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The Internet of Things (IoT): Applications, investments, and challenges for enterprises

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Abstract The Internet of Things (IoT), also called the Internet of Everything or the Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other. The IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. This article presents five IoT technologies that are essential in the deployment of successful IoT-based products and services and discusses three IoT categories for enterprise applications used to enhance customer value. In addition, it examines the net present value method and the real option approach widely used in the justification of technology projects and illustrates how the real option approach can be applied for IoT investment. Finally, this article discusses five technical and managerial challenges.

1. The Internet of Things (IoT)

The Internet of Things (IoT), also called the Internet of Everything or the Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other. The IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. The true value of the IoT for enterprises can be fully realized when connected devices are able to communicate with each other and integrate with vendor-managed inventory systems, customer support systems, business intelligence applications, and business analytics.

Gartner (2014) forecasts that the IoT will reach 26 billion units by 2020, up from 0.9 billion in 2009, and will impact the information available to supply chain partners and how the supply chain operates. From production line and warehousing to retail delivery and store shelving, the IoT is transforming business processes by providing more accurate and real-time visibility into the flow of materials and products. Firms will invest in the IoT to redesign factory workflows, improve tracking of materials, and optimize distribution costs. For example, both John Deere and UPS are already using IoT-enabled fleet tracking technologies to cut costs and improve supply efficiency.

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In addition to manufacturers' adoption of the IoT, various service industries are in the process of adopting the IoT to increase revenue through enhanced services and become leaders in their markets. Disney's MagicBand is a new wristband with RFID chips that serves as a ticket and connects to Disney's data repository regarding park visitors. Kroger's new IoT-based system, Retail Site Intelligence, is one complete retail platform of video analytics, wireless devices, POS devices, handheld sensors, IP cameras, and video management software that was designed to help customers have a better shopping experience by more easily finding the products they want and saving time at checkout.

The adoption of this technology is rapidly gaining momentum as technological, societal, and competitive pressures push firms to innovate and transform themselves. As IoT technology advances and increasing numbers of firms adopt the technology, IoT cost-benefit analysis will become a subject of great interest. Because of the potential but uncertain benefits and high investment costs of the IoT, firms need to carefully assess every IoT-induced opportunity and challenge to ensure that their resources are spent judiciously.

This article begins with a discussion of the five essential IoT technologies used for the deployment of successful IoT-based products and services and identifies three IoT categories for enterprise applications. Then, it examines a net present value approach and a real option approach widely used in the justification of technology projects and discusses how real option valuation can be applied to IoT investment. Finally, this article discusses five technical and managerial challenges: data management, data mining, privacy, security, and chaos.

2. Essential IoT technologies

Five IoT technologies are widely used for the deployment of successful IoT-based products and services:

1. radio frequency identification (RFID);
2. wireless sensor networks (WSN);
3. middleware;
4. cloud computing; and
5. IoT application software.

2.1. Radio frequency identification (RFID)

Radio frequency identification (RFID) allows automatic identification and data capture using radio waves, a tag, and a reader. The tag can store more data than traditional barcodes. The tag contains data in the form of the Electronic Product Code (EPC), a global RFID-based item identification system developed by the Auto-ID Center. Three types of tags are used. *Passive* RFID tags rely on radio frequency energy transferred from the reader to the tag to power the tag; they are not battery-powered. Applications of these can be found in supply chains, passports, electronic tolls, and item-level tracking. *Active* RFID tags have their own battery supply and can instigate communication with a reader. Active tags can contain external sensors to monitor temperature, pressure, chemicals, and other conditions. Active RFID tags are used in manufacturing, hospital laboratories, and remote-sensing IT asset management. *Semi-passive* RFID tags use batteries to power the microchip while communicating by drawing power from the reader. Active and semi-passive RFID tags cost more than passive tags.

2.2. Wireless sensor networks (WSN)

Wireless sensor networks (WSN) consist of spatially distributed autonomous sensor-equipped devices to monitor physical or environmental conditions and can cooperate with RFID systems to better track the status of things such as their location, temperature, and movements (Atzori, Iera, & Morabito, 2010). WSN allow different network topologies and multihop communication. Recent technological advances in low-power integrated circuits and wireless communications have made available efficient, low-cost, low-power miniature devices for use in WSN applications (Gubbi, Buyya, Marusic, & Palaniswami, 2013).

WSN have primarily been used in cold chain logistics that employ thermal and refrigerated packaging methods to transport temperature-sensitive products (Hsueh & Chang, 2010; White & Cheong, 2012). WSN are also used for maintenance and tracking systems. For example, General Electric deploys sensors in its jet engines, turbines, and wind farms. By analyzing data in real time, GE saves time and money associated with preventive maintenance. Likewise, American Airlines uses sensors capable of capturing 30 terabytes of data per flight for services such as preventive maintenance.

2.3. Middleware

Middleware is a software layer interposed between software applications to make it easier for software developers to perform communication and input/output. Its feature of hiding the details of different technologies is fundamental to free IoT developers from software services that are not directly relevant