White Paper
Internet of Things
February 2015

IT@Intel
Exploring the Internet of Things in the Enterprise

We envision the IoT fundamentally changing how we use information technology to run Intel's business.

Executive Overview

Intel IT is conducting two proofs of concept, using the Intel® IoT Platform, to evaluate the business value of the Internet of Things (IoT) in the enterprise setting. One proof of concept focuses on asset utilization and energy efficiency in Intel's office buildings. The other explores how IoT solutions can improve data center operations. In both proofs of concept, we are evaluating the reusability, interoperability, and scalability of the solution.

We envision the IoT fundamentally changing how we use information technology to run Intel's business. The IoT is enabling us to take new approaches to old problems by integrating the four major IoT components: sensors, the Intel® IoT Gateway, wireless networks, and data and storage. Integrating the IoT into our IT environment has the potential to provide value in the following areas:

- Flexibility, agility, and scalability
- Operational and capital expenditures
- Efficiency and productivity

Although IoT technology is still maturing and technology gaps exist, the Intel IoT Platform is a major advance in quickly deploying edge-to-cloud IoT solutions. The platform goes beyond simply connecting sensors to the cloud through a gateway. It provides manageability, security, API extensibility, and analytic capabilities—all the building blocks needed for a scalable, interoperable, manageable, and secure edge-to-cloud solution—thereby accelerating time to market and reducing the cost of deploying and maintaining IoT solutions.

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Acronyms

BMS	building management system
CRAC	computer room air conditioning
IoT	Internet of Things
PoC	proof of concept

Background

In 1991, Mark Weiser, a computer scientist at Xerox PARC, wrote, "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."[1] Weiser could not have envisioned what has come to be called the Internet of Things (IoT), but his insight from over two decades ago still holds true.

The IoT features billions of devices, all connected to the Internet (see Figure 1). Many of these devices are so much a part of everyday living that they are hardly noticed. As edge devices gain more compute capabilities and more devices become connected to one another, there is great potential to integrate the IoT with traditional IT information systems, business processes, and analytics—thus expanding the information technology spectrum.

However, all these connected devices are of little value without data, and therein lies the real power of the IoT: acquiring data, analyzing data, and acting on that data. Devices connect to the Internet, integrate greater compute capabilities, and use data analytics and decision engines to extract meaningful information. The result is added value for individuals, businesses, and society.

An IoT solution must include the ability to sense and expose data, manage and organize the data, and perform analysis or prediction for the purpose of evaluation or action. These functions can exist throughout the data pipeline—on sensors at the edge or deep in the cloud, where more rigorous analytics can be performed.

[1] Mark Weiser, "The Computer for the 21st Century," Scientific American: Special Issue on Communications (1991). http://web.stanford.edu/class/cs240e/papers/weiser.pdf (reprinted from the 1991 issue)

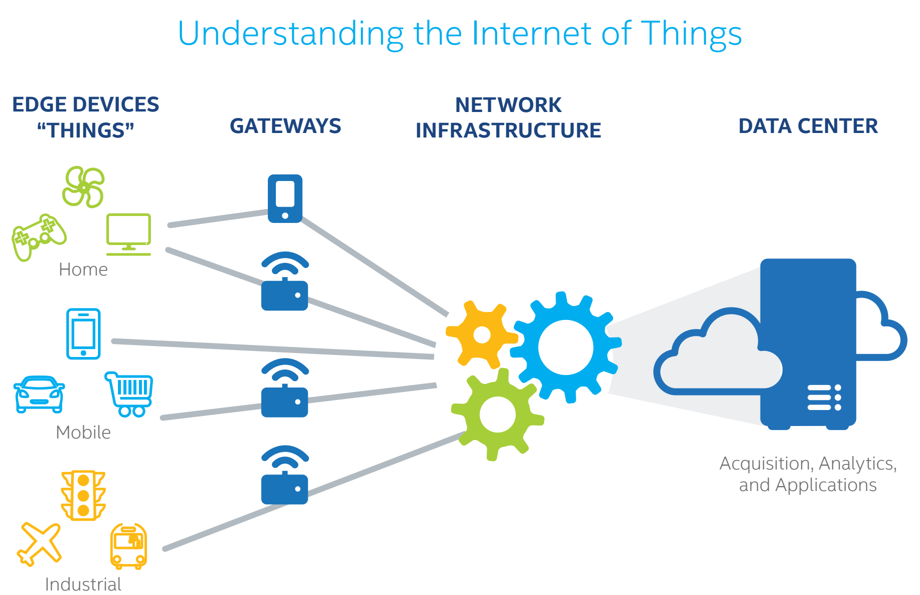


Figure 1. Through data acquisition, data analysis, and informed action, the Internet of Things expands the information technology spectrum.

Because the Intel IoT Platform focuses on horizontal value—reusability, scalability, and interoperability—it enables a broad ecosystem of third-parties to focus on more vertical solutions in specific industries or applications.

The IoT is already prevalent in the consumer marketplace. For example, it is possible to use a smartphone to control home heating and cooling systems, irrigation systems, security, lighting, and pool equipment, or to text-message a command to a smart appliance. While effective, these predominantly proprietary systems lack the maturity or operational properties that have evolved in traditional IT systems. Also, similar to the broader IoT industry, current smart home systems lack the fundamental benefits of reusability, scalability, and interoperability that modern enterprises require.

Intel is enabling an end-to-end IoT platform that provides a common hardware, software, tools, systems integration, and network and cloud infrastructure. This infrastructure is necessary to accelerate development and deployment of solutions that deliver secure intelligence end-to-end across a broad ecosystem of solutions over multiple vertical markets. Intel IT is exploring the value proposition of the Intel® IoT Platform, based on its reusability, scalability, and interoperability. We are also exploring solutions to traditional IT usages or problems through the use of IoT technology and are testing smart usages through which the IoT can unlock productivity or increase environmental intelligence to complement traditional IT systems and business processes.

The Internet of Things: Usages and Benefits

We are currently exploring new ways to harness the power of IoT technologies to transform Intel's business environment. Integrating the IoT into our IT environment has the potential to provide value in the following areas: flexibility, agility, and scalability; operational expenditures and capital expenditures; and efficiency and productivity.

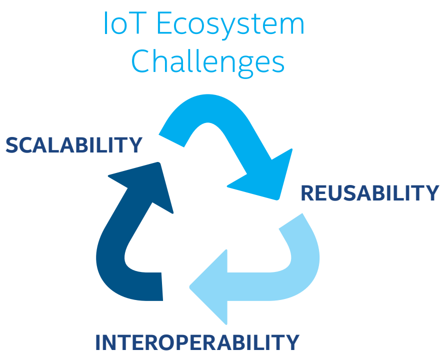
We envision the IoT fundamentally changing how we use information technology to run Intel's business, enabling us to take new approaches to old problems by integrating IoT components with traditional IT systems and business processes. We see transformational possibilities for IoT in the evolution of enterprise information technology systems and are pursuing IoT-based innovations in the following areas:

- **Smart buildings.** Applications include energy and environmental management; corporate asset tracking; asset efficiency related to use, cost, and energy consumption; and room or facilities occupancy management.
- **Data center usages.** Applications include energy and environmental management, physical equipment and IT asset management, and utilization.
- **Factory usages.** Applications include predictive maintenance, intra-factory data transport, remote monitoring, and maintenance.
- **Supply chain optimization.** Applications include inbound tracking, warehousing, supplier security management, and capacity utilization.
- **Mobile worker productivity.** Applications include information assistance, mobile productivity, and group collaboration.

The Internet of Things: Challenges and Technology Gaps

To fully realize the transformational power of the IoT, we must first address several challenges associated with integrating the IoT with our enterprise systems and components. The technology also needs to mature to eliminate existing technology gaps.

Three main challenges exist across the IoT ecosystem:



- **Reusability.** Early IoT efforts were usually optimized for a specific purpose; the sensor and supporting software had limited versatility. Optimization can provide high performance but can be costly and inflexible. As the IoT has expanded and evolved, the focus has shifted to platforms that can serve multiple applications. However, general-purpose systems can be difficult to design for maximum flexibility and can have steeper learning curves.
- **Interoperability.** Ultimately, IoT technologies must operate seamlessly with IT systems, operations, business processes, and end-user experiences. To provide business value across the enterprise, IoT solutions should integrate with network, provisioning, security, and management systems.
- **Scalability.** The number and type of connected devices changes constantly, especially in an enterprise setting. IoT solutions should be able to easily and affordably scale—both up and down—in relation to operations (alerts and events, setup and deployment, and sustaining activities), scalable data management, and resources (network, compute, and storage).

We are continually exploring solutions to these challenges and are beginning to implement the solutions that show business value.

We have identified the following technology gaps, which we intend to address in our IoT solutions at Intel:

- **Enterprise security and privacy.** We have identified issues relating to device trust, integrity, and verification; data protection; device and network access models; and data policy models that address data governance and protection of privacy. Because IoT devices may be either personally owned or corporate owned, we will need to develop user agreements and policies for data governance, data minimization, and reasonable personal use.
- **Secure wireless enterprise connectivity.** The connectivity issues that face creators of IoT solutions include wireless LAN integration and node scaling, sensor-based wireless infrastructure, and gateways that are easy to set up and integrate with access points. In addition, sensors need batteries that can last up to several years; otherwise, the overhead associated with replacing them in a large deployment is cost-prohibitive.
- **Enterprise management and operations integration.** To offer optimal business value, IoT solutions must integrate with operations and services management as well as device provisioning and management.
- **Enterprise data management and APIs.** In the area of data management, IoT solutions must support data management for enterprise consumption, data services for administration, and developer services.

Intel® IoT Platform

The opportunities for enterprises—including Intel—to benefit from the IoT are significant. We are addressing the challenges associated with IoT and beginning to integrate it into our own IT environment. The Intel® IoT Platform includes the building blocks needed for a scalable, interoperable, manageable, and secure edge-to-cloud solution—thereby accelerating time to market and reducing the cost of deploying and maintaining IoT solutions.

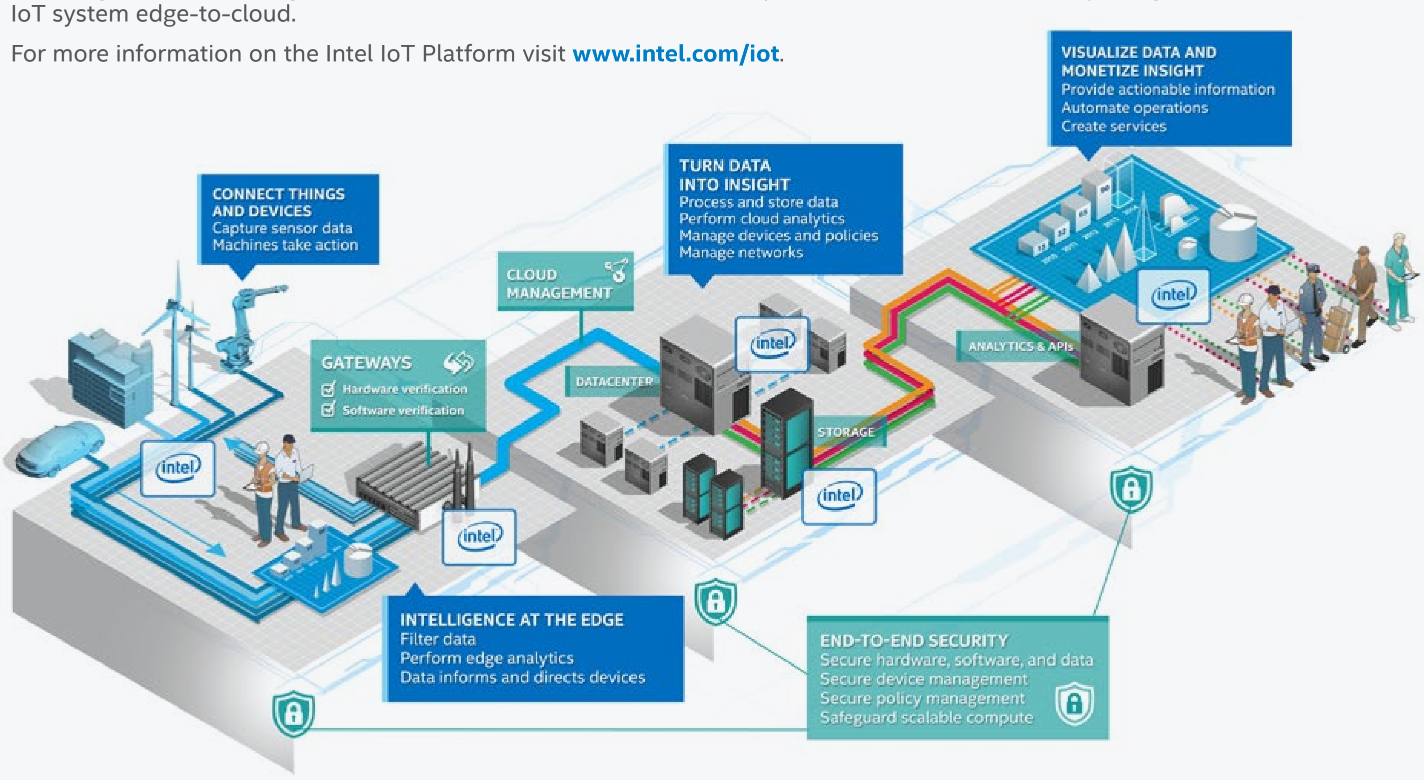
We are currently testing the Intel IoT Platform (see Proofs of Concept). We expect the Intel IoT Platform to help us reduce solution complexity and deliver actionable intelligence and innovations to market faster by offering a defined, repeatable foundation for how devices will connect and deliver trusted data to the cloud.

The following modular, standardized, and scalable Intel® technologies seamlessly combine to create the Intel IoT Platform:

- **Devices and gateways.** At the edge, devices and sensors generate data. Gateways, which are physically placed between the edge device and the cloud, aggregate data, compute data, and control data at the edge. More than just a filter, the gateway can use edge computing to turn information into actions. For example, the gateway can send instructions back to an actuator for real-time closed-loop control.
- **Edge and cloud management.** Device, security, and advanced data management provide end users with the capabilities to manage and deploy large-scale IoT systems. The Wind River Edge Management System* provides cloud connectivity to facilitate device configuration, file transfers, data capture, and rules-based data analysis and response.
- **Service creation and APIs.** Users of the Intel IoT Platform have access to the Intel® Mashery™ API Management tools. These APIs can be shared internally and with third-party developers, who can then build value on top of the deployed IoT solution.
- **Analytics and databases.** Intel is expanding its cloud analytics support for IoT developer kits to include the Intel® IoT Gateway development kit series, in addition to Intel® Galileo boards and Intel® Edison modules. Compute at the edge combined with cloud analytics enables IoT application developers to detect trends and anomalies, achieve real-time insights, and streamline operations.
- **End-to-end security.** The Intel IoT Platform features tightly integrated hardware and software security from the edge to the cloud, along with immutable hardware identification, secure boot, white lists for connected device agents, monitoring software, data protection, and policy management.

IoT solutions based on the Intel IoT Platform make existing devices more intelligent, because data can begin to be computed and managed locally at the edge where the data is first collected and ingested into the system. As the data moves through an IoT solution, it can seamlessly integrate with other data, systems, and infrastructure. Significant benefits result when compute begins at the edge and only the desired data is moved for additional processing in the cloud or shared real time with an end user. Edge processing has multiple benefits that include lower cost to move and store data and faster compute velocity during post-edge data processing. Compute location and data movement rely on the foundation of security designed to support the IoT system edge-to-cloud.

For more information on the Intel IoT Platform visit **www.intel.com/iot**.



Proofs of Concept

We are conducting two proofs of concept (PoCs), using the Intel IoT Platform, that show the business value of the IoT in the enterprise setting. These PoCs are helping us further understand what is needed to build enterprise-ready IoT solutions. One of the PoCs focuses on asset utilization and energy efficiency in Intel's office buildings, and the other one explores how IoT solutions can improve data center operations. In both PoCs, we are evaluating the reusability, interoperability, and scalability of the solutions using the Intel IoT Platform, while demonstrating the IoT's potential to solve new or traditional IT usages.

Smart Buildings: Room Availability

Occupancy detection and prediction is an essential component of a smart building solution, because it enables energy efficiency while supporting user comfort and needs.

As a starting point for exploring how we can put the IoT to work in Intel's buildings, our current PoC (see Figure 2) focuses on conference room availability. Conference rooms are in high demand at Intel. While we have an online system for booking conference rooms, we were unable to tell from looking at the schedule whether a room was actually being used. The result was inefficient use of corporate assets, and energy or resources, and loss of employee time. The room availability PoC uses multiple sensors—motion, temperature, light, and audio—to detect if a conference room is in use or not (without invading employee privacy).

We are using the results of the room availability PoC to demonstrate that the Intel IoT platform can enable a common reference design that is reusable, scalable, and interoperable across multiple smart building usages—thereby demonstrating IT flexibility, agility, scalability, and efficiencies in operational and capital expenditures. We anticipate an increase in employee productivity resulting from the ability to use their smart devices to interact in real time with IoT-enabled smart building services.

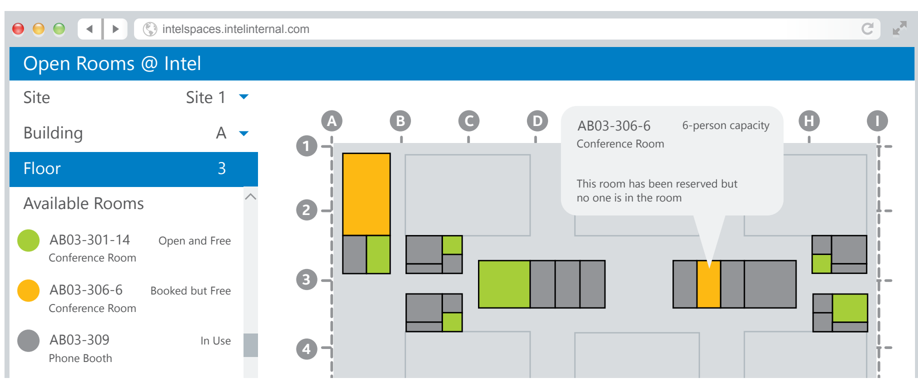


Figure 2. Multiple sensors located in conference rooms can provide real-time confirmation that a room is in use.

Applying IoT Applications in Buildings – Advantages

- **Energy efficiency.** Adjusting lighting luminosity, HVAC systems, irrigation, and water use are just a few of the ways in which the use of intelligent sensors can help improve a building's energy efficiency.
- **Employee productivity.** Delivery of location-based information can help employees find needed resources and connect to the data they need.
- **Integrated building operations.** Buildings can operate efficiently by integrating real-time information into building systems. For example, elevator operation could be optimized to minimize transit time, kiosks in lobbies could present a variety of information, and parking garages could provide space availability and directions.
- **Occupant satisfaction.** Employees could find out—in real time—whether machines are available in the fitness center, how busy the cafeteria is, or where the shuttle is. Another IoT application could adjust the light and heat in an employee's work space.

Smart Data Centers: Operational Efficiency

Data centers provide excellent opportunities to collect granular data that can be aggregated into a usable picture of the physical environment with regard to temperature airflow, pressure differential, relative humidity, power demand, air quality, and the number of people accessing the room or a specific space. This data is often available locally through readouts on the cooling and power equipment itself or through a Building Management System (BMS). However, these systems are often made by different manufacturers or represent different generations of equipment that do not have backward compatibility. In addition, many BMSs are proprietary, requiring expensive licensing or fees to collect the data from existing sensors. If the data is not available through a BMS, it must be manually collected and reported, while system efficiency adjustments are ad hoc and manual, requiring local support. These limitations make data center monitoring a deployment scenario where IoT technology can improve the operational efficiency of the data center and help reduce operational costs.

We are conducting a PoC to demonstrate how wireless sensors can be placed throughout a data center to gather information (see Figure 3 and Table 1). We are using this information to manage the room's mechanical infrastructure by either manual adjustments to cooling devices or automatic changes made through the BMS to fan speeds and chilled water valves. We plan to integrate the collected data with Intel® Datacenter Manager utilities, which will provide expanded visibility and business intelligence. Similar to our work on the room availability PoC, we are laying the foundation for a reusable, scalable, and interoperable data center reference design for IoT technology.

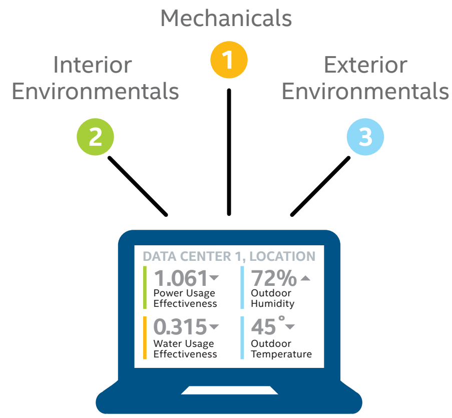


Figure 3. Wireless sensors located throughout the data center can improve operational efficiency.

Table 1. Wireless Sensors Can Be Used in the Data Center to Gather Information

	Sensor	Usage
Mechanicals	**CRAC**	Identifies unit efficiency, demand, and actual output capacity.
	Chilled Water Valve Position	Identifies the approximate flow and demand on the unit.
	Power (distribution level)	Identifies total room demand compared to individual device readings and provides a reference to determine whether proper electrical phase balancing is being maintained.
Interior Environmentals	**Air Volume**	When compared to power demand and other references, determines whether the room is in equilibrium with the power demand.
	Air Quality	Used with air-side economizer solutions to identify specific airborne chemicals or particulates that may exist at different times of the day or seasons and cause long-term degradation of compute equipment.
	Occupancy	Helps determine building asset or space utilization based on cause and effect. For example, motion sensors in rooms or workstations sensors that determine occupancy by recognizing persistent movement.
	Static Air Pressure	Enables the most efficient supply air solution for a specific server workload.
	Temperature (front and top of the rack)	Serves as a quick reference for device supply air temperature and identifies air moving across from the hot aisle to the cold aisle; could possibly be used for thermal mapping to help determine the overall cooling efficiency and find trouble spots within the room.
Exterior Environmentals	**Relative Humidity**	Serves as a reference to meet compute manufacturers' environmental requirements.
	Weather Station	Provides input to chiller plant efficiency and the ability to use wet-side or air-side economizers.
	Cooling Tower Fan and Pump Speeds	Provides input about data center cooling demand and weather conditions.

Next Steps

We are beginning to implement IoT solutions throughout Intel, and we are excited about the opportunities they present to increase employee productivity, increase environmental awareness, address traditional operational and capital expenditure opportunities, and develop new applications of an IoT-enabled modern IT system. Over the next year we plan to expand our IoT efforts to include the following:

- Integration with our platform-as-a-service provider of IT services
- Deployment of an edge management system
- Integration of IoT data into our internal data center management tools for automatic decision support
- Enhanced security and privacy
- Implementation of public, private, and hybrid cloud hosting of IoT services

Conclusion

By using the Intel IoT Platform as a foundation, we can explore new ways to harness the power of IoT technologies to help create an enterprise environment that is more efficient and productive. PoCs, such as those we are conducting for conference room availability and data center operations, are helping us understand how to deploy secure IoT solutions that are reusable, interoperable, and scalable. By capturing data from devices and sensors at the edge and aggregating and analyzing that data in the cloud, we anticipate gaining insights that can provide value to Intel.

For more information on Intel IT best practices, visit **www.intel.com/IT**.

IT@Intel

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Our goal is simple: improve efficiency throughout the organization and enhance the business value of IT investments.

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