Watson Internet of Things

The impact of the Internet of Things on product development

Discover how to transform your engineering processes and tools to gain a competitive advantage from the Internet of Things

Watson IoT™

IBM

Introduction

Every day, around the world, engineering organizations are exploring the new technological possibilities of the Internet of Things (IoT). Today's products have moved beyond mechanical and electrical components to now include complex combinations of hardware, sensors, data storage, microprocessors, software and ubiquitous connectivity. Companies that can adapt to the fast pace of change in this IoT world—incorporating and analyzing data from a wide variety of sources—have an unprecedented opportunity to accelerate innovation, meet increasing consumer expectations and gain advantages in a new era of competition.

But to succeed in the IoT world, companies also have to re-examine the entire way they do business. Traditional problems can now be approached in a completely novel way, which can be hugely disruptive to incumbent players. Small startup companies with a good idea and a little crowdfunding (that is, funding raised online) are growing into global businesses within a matter of months. The ability to be first to market with innovative offerings (both products and services) is more important than ever. To do this, companies need to use the IoT innovations to revitalize their own development, manufacturing and operational processes.

Continuous engineering can help manufacturers transform their business models to take advantage of the opportunities offered by the IoT, while enabling engineers to address the challenges of developing the next generation of smart products. This white paper explores how you can use the best practices of continuous engineering to harness the power of the IoT and increase the pace of innovation to obtain a strategic advantage.

The wave of business change

Although the IoT is still in its infancy, industry analysts expect the installed base of connected "things" to be 212 billion by the end of 2020, including 30.1 billion connected autonomous things.[1] Spending on technology and services is forecasted to explode, as companies rush to invent new capabilities that span traditional product categories. In fact, the IoT market is expected to be USD8.9 trillion by 2020.[1]

Today, most connected things belong to the consumer IoT (with smartphones topping the list). But another, less visible industrial IoT (IIoT), with its heavy-duty infrastructure (such as power and transportation) and applications (such as industrial equipment, smart plants, smart vehicles and advanced medical devices) is where the most significant transformation is about to occur. By taking advantage of the IIoT, companies are finding new ways to drive efficiencies into their operations and deliver transformational value to customers.

In fact, companies across virtually every industry are exploring ways to exploit the instrumentation, interconnectedness and intelligence of IoT products. The availability of operational data combined with analytics can provide a huge competitive edge—enabling businesses to develop new capabilities and services that extend product value. Companies can analyze the data that is generated by products, corporate assets and the operating environment, and use insights from that data to accelerate innovation, increase customer satisfaction, and enable new business models (such as delivering products as a service).

The IoT expands the possibilities for new kinds of systems and applications because devices can talk not only to central computers and phones, but also to *each other*. This device-to-device communication provides the starting point for entirely new categories of applications and products—both for the consumer and different industries (such as manufacturing, healthcare and energy). But there is also an inherent complexity in these IoT environments, and companies need the right solutions to help manage the complexity.

In addition, companies need to be able to apply IoT insights to transform their business processes to meet changing consumer demands. Heterogeneous products and systems can now be integrated to deliver new services. By using sensors with granular data analysis, production

The Internet of Things is driving changes across industries

- A nuclear energy company is using analytics for predictive maintenance, centralized control systems, remote asset monitoring and real-time safety inspections.
- An automotive manufacturer is exploring new technologies for connected vehicles, assisted driving (such as lane-change alerts and emergency braking) and driverless vehicles.
- A rail transport company is improving operations with remote asset monitoring, rail repair sensing, driver assistance and engine performance optimization.
- An aerospace firm is using analytics for predictive maintenance, real-time in-flight control, unmanned or remotely piloted aircraft, and asset monitoring.
- A medical device manufacturer is using new technologies for disease outbreak monitoring, remote testing with wireless transmission and robotic surgeries.

processes can be changed automatically—such as by modifying ingredient mixtures, temperatures or pressures—to help improve quality *without* human intervention. While this use of sensors and industrial automation is not new, the technology is now practical from both an economic and a logistical standpoint. Companies can leverage more sensors and build more intelligence into almost every device.

As devices and systems talk more to each other, and not just to a central controller (whether it's a PC, smartphone or cloud), the opportunities for performance tuning and improved efficiency grow increasingly higher. More commonality and standardization between devices can support economies of scale and strategic reuse. What's more, the products themselves can create insights to drive real-time innovation—for example, enabling companies to quickly respond to changes in market dynamics or world events (such as changing commodity or energy prices, new regulations, social media feedback, or geo-mapping data).

The changing nature of products

To take advantage of the IoT, today's products are designed with interconnection and interoperation in mind. These products combine real-time analyses with machine-to-machine, machine-to-infrastructure, and user-to-machine communication, so that they can adapt continually to changing circumstances. This complicated interconnection with back-end systems and other intelligent products effectively transforms today's products into systems of systems, dramatically increasing overall complexity.

The complexity of smart products is compounded by the fact that many new features are driven by the interaction of software running both on the device and in the cloud, making it unclear where the product actually begins and ends. Today's consumers can access functionality through a wide range of devices—for example, controlling the temperature in their home through a smartphone, a computer and a physical thermostat. Meanwhile, the IoT devices can also talk to each other. The result is that the de facto product experience may revolve around multi-device access. In addition, many products

With an intelligent, proactive, closed-loop development process, product engineers and developers can:

- Integrate and analyze data that crosses the boundaries of traditional engineering domains, including mechanical, electrical and software engineering
- Verify that the system is working appropriately before expensive physical products are built for testing
- Run different types of analysis when traditional testing is not enough for certification or complexity
- Handle multiple and different requirements, along with tens to hundreds of product variations in parallel

are now closely tied to services. In the case of a smart audio system, the product is a simple box of wireless speakers and audio components, but the accompanying streaming music services offer the unique value consumers are seeking.

The power of this software-defined functionality is that products can "learn" from their operational environment—and they can be improved through transparent software updates. Products can send early warnings about impending parts failures to the manufacturers, which enables proactive maintenance services that reduce unplanned downtime. Sometimes, the repairs can even be performed remotely via software. Data on product usage and performance can also feed insights back to product design, so companies can offer new services or capabilities that were completely outside the scope of the initially released product.

Tesla, for example, sends software upgrades to its cars, continually improving the customer experience with new services. In fact, the company recently announced that a software update—not a repair performed by a mechanic—would enable almost complete driverless operation of its cars.[2] Corrective software updates can also be autonomously requested by the car at any time. For this strategy to be effective, however, it's essential that the software is kept up to date as the product evolves throughout its life. For example, will a manufacturer like Tesla be able to keep track of all the options and after-market modifications—serial number by serial number—to push down the right software update? Safety, reliability and security can all be key concerns. Brake or engine failure because of a software error could be catastrophic.

Finally, products are increasingly tailored for specific markets to address slight cultural preferences or legal mandates. An obvious example is a car delivered to both North American and UK markets. Most of the design is common between the two variants of the car, except for the driver's position. But for other products, and even in automobiles, manufacturers are delivering subtle customizations to maximize appeal to a greater number of market segments.

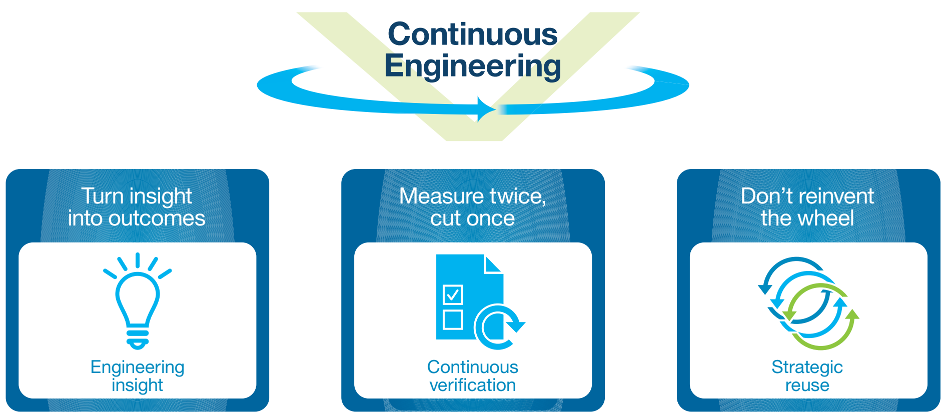
The ripple effect on product development

As companies evolve their products to take advantage of the IoT, product development processes and technologies must also evolve. Traditional "end-to-end" engineering practices were not designed to support today's systems of systems. Producing in linear phases—requirements definition, followed by design, followed by building, testing and so on—can result in bottlenecks and delays that slow down product releases. In this traditional model, the only design feedback is through sales figures and consumer complaints—after design and production are complete. Operations support is often an isolated function provided by a separate company.

Providing operational performance feedback to product development is essential in the IoT era. But rather than simply react to feedback like warranty claims or product failures, a *proactive* approach is needed—an approach that enables engineers to apply analytics to operational and performance data to derive meaningful insight. The result is that engineering teams can learn dynamically and update product performance much faster than in the past.

The increased complexity of IoT products demands greater engineering discipline, requiring engineers to understand the *business impact* of their decisions and the relationship of engineering, operation and service functions with each other. Engineers must rethink everything from how they handle regulatory compliance and predictive maintenance, to how they integrate design changes and related services, to how they deploy agile software development and other best practices.

The complexity of products, including sensors and the need to generate data, dictates that they be designed as systems. Moreover, the interaction of these complex products with their connected operating environment, which itself is unpredictable, requires that they be designed as systems within systems. With related software-based functionality and services thrown in to the mix, engineers need to be able to understand the impact of design decisions, regardless of engineering discipline. The set of capabilities that help them do this is called *continuous engineering*.



Continuous engineering can help manufacturers take advantage of new opportunities to offer IoT products, while enabling their engineers to better address the challenges of developing them.

Continuous engineering: Converting innovation challenges into opportunities

Managing the challenges of IoT product development is possible with continuous engineering. Continuous engineering is an enterprise capability designed to speed the delivery of increasingly sophisticated and connected products by helping businesses better meet the accelerated pace of change. Continuous engineering can help companies:

- **Improve the customer experience:** Adopt customer insight and build relevant products
- **Manage complexity:** Improve innovation speed and increase development efficiency
- **Embrace connectivity:** Manipulate imperfect information to create larger, interconnected systems
- **Collaborate across disciplines:** Integrate early to avoid last-minute, disruptive integration issues

Applying continuous engineering to IoT products

Continuous engineering is essential for manufacturers needing to constantly update products to address dynamic requirements—which is the "new normal" for the IoT era.

Address complexity

With IoT products essentially being systems of systems, the discipline of systems engineering is essential for their successful design. Systems engineering helps engineers collaborate across disciplines to help prevent misunderstandings that can lead to unforeseen design problems. Traditional, siloed engineering teams have almost no way to share data and learn from each other. But with systems engineering, if customers demand a new feature, integrated teams can more quickly determine how to meet the demand. If a safety standard has changed, activities can be more easily coordinated across multiple disciplines for faster compliance.

Another key capability for managing complexity is to strategically reuse design information. With strategic reuse of common design elements, engineering organizations can quickly customize IoT products for specific markets at a reasonable cost, schedule and quality. The practice gives teams the ability to use designs, components and subsystems that have already been completed—and that are known to work—to increase efficiencies and tame complexity.

Traditionally, engineers have used a "clone-and-own" approach to reuse. In this approach, design assets are simply copied and modified to meet a new product's needs. However, changes cannot be easily propagated between the two completely separate copies of engineering assets—especially when there is little tracking on where the clones are used or stored. Without effective reuse, complexity escalates exponentially with each additional product configuration. And in the IoT world, organizations may be creating hundreds or thousands of product variants, mixing and matching different components for specific needs.

Using an approach centered on the construction of product lines, organizations can more accurately track components and variants, respond to change, and optimize product designs and engineering collaboration. Called *product line engineering*, this approach provides organizations with the enormous power to diagnose and resolve issues *before* they impact the business. By comparing behavior across product variations, problems can be isolated and fixed faster. For example, if product variants A, B and C share 80 percent of the same design, their operational data can provide insights into the aspects of the design that affect performance. Likewise, by correlating data across product lines, engineers can identify why one configuration failed and not the other one—and get started correcting the design.

Product lines can help engineers locate the right design data associated with a product failure. For example, if a problem occurs only in a specific market, the cause is likely in customization for that market. If the problem occurs in multiple markets, the cause is likely in the common design. With the help of strategic reuse, engineers can fix the defect in one place, and the fix can be propagated to all markets before failure. Quality is important, since reusing a faulty component across a product line can be disastrous for business. And testing requires more upfront planning. For example, test teams can define one test plan for the common features and create unique test plans for aspects of a variant.

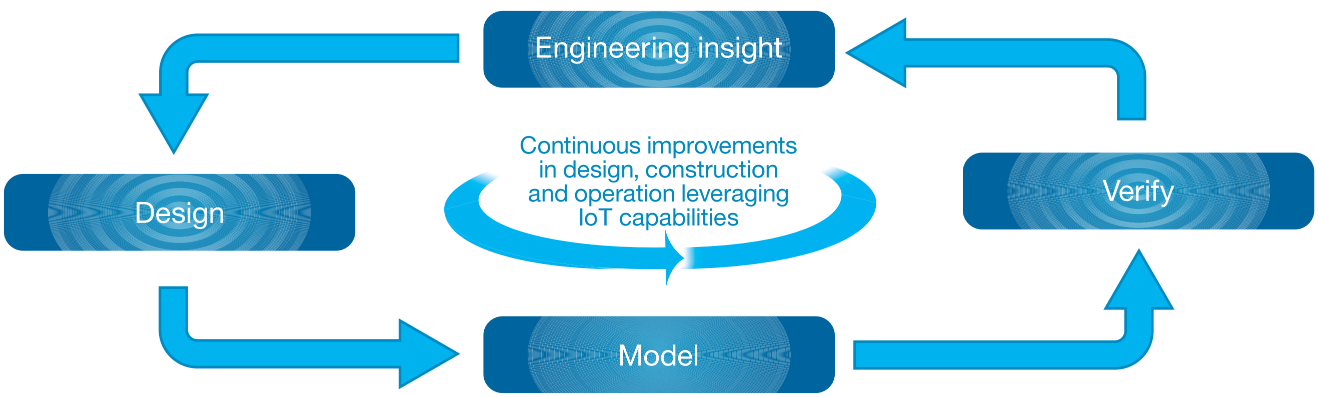
Beyond the product development phase, the ability to track specific IoT product variants once they are "in the wild" is more important than ever. For example, today's engineers need to know exactly what software is deployed on what products in the field, so they can do all the right testing of different configurations before releasing software updates. (They don't want to inadvertently break anything—especially in industrial assets that have long lifecycles.) Development teams also need to be able to understand how as-maintained bills of materials relate to as-delivered and as-designed bills of materials. This *configuration management* can help them identify commonalities that can increase efficiencies in development. For example, specific design components can be reused to help eliminate redundant processes, avoid rework and accelerate IoT solutions to market.

Comply with safety and security regulations

Today's IoT products have to accommodate elements that were typically unknown when the system was first built. They can have millions of components that are themselves complex, including components manufactured by different organizations, with different requirements and business goals. This can create an exceedingly difficult environment for demonstrating compliance with government regulations. While the failure of a smartphone application or wearable fitness device might just be annoying to consumers, the potential for damage is minor when compared to regulated safety or reliability issues in an aircraft, power plant or offshore oil rig. And what if a smartphone is connected to the aircraft, power plant or oil rig? In the IoT realm, everything can be connected, leading to new opportunities—and new vulnerabilities.

Regulatory compliance is an even more complex challenge when devices are connected in real time with multiple software-driven decision points and reliance on data analytics. New design methodologies need to be tailored to these systems of systems. It's not just the financial penalties of noncompliance that are at stake; public health and safety can also be at risk.

The proliferation of software and connectedness within IoT products has increased the number of potential entry points for security breaches, along with the potential for security flaws. Fortunately, many design standards are evolving to help engineers minimize safety and security risks. Adherence to these standards is mandatory in safety-critical applications in a number of industries such as aerospace and medical devices.



Continuous engineering enables closed-loop product development, increasing the pace of innovation through continuous iterations.

Proving compliance can be challenging, however. It requires rigor in managing changes to requirements and the ability to demonstrate that appropriate testing is applied to all requirements, at each level of design.

An integrated tool chain with *traceability* is vital here. By linking designs and requirements with data on testing and integration, engineers can *trace* the use of design elements throughout the development cycle. This way, they can quickly understand the relationships between different artifacts and predict the system-wide impact of changes—including the potential impact on related parts and software code. Open standards, such as the Open Services for Lifecycle Collaboration (OSLC) specifications, enable this cross-domain integration. Information can be linked across the product lifecycle—from the initial bill-of-materials phase through operations—helping enhance performance and responsiveness of the entire organization.

Improve quality and cycle time

To be competitive, manufacturers must strive to continuously improve the quality of their products, while getting them to market sooner. These seem like conflicting goals, but fortunately, there are some practices for achieving them, namely *continuous verification and validation*.

Continuous validation helps engineering teams make sure they have captured the correct requirements—and validated them throughout the development process—so they can *design the right product* to meet customer needs. *Continuous verification* helps teams make sure they are adhering to those requirements so they can *build the product right*. The advantage is that manufacturers can detect defects early in the development cycle, greatly reducing the cost of repairing defects that are found later. This ultimately produces a higher quality product that meets customers' deadlines and expectations.

Using continuous validation and verification, companies can analyze operational data to determine if the performance of IoT products actually meets requirements. Computer models and other virtual prototypes are essential in the early stages to validate how the product's behavior compares with the system's design. Test cases can then be run continuously as the design evolves, using both logical and physical models to abstract mechanics, electronics and software entities. Integration issues can be discovered early, using system-level use cases for analysis.

Not only does virtual prototyping and testing help engineers understand the dynamic behavior of the system as a whole (including all subsystems), it saves time because there is no longer a need to create numerous prototypes. Model-based simulations make it more convenient to capture status and can help engineers quickly pinpoint the optimal design.

Continuous verification can help engineering teams balance quality and speed, so they can deliver products faster without sacrificing features. Real-time analysis of test data means that engineers can make informed decisions and proactive changes based on quantitative information. Defect tracking and change management enable teams to rigorously address and prioritize problems and issues. Test automation also makes it more efficient to validate and verify product performance against requirements—throughout the design lifecycle—to help reduce errors and achieve faster time to quality.

Adapt to change

The leading manufacturers of IoT products will be those that can adapt to changes—changes in both consumer sentiment and in technology—that require them to continuously re-engineer their products to remain relevant in their target markets. Unlike products in the past, smart, connected IoT products can provide operational and performance information that can be a treasure trove for manufacturers if used properly. Unfortunately, 90 percent of this information is unstructured, and 60 percent is obsolete within milliseconds after it is created.[3] However, proper use of analytics can provide insight—both for engineers and for operators of the product—to improve both the design and operation of the product.

IBM estimates that 90 percent of all data generated by IoT devices such as smartphones, tablets, connected vehicles and appliances is never analyzed or acted on. As much as 60 percent of this data begins to lose value within milliseconds of being generated.[3]

Traditionally, operations were performed separately from manufacturing. But now, product performance and usage data can be used to help improve the design of the product itself. Engineering teams need to work in new ways with operations staff, field workers and service providers to define the right data to collect from products. Then, with real-time monitoring and analytics, products can identify when preventive maintenance is required before any failure occurs. In fact, IoT products can often be repaired remotely via software, reducing product downtime and the need to dispatch repair personnel.

The analytics that help predict failures can also provide insight into engineering improvements that should be made within the product. Condition-based monitoring is especially useful for maintaining industrial systems, which have a much longer lifecycle than consumer products. Predictive maintenance can help lower the cost of keeping all types of products functional longer.

In addition, by developing maintenance efficiencies, manufacturers can also transform their business model to deliver service at a lower cost. For example, aircraft engines are designed to deliver power by the hour with low, predictable costs. Airline clients don't own the engine itself, so they don't have to worry about maintenance. Meanwhile, manufacturers charge more (or profit more for an equivalent charge) for the service aspect of what they deliver.

Given that most of the functionality of IoT products is provided by software, the ability of a manufacturer to adapt a product to market changes rests largely upon that manufacturer's competency in software development. An agile approach to product design is critical for both IoT systems engineering and software development teams. Late-stage and post-purchase design changes are common in IoT development. Synchronizing the work of hardware and software development is a key challenge, since software updates can be made exponentially faster than a traditional hardware update. Leading manufacturers use DevOps systems to manage the delivery of software, enabling developers and engineers to focus on innovation.

Today's manufacturers need to make quicker decisions based on a lot more data. This means product development teams need to be much more agile in how they react to the information, organize their development processes, empower individuals and deploy tools across the development infrastructure. Islands of data cannot support this new model of product development.

Agile methodologies are designed to be responsive to change, shifting the focus of projects to better align with customer needs. Customer feedback loops help ensure a collaborative process. And now, IoT products can submit their own feedback. For example, products that receive remote software updates—based on analysis of product data from a complex IoT ecosystem—can help inform design changes for performance, reliability or new features. This means the overall development process can be much more integrated and agile than ever before. It can no longer take years to change a product; new versions need to be available in weeks or months to keep up with consumer and end-user needs.

Conclusion

The IoT is changing consumer behavior and expectations, and leading businesses are responding to its challenges and opportunities. Product development in the IoT world is increasingly consumer driven, requiring proactive development processes that include feedback loops as early and as often as possible in the design process. The capabilities of continuous engineering for helping developers to manage complexity, to comply with regulations, to improve quality and cycle time, and to adapt to change—are essential for accelerating the pace of innovation for the IoT world.

For more information

To learn how IBM can help your engineering organization harness the power of the Internet of Things, please contact your IBM representative or IBM Business Partner, or visit: **ibm.com/**internet-of-things/business-solutions/product-development

Additionally, IBM Global Financing provides numerous payment options to help you acquire the technology you need to grow your business. We provide full lifecycle management of IT products and services, from acquisition to disposition. For more information, visit: **ibm.com**/financing

Footnotes:

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