufacturer, the context switches to customer support systems. The information that is gained on driving conditions, driving habits, security, and maintenance records is fed to the manufacturer's customer support systems, forming a customer-care system of systems. In both scenarios, the Internet-of-Things solution is the coordination and interaction of many smaller systems, each with levels of autonomy, dependence, and interaction.

Other examples of system of systems include IBM Smarter Cities® and Smart Grid, environment-based, ground transportation, aviation and aeronautics, security and surveillance. They also include pharmaceutical, medical and healthcare, retail, supply chain, processing and manufacturing, agriculture, grocery and food traceability, media and entertainment, and operational scenarios and business cases.

Business challenges with the Internet of Things

The Internet of Things has arrived and will continue to evolve and affect corporate environments. Business and technology executives who are responsible for these environments need to understand the challenges and approaches to consider in an Internet-of-Things-centric ecosystem. The primary focus must on critical operational considerations, such as scalability, availability, manageability, data management, security, and usability. These considerations are in the context of a hybrid environment where many aspects of a deployment are not within the control of the corporation.

Scalability

An Internet of Things environment contains two scalability issues, each of which poses unique challenges for users and corporations. The first scalability issue is based on the number of connected devices. The second issue is based on the volume of generated data.

Scalability issues for connected devices include the number of concurrent connections, or throughput, that a system can support and the quality of service (QoS) level that can be guaranteed. Here, Internet scalability is a critical factor. Currently, most Internet-connected devices use IPv4, which is based on a 32-bit

addressing scheme and is limited to 2^{32} (4,294,967,296) unique addresses. Considering that Internet-of-Things forecasts describe a possible 50 - 100 billion devices, optimum scalability would require migrating to IPv6, which implements a 128-bit addressing scheme that can support up to 2^{128} addresses (3.4×10^{38} devices). Several initiatives are underway to influence the direction of IPV6 to enable the Internet of Things. One such initiative is the IoT6 project, which is focused on researching, designing, and developing a highly scalable IPv6-based service-oriented architecture.[4]

Challenges for scalability that are based on data volume highlight performance issues that are associated with data collection, processing, storage, query, and display. Internet-of-Things systems need to handle both device and data scalabilities.

Availability

Internet-of-Things availability involves recoverability and reliability. End-to-end system availability might require technical principles across components and building blocks that are driven by specific industry use-case needs.

One architecture implication to availability is driven by the increased demand around cloud computing and *x*-as-a-service, such as software as a service. Corporations must closely look at the implications to the services and capabilities that are required of an Internet-of-Things environment. They might need to re-examine their cloud-based service-level agreements (SLAs) to determine whether they can obtain the level of availability that is required.

An innovative solution addresses fault avoidance, or fault intolerance, in ways that will facilitate a business to meet customer expectations and enterprise needs, if the business has a hybrid environment of on-premise and cloud solutions.

Manageability

Currently, only IT-related systems, such as servers, computers, and storage devices, are managed under a governance model. Although mobile devices, such as phones and tablets, are reasonably managed, most other Internet-of-Things devices are not managed systematically as part of a larger ecosystem. In the Internet of Things, most devices operate remotely without direct human interaction, which requires management of such devices in the same way, that is, remotely and without human intervention. Simply applying current network and systems management techniques and technologies is not sufficient. New approaches are needed to develop an Internet-of-Things architecture and to manage its lifecycle.

Managing data

Big data and the Internet of Things are computing paradigms that, together, fundamentally change the nature of how we work, play, and interact with our environment. Where big data is all about volume, velocity, verity, and veracity, the Internet of Things is about using that data in meaningful ways to improve productivity and quality of life.[5]

For example, the Internet of Things can collect temporospatial information, which is both temporal (time) and spatial (location) data. This information, when combined with analytic technology, provides new insight into when, where, and how devices and humans can or should interact. The key issue is how corporations handle storing, managing, and manipulating this data. Many corporations are already using such technologies as IBM SPSS®, Tealeaf, and IBM Cognos® to conduct complex analysis and gaining insight into patterns, unusual events, and anomalies. The innovations come from using these technologies in an Internet-of-Things context to deliver new capabilities in support of key business processes such as e-commerce, supply chain, and customer experience management. However, to reach this level of capability, enhancements are needed in database, content management, and information technologies.

Security

Traditional IT security establishes secure boundaries and firewalls around internal IT systems. But with the Internet of Things, the concept of *controlled access* is changing to one of *controlled trust* that offers the widest range of possible solutions. Security challenges require Internet-of-Things implementations to effectively deal with authorization, authentication, access control, privacy, and trust requirements without negatively impacting usability.

[4] IoT6 Project: http://www.iot6.eu

[5] Big Data at the Speed of Business: What is big data: http://www.ibm.com/software/data/bigdata

Usability

Usability has a broad role in the solutions of the future. Traditionally, most IT solutions were task-based and allowed for task-based training. With Internet-of-Things solutions, this type of training can be complex and ineffective, which requires devices to offer new and higher usability levels that bridge cultural differences and wide ranges of user knowledge and skills. Internet-of-Things systems can provide detailed visibility of complex systems, which necessitate a usability design that allows ease-of-use and appealing aesthetics, multilingual support, and context help.

The Internet of Things uses innovation in many fields, from wireless sensors to nanotechnology, making it a natural fit for the IBM Smarter Planet® initiative.

Cross-industry concepts for Internet of Things

Internet-of-Things concepts affect almost all industries and the solution capabilities that are provided, from business smart grid demand and response, logistics to smart home and services, as shown in Figure 2. Industry analysts predict that the Internet of Things will be key in the areas of waste management, urban planning, sustainable urban environment, continuous care, emergency response, intelligent shopping, smart product management, smart meters, home automation and smart events.

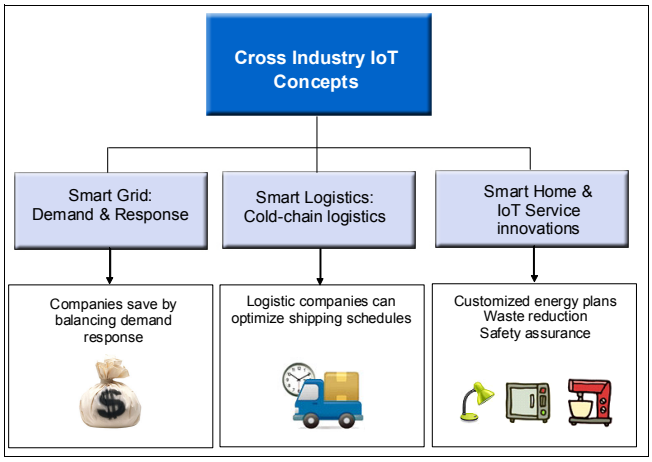

Figure 2 Cross-industry Internet of Things concepts

Smart grid demand and response

In the energy, utility, and renewable energy industries, smart grid demand and response are critical elements in managing the balance between demand and response, especially in the renewable energy resources industry. This balance remains a key factor as we continue to deploy distributed and renewable resources such as wind turbines and solar panels. From an Internet-of-Things perspective, the decisions that are made in these industries will directly impact other industries. For example, design choices in automotive, consumer electronics, and home appliances will factor in the ability to use and deploy options that are provided by power companies.

Internet-of-Things-based demand and response systems can integrate varied information sources, such as the predicted output of distributed generators, the current load of electrical grids, and the predicated usage of electrical vehicles and smart appliances. By using real-time and historical data, an Internet-of-Things demand and response system can calculate and forecast the balance point over a time range, automatically sending control information to generators, electrical grids, and smart appliances, maintaining the desired balance. For example, a utility company can save a significant amount of money in new equipment while continuing to maintain the reliability and integrity of the electrical grid.

Another example of how the Internet of Things can improve demand and response is traffic management. Traffic engineers and planners use data and modeling information that is provided by real-time sensors to analyze traffic patterns. They then use the collected data to dynamically adjust the timing of traffic lights and on/off ramps, therefore, easing congestion and improving traffic flow in real time, not on projection models.

Smart cold-chain logistics

The healthcare, grocery, pharmaceutical, chemical and transportation industries are looking to Internet-of-Things solutions to aid them in cold-chain logistics-based solutions. The concept of *cold-chain logistics* pertains to the special supply chain that is required for items as ice-cream, medicine, and high value vegetable, meats and fishes. End-to-end delivery of these goods involves multiple steps in the logistic chain, such as storage containers in various warehouses, multiple vehicle transport, vendors across multiple locations, and complex regulatory compliance. These multiple steps require you to monitor the food lifecycle throughout the logistics process. An Internet-of-Things-based system can manage location

information for the goods and monitor and log temperature and humidity information to ensure end-to-end delivery quality. An Internet-of-Things approach can help logistic companies to optimize shipping schedules and differentiate their services.

Smart home and Internet-of-Things services

Home appliances, consumer electronics, residential construction, telecommunications, home security, and healthcare are a few industries that see great potential with Internet-of-Things-based solutions that are related to a smart home. The future smart home will contain a broad range of new applications that connect smart appliances with managing devices, such as dynamic lighting, automation, energy management, security, and remote health monitoring.

Even today, you can monitor your locks, appliances, lighting, and home temperature with your smartphone. Such interconnected smart applications and devices form an Internet-of-Things service platform for developing new service innovations, such as customized energy plans, waste reduction, and safety assurance. This Internet-of-Things platform can help you adapt your business model to emerging industry scenarios.

How IBM can help

The Internet of Things envisions a future Internet as a dynamic global network infrastructure, where physical and virtual things have identities and physical attributes, and use self-configuring capabilities that are based on standard communication protocols. The Internet-of-Things is about improving optimization and information systems in a real-time environment, bringing real-time dynamics to otherwise static systems. In this future network, all objects use intelligent interfaces to seamlessly integrate into a global information network that provides a new meaning to the term *customer experience*. For IBM, the Internet of Things is a technology revolution that supports the concept of a Smarter Planet.[6]

If your company is looking to optimize the potential power of linking Internet of Things to strategic business imperatives, it is time to talk to IBM. Currently IBM is investigating the linkages between the Information of Things and IBM Smarter Commerce™, IBM Smarter Analytics™, Smarter Computing Infrastructures, and Mobile First. To learn more about these topics or to begin a dialogue about the potential implications of Internet of Things in your business, see “The Platform for an Engaging Enterprise” at:

http://www.ibm.com/systems-of-interaction

Resources for more information

For more information about the Internet of Things, see the following resources:

- Internet of Things: Strategic Roadmap 2009

  http://www.grifs-project.eu/data/File/CERP-IoT%20SRA_IoT_v11.pdf

- Brand value

  http://www.brandvalued.com/about-the-book/our-ten-case-studies

- “That ‘Internet of Things’ Thing,” by K. Ashton, *RFID Journal*

  http://www.rfidjournal.com/article/view/4986

- Top 5 Web Trends 2009

  http://www.readwriteweb.com/archives/top_5_web_trends_of_2009_internet_of_things.php

- ITU Internet Reports 2005: The Internet of Things - Executive Summary.

  http://www.itu.int/osg/spu/publications/internetofthings/InternetofThings_summary.pdf

- Internet of Things in 2020

  http://www.smart-systems-integration.org/public/internet-of-things/the-internet-of-things/?searchterm=internet%20of%20things

[6] What is a Smarter Planet: The Internet of Things: http://www.ibm.com/smarterplanet/us/en/overview/article/iot_video.html

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