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SPOTLIGHT ON MANAGING THE INTERNET OF THINGS

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by Michael E. Porter and James E. Heppelmann

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SPOTLIGHT

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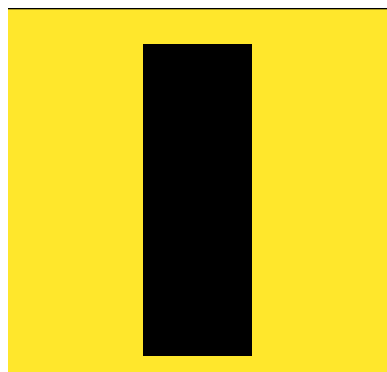
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How Smart, Connected Products Are Transforming Competition

by Michael E. Porter and James E. Heppelmann



Information technology is revolutionizing products. Once composed solely of mechanical and electrical parts, products have become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in myriad ways. These “smart, connected products”—made possible by vast improvements in processing power and device miniaturization and by the network benefits of ubiquitous wireless connectivity—have unleashed a new era of competition.

Smart, connected products offer exponentially expanding opportunities for new functionality, far greater reliability, much higher product utilization, and capabilities that cut across and transcend traditional product boundaries. The changing nature of products is also disrupting value chains, forcing companies to rethink and retool nearly everything they do internally.

These new types of products alter industry structure and the nature of competition, exposing companies to new competitive opportunities and threats. They are reshaping industry boundaries and creating entirely new industries. In many companies, smart, connected products will force the fundamental question, “What business am I in?”

Smart, connected products raise a new set of strategic choices related to how value is created and captured, how the prodigious amount of new (and sensitive) data they generate is utilized and managed, how relationships with traditional business partners such as channels are redefined, and what role companies should play as industry boundaries are expanded.

The phrase “internet of things” has arisen to reflect the growing number of smart, connected products and highlight the new opportunities they can represent. Yet this phrase is not very helpful in understanding the phenomenon or its implications. The internet, whether involving people or things, is simply a mechanism for transmitting information. What makes smart, connected products fundamentally different is not the internet, but the changing nature of the “things.” It is the expanded capabilities of smart, connected products and the data they generate that are ushering in a new era of competition.

Companies must look beyond the technologies themselves to the competitive transformation taking place. This article, and a companion piece to be published soon in HBR, will deconstruct the smart, connected products revolution and explore its strategic and operational implications.

The Third Wave of IT-Driven Competition

Twice before over the past 50 years, information technology radically reshaped competition and strategy; we now stand at the brink of a third transformation. Before the advent of modern information technology, products were mechanical and activities in the value chain were performed using manual, paper processes and verbal communication. The first wave of IT, during the 1960s and 1970s, automated individual activities in the value chain, from order processing and bill paying to computer-aided design and manufacturing resource planning. (See “How Information Gives You Competitive Advantage,” by Michael Porter and Victor Millar, HBR, July 1985.) The productivity of activities dramatically increased, in part because huge amounts of new data could be captured and analyzed in each activity. This led to the standardization of processes across companies—and raised a dilemma for companies about how to capture IT’s operational benefits while maintaining distinctive strategies.

The rise of the internet, with its inexpensive and ubiquitous connectivity, unleashed the second wave of IT-driven transformation, in the 1980s and 1990s (see Michael Porter’s “Strategy and the Internet,” HBR, March 2001). This enabled coordination and



INSIGHT CENTER Find our monthlong series of articles on the internet of things at hbr.org/insights/iot.

Idea in Brief**A CHANGING ENVIRONMENT**

Smart, connected products offer exponentially expanding opportunities for new functionality and capabilities that transcend traditional product boundaries.

The changing nature of products is disrupting value chains and forcing companies to rethink nearly everything

they do, from how they conceive, design, and source products; to how they manufacture, operate, and service them; to how they build and secure the necessary IT infrastructure.

THE NEW STRATEGIC CHOICES

Smart, connected products raise a new set of strategic choices about how value is created and captured, how companies work with traditional and new partners, and how they secure competitive advantage as the new capabilities reshape industry boundaries. For

many firms, smart, connected products will force the fundamental question, “What business am I in?”

This article provides a framework for developing strategy and achieving competitive advantage in a smart, connected world.

integration across individual activities; with outside suppliers, channels, and customers; and across geography. It allowed firms, for example, to closely integrate globally distributed supply chains.

The first two waves gave rise to huge productivity gains and growth across the economy. While the value chain was transformed, however, products themselves were largely unaffected.

Now, in the third wave, IT is becoming an integral part of the product itself. Embedded sensors, processors, software, and connectivity in products (in effect, computers are being put inside products), coupled with a product cloud in which product data is stored and analyzed and some applications are run, are driving dramatic improvements in product functionality and performance. Massive amounts of new product-usage data enable many of those improvements.

Another leap in productivity in the economy will be unleashed by these new and better products. In addition, producing them will reshape the value chain yet again, by changing product design, marketing, manufacturing, and after-sale service and by creating the need for new activities such as product data analytics and security. This will drive yet another wave of value-chain-based productivity improvement. The third wave of IT-driven transformation thus has the potential to be the biggest yet, triggering even more innovation, productivity gains, and economic growth than the previous two.

Some have suggested that the internet of things “changes everything,” but that is a dangerous oversimplification. As with the internet itself, smart, connected products reflect a whole new set of technological possibilities that have emerged. But the rules of competition and competitive advantage remain the same. Navigating the world of smart, connected products requires that companies understand these rules better than ever.

What Are Smart, Connected Products?

Smart, connected products have three core elements: physical components, “smart” components, and connectivity components. Smart components amplify the capabilities and value of the physical components, while connectivity amplifies the capabilities and value of the smart components and enables some of them to exist outside the physical product itself. The result is a virtuous cycle of value improvement.

Physical components comprise the product’s mechanical and electrical parts. In a car, for example, these include the engine block, tires, and batteries.

Smart components comprise the sensors, microprocessors, data storage, controls, software, and, typically, an embedded operating system and enhanced user interface. In a car, for example, smart components include the engine control unit, anti-lock braking system, rain-sensing windshields with automated wipers, and touch screen displays. In many products, software replaces some hardware components or enables a single physical device to perform at a variety of levels.

Connectivity components comprise the ports, antennae, and protocols enabling wired or wireless connections with the product. Connectivity takes three forms, which can be present together:

- **One-to-one:** An individual product connects to the user, the manufacturer, or another product through a port or other interface—for example, when a car is hooked up to a diagnostic machine.
- **One-to-many:** A central system is continuously or intermittently connected to many products simultaneously. For example, many Tesla automobiles are connected to a single manufacturer system that monitors performance and accomplishes remote service and upgrades.

- Many-to-many: Multiple products connect to many other types of products and often also to external data sources. An array of types of farm equipment are connected to one another, and to geolocation data, to coordinate and optimize the farm system. For example, automated tillers inject nitrogen fertilizer at precise depths and intervals, and seeders follow, placing corn seeds directly in the fertilized soil.

Some have suggested that the internet of things “changes everything,” but that is a dangerous oversimplification. The rules of competition and competitive advantage still apply.

Connectivity serves a dual purpose. First, it allows information to be exchanged between the product and its operating environment, its maker, its users, and other products and systems. Second, connectivity enables some functions of the product to exist outside the physical device, in what is known as the product cloud. For example, in Bose’s new Wi-Fi system, a smartphone application running in the product cloud streams music to the system from the internet. To achieve high levels of functionality, all three types of connectivity are necessary.

Smart, connected products are emerging across all manufacturing sectors. In heavy machinery, Schindler’s PORT Technology reduces elevator wait times by as much as 50% by predicting elevator demand patterns, calculating the fastest time to destination, and assigning the appropriate elevator to move passengers quickly. In the energy sector, ABB’s smart grid technology enables utilities to analyze huge amounts of real-time data across a wide range of generating, transforming, and distribution equipment (manufactured by ABB as well as others), such as changes in the temperature of transformers and secondary substations. This alerts utility control centers to possible overload conditions, allowing

adjustments that can prevent blackouts before they occur. In consumer goods, Big Ass ceiling fans sense and engage automatically when a person enters a room, regulate speed on the basis of temperature and humidity, and recognize individual user preferences and adjust accordingly.

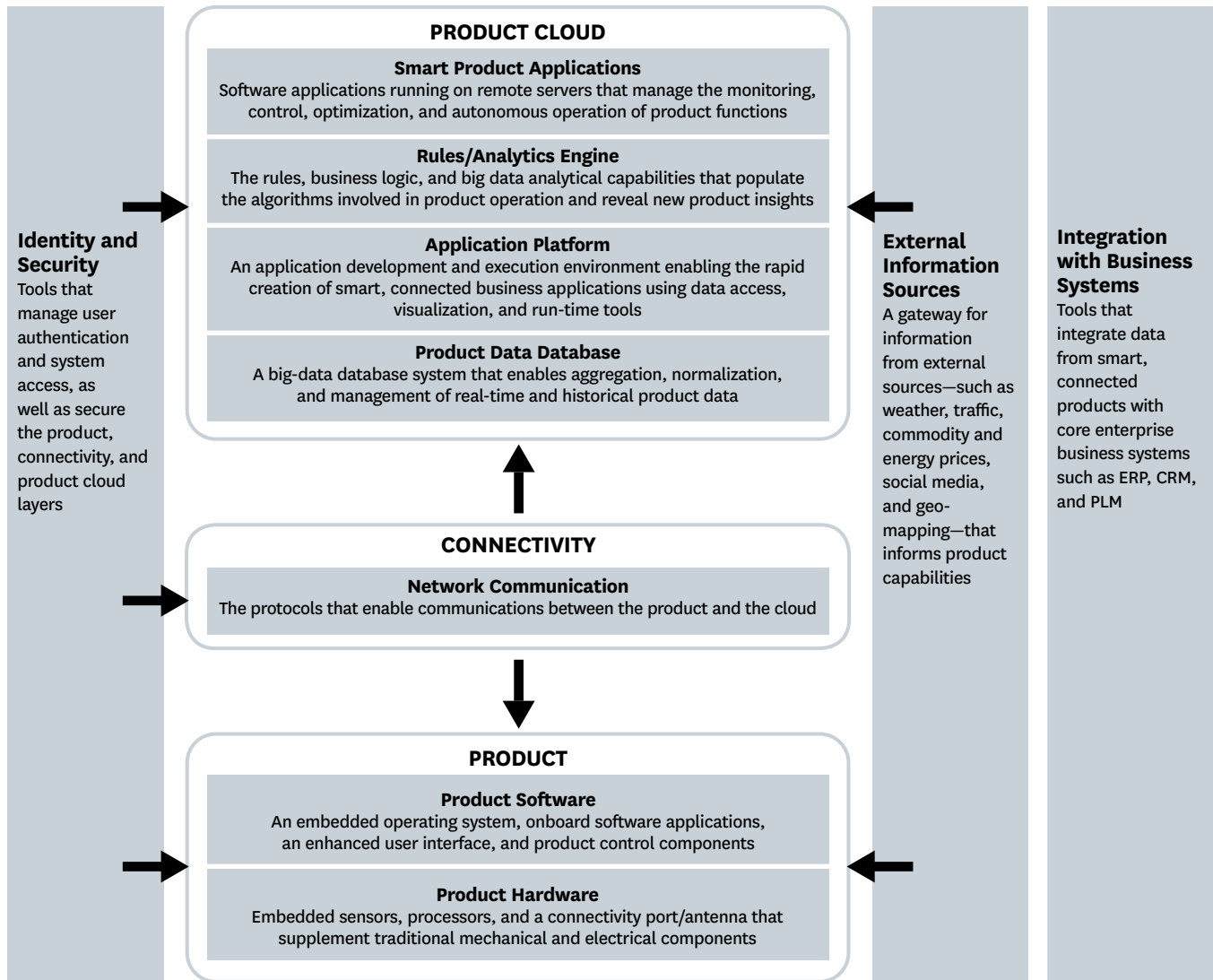
Why now? An array of innovations across the technology landscape have converged to make smart, connected products technically and economically feasible. These include breakthroughs in the performance, miniaturization, and energy efficiency of sensors and batteries; highly compact, low-cost computer processing power and data storage, which make it feasible to put computers inside products; cheap connectivity ports and ubiquitous, low-cost wireless connectivity; tools that enable rapid software development; big data analytics; and a new IPv6 internet registration system opening up 340 trillion trillion trillion potential new internet addresses for individual devices, with protocols that support greater security, simplify handoffs as devices move across networks, and allow devices to request addresses autonomously without the need for IT support.

Smart, connected products require that companies build an entirely new technology infrastructure, consisting of a series of layers known as a “technology stack” (see the exhibit “The New Technology Stack”). This includes modified hardware, software applications, and an operating system embedded in the product itself; network communications to support connectivity; and a product cloud (software running on the manufacturer’s or a third-party server) containing the product-data database, a platform for building software applications, a rules engine and analytics platform, and smart product applications that are not embedded in the product. Cutting across all the layers is an identity and security structure, a gateway for accessing external data, and tools that connect the data from smart, connected products to other business systems (for example, ERP and CRM systems).

This technology enables not only rapid product application development and operation but the collection, analysis, and sharing of the potentially huge amounts of longitudinal data generated inside and outside the products that has never been available before. Building and supporting the technology stack for smart, connected products requires substantial investment and a range of new skills—such

THE NEW TECHNOLOGY STACK

Smart, connected products require companies to build and support an entirely new technology infrastructure. This “technology stack” is made up of multiple layers, including new product hardware, embedded software, connectivity, a product cloud consisting of software running on remote servers, a suite of security tools, a gateway for external information sources, and integration with enterprise business systems.



as software development, systems engineering, data analytics, and online security expertise—that are rarely found in manufacturing companies.

What Can Smart, Connected Products Do?

Intelligence and connectivity enable an entirely new set of product functions and capabilities, which can be grouped into four areas: monitoring, control, optimization, and autonomy. A product can potentially

incorporate all four (see the exhibit “Capabilities of Smart, Connected Products”). Each capability is valuable in its own right and also sets the stage for the next level. For example, monitoring capabilities are the foundation for product control, optimization, and autonomy. A company must choose the set of capabilities that deliver its customer value and define its competitive positioning.

Monitoring. Smart, connected products enable the comprehensive monitoring of a product’s

condition, operation, and external environment through sensors and external data sources. Using data, a product can alert users or others to changes in circumstances or performance. Monitoring also allows companies and customers to track a product's operating characteristics and history and to better understand how the product is actually used. This data has important implications for design (by reducing overengineering, for example), market segmentation (through the analysis of usage patterns by customer type), and after-sale service (by allowing the dispatch of the right technician with the right part, thus improving the first-time fix rate). Monitoring data may also reveal warranty compliance issues as well as new sales opportunities, such as the need for additional product capacity because of high utilization.

In some cases, such as medical devices, monitoring is the core element of value creation. Medtronic's digital blood-glucose meter uses a sensor inserted under the patient's skin to measure glucose levels in tissue fluid and connects wirelessly to a device that alerts patients and clinicians up to 30 minutes before

a patient reaches a threshold blood-glucose level, enabling appropriate therapy adjustments.

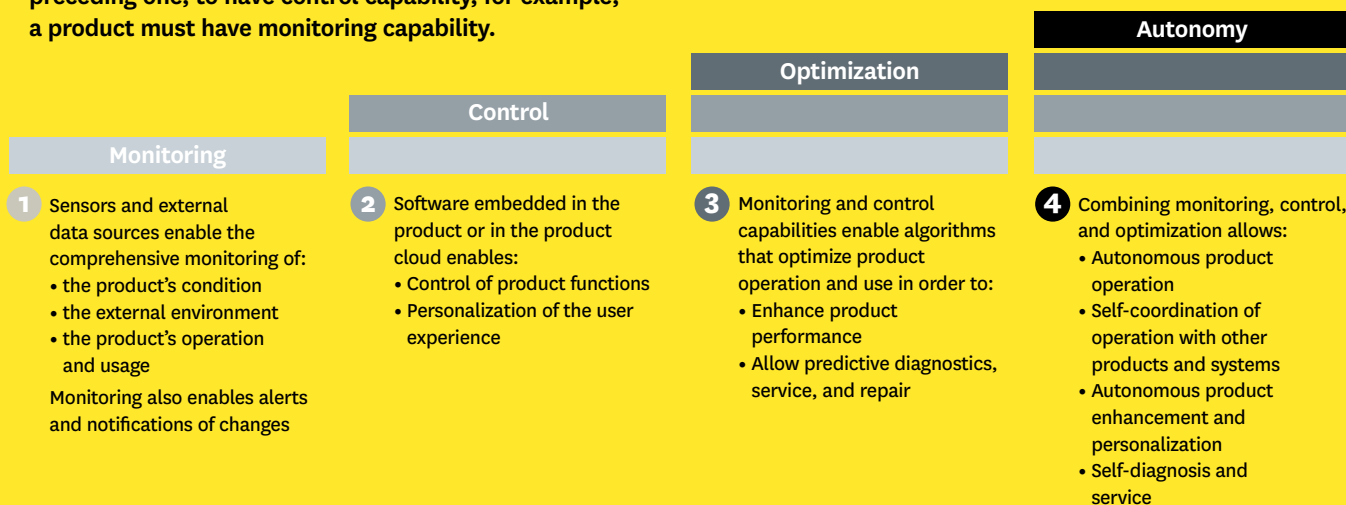
Monitoring capabilities can span multiple products across distances. Joy Global, a leading mining equipment manufacturer, monitors operating conditions, safety parameters, and predictive service indicators for entire fleets of equipment far underground. Joy also monitors operating parameters across multiple mines in different countries for benchmarking purposes.

Control. Smart, connected products can be controlled through remote commands or algorithms that are built into the device or reside in the product cloud. Algorithms are rules that direct the product to respond to specified changes in its condition or environment (for example, "if pressure gets too high, shut off the valve" or "when traffic in a parking garage reaches a certain level, turn the overhead lighting on or off").

Control through software embedded in the product or the cloud allows the customization of product performance to a degree that previously was not cost

CAPABILITIES OF SMART, CONNECTED PRODUCTS

The capabilities of smart, connected products can be grouped into four areas: monitoring, control, optimization, and autonomy. Each builds on the preceding one; to have control capability, for example, a product must have monitoring capability.



Smart, connected products ultimately can function with complete autonomy. Human operators merely monitor performance or watch over the fleet or the system, rather than over individual units.

effective or often even possible. The same technology also enables users to control and personalize their interaction with the product in many new ways. For example, users can adjust their Philips Lighting hue lightbulbs via smartphone, turning them on and off, programming them to blink red if an intruder is detected, or dimming them slowly at night. Doorbot, a smart, connected doorbell and lock, allows customers to give visitors access to the home remotely after screening them on their smartphones.

Optimization. The rich flow of monitoring data from smart, connected products, coupled with the capacity to control product operation, allows companies to optimize product performance in numerous ways, many of which have not been previously possible. Smart, connected products can apply algorithms and analytics to in-use or historical data to dramatically improve output, utilization, and efficiency. In wind turbines, for instance, a local microcontroller can adjust each blade on every revolution to capture maximum wind energy. And each turbine can be adjusted to not only improve its performance but minimize its impact on the efficiency of those nearby.

Real-time monitoring data on product condition and product control capability enables firms to optimize service by performing preventative maintenance when failure is imminent and accomplishing repairs remotely, thereby reducing product downtime and the need to dispatch repair personnel. Even when on-site repair is required, advance information about what is broken, what parts are needed, and how to accomplish the fix reduces service costs and improves first-time fix rates. Diebold, for example, monitors many of its automated teller machines for early signs of trouble. After assessing a malfunctioning ATM's status, the machine is repaired remotely if possible, or the company deploys a technician who has been given a detailed diagnosis of the problem, a recommended repair process, and, often, the needed

parts. Finally, like many smart, connected products, Diebold's ATMs can be updated when they are due for feature enhancements. Often these can occur remotely, via software.

Autonomy. Monitoring, control, and optimization capabilities combine to allow smart, connected products to achieve a previously unattainable level of autonomy. At the simplest level is autonomous product operation like that of the iRobot Roomba, a vacuum cleaner that uses sensors and software to scan and clean floors in rooms with different layouts. More-sophisticated products are able to learn about their environment, self-diagnose their own service needs, and adapt to users' preferences. Autonomy not only can reduce the need for operators but can improve safety in dangerous environments and facilitate operation in remote locations.

Autonomous products can also act in coordination with other products and systems. The value of these capabilities can grow exponentially as more and more products become connected. For example, the energy efficiency of the electric grid increases as more smart meters are connected, allowing the utility to gain insight into and respond to demand patterns over time.

Ultimately, products can function with complete autonomy, applying algorithms that utilize data about their performance and their environment—including the activity of other products in the system—and leveraging their ability to communicate with other products. Human operators merely monitor performance or watch over the fleet or the system, rather than individual units. Joy Global's Longwall Mining System, for example, is able to operate autonomously far underground, overseen by a mine control center on the surface. Equipment is monitored continuously for performance and faults, and technicians are dispatched underground to deal with issues requiring human intervention.

Reshaping Industry Structure

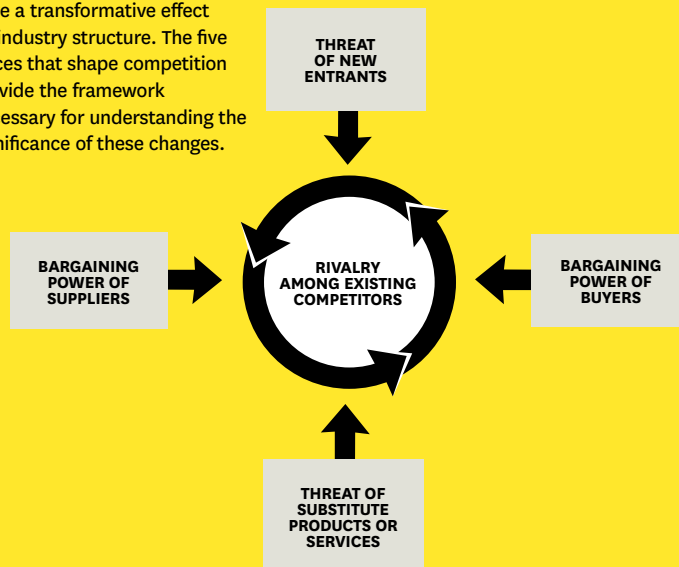
To understand the effects of smart, connected products on industry competition and profitability, we must examine their impact on industry structure. In any industry, competition is driven by five competitive forces: the bargaining power of buyers, the nature and intensity of the rivalry among existing competitors, the threat of new entrants, the threat of substitute products or services, and the bargaining power of suppliers. The composition and strength of these forces collectively determine the nature of industry competition and the average profitability for incumbent competitors. Industry structure changes when new technology, customer needs, or other factors shift these five forces. Smart, connected products will substantially affect structure in many industries, as did the previous wave of internet-enabled IT. The effects will be greatest in manufacturing industries.

Bargaining power of buyers. Smart, connected products dramatically expand opportunities for product differentiation, moving competition away from price alone. Knowing how customers actually use the products enhances a company's ability to segment customers, customize products, set prices to better capture value, and extend value-added services. Smart, connected products also allow companies to develop much closer customer relationships. Through capturing rich historical and product-usage data, buyers' costs of switching to a new supplier increase. In addition, smart, connected products allow firms to reduce their dependency on distribution or service partners, or even disintermediate them, thereby capturing more profit. All of this serves to mitigate or reduce buyers' bargaining power.

GE Aviation, for example, is now able to provide more services to end users directly—a move that improves its power relative to its immediate customers, the airframe manufacturers. Information gathered from hundreds of engine sensors, for example, allows GE and airlines to optimize engine performance by identifying discrepancies between expected and actual performance. GE's analysis of fuel-use data, for example, allowed the Italian airline Alitalia to identify changes to its flight procedures, such as the position of wing flaps during landing, that reduced fuel use. GE's deep relationship with the airlines serves to improve differentiation with them while improving its clout with airframe manufacturers.

THE FIVE FORCES THAT SHAPE INDUSTRY COMPETITION

Smart, connected products will have a transformative effect on industry structure. The five forces that shape competition provide the framework necessary for understanding the significance of these changes.



HBR.ORG For a full discussion of competitive strategy, see Michael Porter's article "The Five Competitive Forces That Shape Strategy" (HBR, January 2008).

However, smart, connected products can increase buyer power by giving buyers a better understanding of true product performance, allowing them to play one manufacturer off another. Buyers may also find that having access to product usage data can decrease their reliance on the manufacturer for advice and support. Finally, compared with ownership models, "product as a service" business models or product-sharing services (discussed below) can increase buyers' power by reducing the cost of switching to a new manufacturer.

Rivalry among competitors. Smart, connected products have the potential to shift rivalry, opening up numerous new avenues for differentiation and value-added services. These products also enable firms to tailor offerings to more-specific segments of the market, and even customize products for individual customers, further enhancing differentiation and price realization.

Smart, connected products also create opportunities to broaden the value proposition beyond products per se, to include valuable data and enhanced service offerings. Babolat, for example, has produced tennis rackets and related equipment for 140 years. With its new Babolat Play Pure Drive system, which puts sensors and connectivity in the racket handle, the company now offers a service to help players improve their game through the tracking and analysis of ball speed, spin, and impact location, delivered through a smartphone application.

Offsetting this shift in rivalry away from price is the migration of the cost structure of smart, connected products toward higher fixed costs and lower variable costs. This results from the higher upfront costs of software development, more-complex product design, and high fixed costs of developing the technology stack, including reliable connectivity, robust data storage, analytics, and security (see again the exhibit “The New Technology Stack”). Industries with high fixed cost structures are vulnerable to price pressure as firms seek to spread their fixed costs across a larger number of units sold.

The huge expansion of capabilities in smart, connected products may also tempt companies to get into a feature and function arms race with rivals and give away too much of the improved product performance, a dynamic that escalates costs and erodes industry profitability.

Finally, rivalry among competitors can also increase as smart, connected products become part of broader product systems, a trend we will discuss further. For example, manufacturers of home lighting, audiovisual entertainment equipment, and climate control systems have not historically competed with one another. Yet each is now vying for a place in the emerging “connected home” that integrates and adds intelligence to a wide array of products in the home.

Threat of new entrants. New entrants in a smart, connected world face significant new obstacles, starting with the high fixed costs of more-complex product design, embedded technology, and multiple layers of new IT infrastructure. For example, Thermo Fisher’s TruDefender FTi chemical analyzer added connectivity to a product that already had smart functionality, to enable chemical analysis from hazardous environments to be transmitted to users and mitigation to begin without having to wait for the machine and personnel to be decontaminated. Thermo Fisher needed to build a complete product cloud to securely capture, analyze, and store product data and distribute it both internally and to customers, a substantial undertaking.

Broadening product definitions can raise barriers to entrants even higher. Biotronik, a medical device company, initially manufactured stand-alone pacemakers, insulin pumps, and other devices. Now it offers smart, connected devices, such as a home health-monitoring system that includes a data processing center that allows physicians to

remotely monitor their patients’ devices and clinical status.

Barriers to entry also rise when agile incumbents capture critical first-mover advantages by collecting and accumulating product data and using it to improve products and services and to redefine after-sale service. Smart, connected products can also increase buyer loyalty and switching costs, further raising barriers to entry.

Barriers to entry go down, however, when smart, connected products leapfrog or invalidate the strengths and assets of incumbents. Moreover, incumbents may hesitate to fully embrace the capabilities of smart, connected products, preferring to protect hardware-based strengths and profitable legacy parts and service businesses. This opens the door to new competitors, such as the “productless” OnFarm, which is successfully competing with traditional agricultural equipment makers to provide services to farmers through collecting data on multiple types of farm equipment to help growers make better decisions, avoiding the need to be an equipment manufacturer at all. In home automation, Crestron, an integration solution provider, offers complex, dedicated home systems with rich user interfaces. Product companies are also facing challenges from other nontraditional competitors like Apple, which recently launched a simpler, smartphone-based approach to managing the connected home.

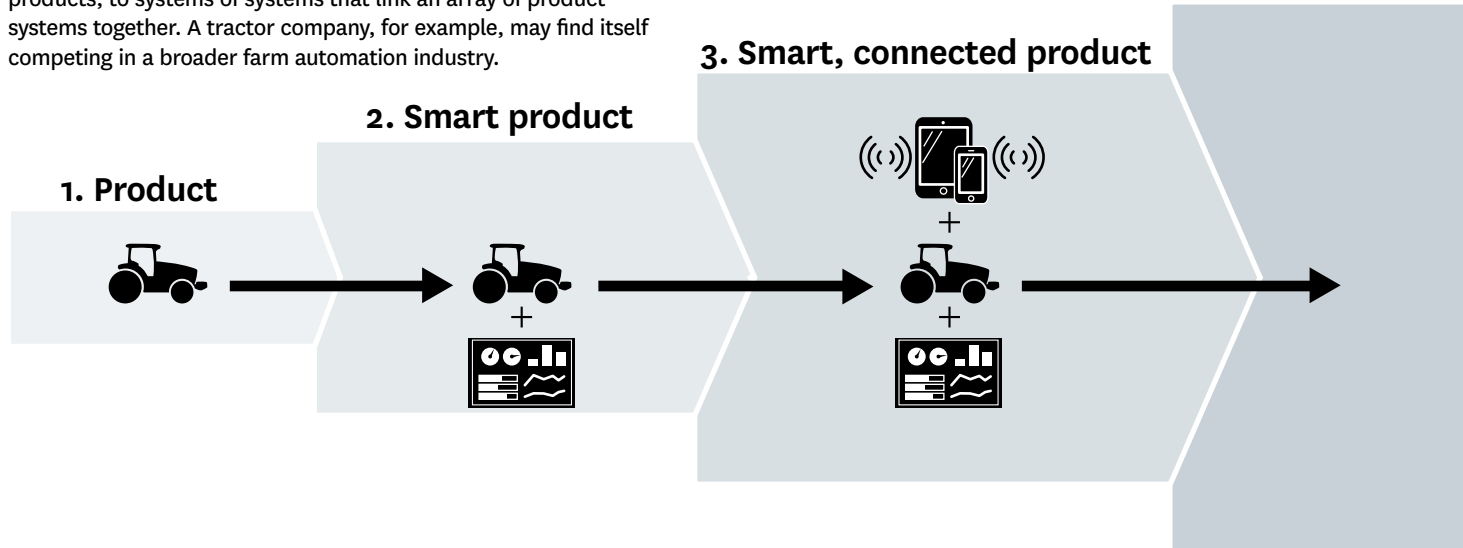
Threat of substitutes. Smart, connected products can offer superior performance, customization, and customer value relative to traditional substitute products, reducing substitution threats and improving industry growth and profitability. However, in many industries smart, connected products create new types of substitution threats, such as wider product capabilities that subsume conventional products. For example, Fitbit’s wearable fitness device, which captures multiple types of health-related data including activity levels and sleep patterns, is a substitute for conventional devices such as running watches and pedometers.

New business models enabled by smart, connected products can create a substitute for product ownership, reducing overall demand for a product. Product-as-a-service business models, for example, allow users to have full access to a product but pay only for the amount of product they use.

A variation of product-as-a-service is the shared-usage model. Zipcar, for example, provides

REDEFINING INDUSTRY BOUNDARIES

The increasing capabilities of smart, connected products not only reshape competition within industries but expand industry boundaries. This occurs as the basis of competition shifts from discrete products, to product systems consisting of closely related products, to systems of systems that link an array of product systems together. A tractor company, for example, may find itself competing in a broader farm automation industry.



customers with real-time access to vehicles when and where they need them. This substitutes for car ownership and has led traditional automakers to enter the car-sharing market with offerings such as RelayRides from GM, DriveNow from BMW, and Dash from Toyota.

Another example is shared bike systems, which are springing up in more and more cities. A smart-phone application shows the location of docking stations where bikes can be picked up and returned, and users are monitored and charged for the amount of time they use the bikes. Clearly, shared usage will reduce the need for urban residents to own bikes, but it may encourage more residents to use bikes since they do not have to buy and store them. Convenient shared bikes will be a substitute not only for purchased bikes but potentially for cars and other forms of urban transportation. Smart, connected capabilities make such substitutions for full ownership possible.

Bargaining power of suppliers. Smart, connected products are shaking up traditional supplier relationships and redistributing bargaining power. As the smart and connectivity components of products deliver more value relative to physical components, the physical components can be

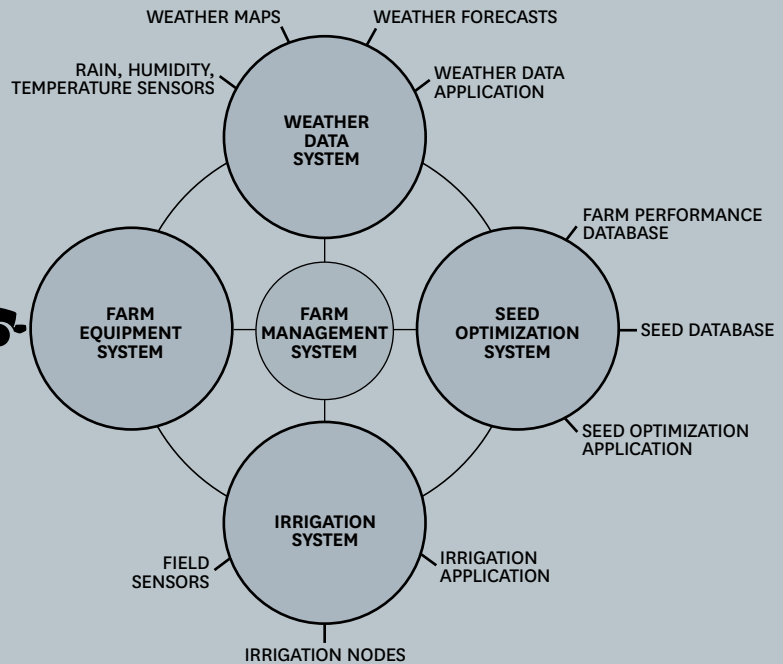
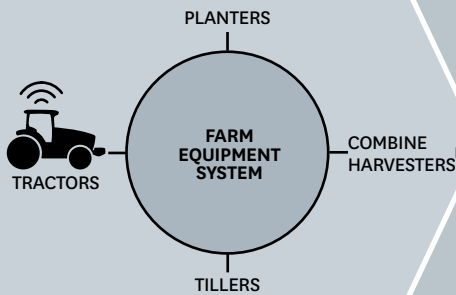
commoditized or even replaced by software over time. Software also reduces the need for physical tailoring and hence the number of physical component varieties. The importance of traditional suppliers to total product cost will often decline, and their bargaining power will fall.

However, smart, connected products often introduce powerful new suppliers that manufacturers have never needed before: providers of sensors, software, connectivity, embedded operating systems, and data storage, analytics, and other parts of the technology stack. Some of these, like Google, Apple, and AT&T, are giants in their own industries. They have talent and capabilities that most manufacturing companies have not historically needed but that are becoming essential to product differentiation and cost. The bargaining power of those new suppliers can be high, allowing them to capture a bigger share of overall product value and reduce manufacturers' profitability.

A good example of these new types of suppliers is the Open Automotive Alliance, in which General Motors, Honda, Audi, and Hyundai recently joined forces to utilize Google's Android operating system for their vehicles. The auto OEMs lacked the specialized capabilities needed to develop a robust

5. System of systems

4. Product system



embedded operating system that delivers an excellent user experience while enabling an ecosystem of developers to build applications. Auto OEMs' traditional clout relative to suppliers is greatly diminished with suppliers like Google, which have not only substantial resources and expertise but also strong consumer brands and numerous related applications (for example, consumers may prefer a car that can sync with their smartphone, music, and apps).

New suppliers of the technology stack for smart, connected products may also gain greater leverage given their relationships with end users and access to product usage data. As suppliers capture product usage data from end users, they can also provide new services to them, as GE has done with Alitalia.

New Industry Boundaries and Systems of Systems

The powerful capabilities of smart, connected products not only reshape competition within an industry, but they can expand the very definition of the industry itself. The competitive boundaries of an industry widen to encompass a set of related products that together meet a broader underlying need. The function of one product is optimized with other related products. For example, integrating smart, connected farm

equipment—such as tractors, tillers, and planters—can enable better overall equipment performance.

The basis of competition thus shifts from the functionality of a discrete product to the performance of the broader product system, in which the firm is just one actor. The manufacturer can now offer a package of connected equipment and related services that optimize overall results. Thus in the farm example, the industry expands from tractor manufacturing to farm equipment optimization. In mining, Joy Global has shifted from optimizing the performance of individual pieces of mining equipment to optimizing across the fleet of equipment deployed in the mine. Industry boundaries expand from discrete types of mining machines to mining equipment systems.

Increasingly, however, industry boundaries are expanding even beyond product systems to systems of systems—that is, a set of disparate product systems as well as related external information that can be coordinated and optimized, such as a smart building, a smart home, or a smart city. John Deere and AGCO, for example, are beginning to connect not only farm machinery but irrigation systems and soil and nutrient sources with information on weather, crop prices, and commodity futures to optimize overall



VIDEO For a case study and video on how Joy Global's smart, connected mining equipment transforms mine performance, go to hbr.org/insights/iot.

CHARTING THE IMPACT ON COMPETITION

This article is the first in a two-part series in which we examine how smart, connected products are shifting competition in many industries. At the most fundamental level, companies must ask four questions:

1 How does the move to smart, connected products affect the structure of the industry and industry boundaries?

2 How do smart, connected products affect the configuration of the value chain or the set of activities required to compete?

3 What new types of strategic choices will smart, connected products require companies to make to achieve competitive advantage?

4 What are the organizational implications of embracing these new types of products and the challenges that affect implementation success?

In this article, we examine the effect of smart, connected products on industry structure and industry boundaries and discuss the new strategic choices facing companies. In part two (forthcoming), we examine value chain impacts and organizational issues.

(Disclosure: PTC does business with more than 28,000 companies worldwide, many of which are mentioned in this article.)

farm performance. Smart homes, which involve numerous product systems including lighting, HVAC, entertainment, and security, are another example. Companies whose products and designs have the greatest impact on total system performance will be in the best position to drive this process and capture disproportionate value.

Some companies—like John Deere, AGCO, and Joy Global—are intentionally seeking to broaden and redefine their industries. Others may find themselves threatened by this development, which creates new competitors, new bases for competition, and the need for entirely new and broader capabilities. Companies that fail to adapt may find their traditional products becoming commoditized or may themselves be relegated to the role of OEM supplier, with system integrators in control.

The net effect of smart, connected products on industry structure will vary across industries, but some tendencies seem clear. First, rising barriers to entry, coupled with first-mover advantages stemming from the early accumulation and analysis of product usage data, suggests that many industries may undergo consolidation.

Second, consolidation pressures will be amplified in industries whose boundaries are expanding. In such cases, single product manufacturers will have difficulty competing with multiproduct companies that can optimize product performance across broader systems. Third, important new entrants are likely to emerge, as companies unencumbered by legacy product definitions and entrenched ways of competing, and with no historical profit pools to protect, seize opportunities to leverage the full potential of smart, connected products to create value. Some of these strategies will be “productless”—that is, the system that connects products will be the core advantage, not the products themselves.

Smart, Connected Products and Competitive Advantage

How can companies achieve sustainable competitive advantage in a shifting industry structure? The basic tenets of strategy still apply. To achieve competitive advantage, a company must be able to differentiate itself and thus command a price premium, operate at a lower cost than its rivals, or both. This allows for superior profitability and growth relative to the industry average.

The foundation for competitive advantage is operational effectiveness (OE). OE requires embracing best practices across the value chain, including up-to-date product technologies, the latest production equipment, and state-of-the-art sales force methods, IT solutions, and supply chain management approaches.

OE is the table stakes of competition. If a company is not operationally effective and continually embracing new best practices, it will fall behind rivals in cost and quality. Yet OE is rarely a source of sustainable advantage, because competitors will implement the same best practices and catch up.

To move beyond OE, a company must define a distinctive strategic positioning. Whereas operational effectiveness is about doing things well, strategic positioning is about doing things differently. A company must choose how it will deliver unique value to the set of customers it chooses to serve. Strategy requires making trade-offs: deciding not only what to do but what not to do.

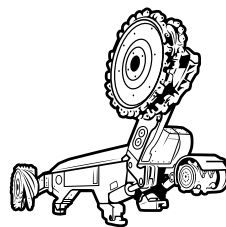
Smart, connected products are defining a new standard for operational effectiveness, dramatically raising the bar in terms of best practices. Every product company will have to decide how to incorporate smart, connected capabilities into its products. But not only the product itself is being affected. As we discussed earlier, the move to smart, connected

products also creates new best practices across the value chain.

The implications of smart, connected products for the value chain will be discussed in detail in the second article in this series (see the sidebar “Charting the Impact on Competition”). Here we focus briefly on how smart, connected products affect product design, service, marketing, human resources, and security, because these shifting internal activities often bear directly on strategy choices.

Design. Smart, connected products require a whole set of new design principles, such as designs that achieve hardware standardization through software-based customization, designs that enable personalization, designs that incorporate the ability to support ongoing product upgrades, and designs that enable predictive, enhanced, or remote service. Expertise in systems engineering and in agile software development is essential to integrate a product’s hardware, electronics, software, operating system, and connectivity components—expertise that is not well developed in many manufacturing companies. Product development processes will also need to accommodate more late-stage and post-purchase design changes quickly and efficiently. Companies will need to synchronize the very different “clock speeds” of hardware and software development; a software development team might create as many as 10 iterations of an application in the time it takes to generate a single new version of the hardware on which it runs.

After-sale service. Smart, connected products offer major improvements in predictive maintenance and service productivity. New service organizational structures and delivery processes are required to take advantage of product data that can reveal existing and future problems and enable companies to make timely, and sometimes remote, repairs. Real-time product usage and performance data allows substantial reductions in field-service dispatch costs and major efficiencies in spare-parts inventory control. Early warnings about impending failure of parts or components can reduce breakdowns and allow more efficient service scheduling. Data on product usage and performance can feed insights back to product design, so that firms can reduce future product failures and associated service required. Product usage data can also be used to validate warranty claims and identify warranty agreement violations.



Joy Global

Smart, connected mining machines such as this Joy Global longwall shearer autonomously coordinate with other equipment to improve mining efficiency.

In some cases, firms can decrease service costs by replacing physical parts with “software parts.” For example, glass cockpit LCD displays in modern aircraft, which can be repaired or upgraded via software, have replaced electrical and mechanical dials and gauges. Product usage data also enables firms to better “design for service”—that is, reduce the complexity or placement of parts that are prone to failure in order to simplify repairs. All these opportunities change the service activities in the value chain substantially.

Marketing. Smart, connected products allow companies to form new kinds of relationships with customers, requiring new marketing practices and skill sets. As companies accumulate and analyze product usage data, they gain new insights into how products create value for customers, allowing better positioning of offerings and more effective communication of product value to customers. Using data analytics tools, firms can segment their markets in more-sophisticated ways, tailor product and service bundles that deliver greater value to each segment, and price those bundles to capture more of that value. This approach works best when products can be quickly and efficiently tailored at low marginal cost through software (as opposed to hardware) variation. For example, whereas John Deere used to manufacture multiple engines with different levels of horsepower to serve different customer segments, it now can modify the horsepower rating on the same engine using software alone.

Human resources. Smart, connected products create major new human resource requirements and challenges. The most urgent of these is the need to recruit new skill sets, many of which are in high demand. Engineering departments, traditionally staffed with mechanical engineers, must add talent in software development, systems engineering, product clouds, big data analytics, and other areas.

Security. Smart, connected products create the need for robust security management to protect the data flowing to, from, and between products; protect products against unauthorized use; and secure access between the product technology stack and other corporate systems. This will require new authentication processes, secure storage of product data, protections against hackers for both product data and customer data, definition and control of access privileges, and protections for products themselves from hackers and unauthorized use.

Implications for Strategy

The path to competitive advantage ultimately rests on strategy. Our research reveals that in a smart, connected world companies face 10 new strategic choices. Each choice involves trade-offs, and each must reflect a company's unique circumstances. The choices are also interdependent. The company's entire set of choices must reinforce one another and define a coherent and distinctive overall strategic positioning for the company.

1 Which set of smart, connected product capabilities and features should the company pursue? Smart, connected products dramatically expand the range of potential product capabilities and features. Companies may be tempted to add as many new features as possible, especially given the often low marginal cost of adding more sensors and new software applications, and the largely fixed costs of the product cloud and other infrastructure. But just because a company *can* offer many new capabilities does not mean that their value to customers exceeds their cost. And when companies get into a features and capabilities arms race, they end up blurring strategic differences and creating zero-sum competition.

How should a company determine which smart, connected capabilities to offer? First, it must decide which features will deliver real value to customers relative to their cost. In residential water heaters, A.O. Smith has developed capabilities for fault monitoring and notification, but water heaters are so long-lived and reliable that few households are willing to pay enough for these features to justify their current cost. Consequently, A.O. Smith offers them as options on only a few models. In commercial water heaters and boilers, however, adoption of such capabilities is high and rising. The value of remote monitoring and operation to commercial customers that often cannot operate without heat and hot water is high relative to their cost, and so these features are becoming standard. Note that the cost of incorporating smart, connected product features will tend to fall over time, as is the case in water heaters and boilers. When deciding what features to offer, then, companies must continually revisit the value equation.

Second, the value of features or capabilities will vary by market segment, and so the selection of features a company offers will depend on what



Tesla

A Tesla vehicle in need of repairs can autonomously call for a corrective software download, or, if necessary, send a notification to the customer with an invitation for a valet to pick up the car and deliver it to a Tesla facility.

segments it chooses to serve. Schneider Electric, for example, makes building products as well as integrated building management solutions that gather volumes of data about energy consumption and other building performance metrics. For one segment of customers, Schneider's solution involves remote equipment monitoring, alerts, and advisory services in reducing energy use and other costs. For the segment of customers that want a fully outsourced solution, however, Schneider actually takes over remote control of equipment to minimize energy consumption on customers' behalf.

Third, a company should incorporate those capabilities and features that reinforce its competitive positioning. A company competing with a high-end strategy can often reinforce differentiation through extensive features, while a low-cost competitor may choose to include only the most basic features that affect core product performance and that lower the cost of operation. For example, A.O. Smith's Lochinvar boiler unit, which competes using a highly differentiated strategy, has made extensive smart, connected product features standard on its core products. In contrast, Rolex, the luxury watch maker, has decided that smart, connected capabilities are not an area in which it will compete.

2 How much functionality should be embedded in the product and how much in the cloud? Once a company has decided which capabilities to offer, it must decide whether the enabling technology for each feature should be embedded in the product (raising the cost of every product), delivered through the product cloud, or both. In addition to cost, a number of factors should be taken into consideration.

Response time. A feature that requires quick response times, such as a safety shutdown in a nuclear power plant, requires that the software be embedded in the physical product. This also reduces the risk that lost or degraded connectivity slows down response.

Automation. Products that are fully automated, such as antilock brakes, usually require that greater functionality be embedded into the device.

Network availability, reliability, and security. Embedding software in the product minimizes dependence on network availability and the amount of data that must flow from the product to cloud-based applications, lowering the risk that sensitive

or confidential data will be compromised during transmission.

Location of product use. Companies that operate products in remote or hazardous locations can mitigate the associated dangers and costs by hosting functionality in the product cloud. As discussed above, Thermo Fisher's chemical analyzers, used in hazardous or toxic environments, have cloud-based capabilities and connectivity that enable the instantaneous transmission of contamination data and allow the immediate initiation of mitigation efforts.

Nature of user interface. If the product's user interface is complex and is changed frequently, the interface may be best located in the cloud. The cloud offers the ability to deliver a much richer user experience and potentially to take advantage of an existing, familiar, and robust user interface like a smartphone.

Frequency of service or product upgrades. Cloud-based applications and interfaces allow companies to make product changes and upgrades easily and automatically.

Home audio equipment maker Sonos, a smart, connected products pioneer, takes advantage of cloud-based capability to "reinvent home audio for the digital age," putting a premium on convenience, variety of music, and ease of use. The company's wireless systems place both the music source and the user interface in the cloud, enabling Sonos to simplify its products' physical design: The portable device, which is controlled from a smartphone, contains only the amplifier and speaker. With this offering, Sonos attempted to disrupt the home audio market. The trade-off? Wireless streamed audio systems do not deliver the level of sound quality that true audiophiles demand. Competitors such as Bose will make different choices and trade-offs to secure their competitive differentiation.

We believe that as smart, connected products evolve, more human-machine interface capabilities may well move out of the product and into the cloud. However, the complexity facing users in operating these interfaces will increase. User interfaces may often overshoot in complexity, and user backlash may drive firms to restore simpler, easy-to-use interfaces for common functions, including on/off controls.

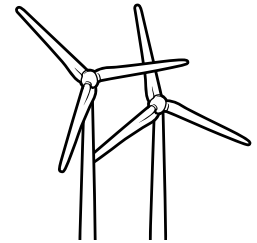
3 Should the company pursue an open or closed system? Smart, connected products involve multiple types of functionality and services, and are often systems encompassing multiple

products. A *closed system* approach aims to have customers purchase the entire smart, connected product system from a single manufacturer. Key interfaces are proprietary, and only chosen parties gain access. The operating data that GE gathers from its aircraft engines, for example, is available only to the airlines operating the engines. An *open system*, by contrast, enables the end customer to assemble the parts of the solution—both the products involved and the platform that ties the system together—from different companies. Here, the interfaces enabling access to each part of the system are open or standardized, allowing outside players to create new applications.

Closed systems create competitive advantage by allowing a company to control and optimize the design of all parts of the system relative to one another. The company maintains control over technology and data as well as the direction of development of the product and the product cloud. Producers of system components are restricted from accessing a closed system or are required to license the right to integrate their products into it. A closed approach may result in one manufacturer's system becoming the de facto industry standard, enabling this company to capture the maximum value.

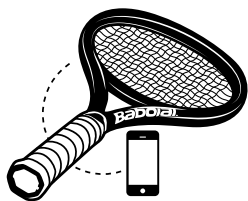
A closed approach requires significant investment and works best when a single manufacturer has a dominant position in the industry that can be leveraged to control the supply of all parts of the smart, connected product system. If either Philips Healthcare or GE Healthcare were the dominant manufacturer of medical imaging equipment, for example, it could drive a closed approach in which it could sell medical imaging management systems that included only its own or partners' equipment to hospitals. However, neither company has the clout to restrict hospitals' choice of other manufacturers' equipment, so both companies' imaging system platforms interface with other manufacturers' machines.

A fully open system enables any entity to participate in and interface with the system. When Philips Lighting introduced the hue smart, connected lightbulb, for example, it included a basic smartphone application that allowed users to control the color and intensity of individual bulbs. Philips also published the application programming interface, which led independent software developers to quickly release dozens of applications that extended the utility of the hue bulbs, boosting sales. The open



Wind Turbine

When smart wind turbines are networked, software can adjust the blades on each one to minimize impact on the efficiency of turbines nearby.



Babolat

Babolat's Play Pure Drive product system puts sensors and connectivity in the tennis racket handle, allowing users to track and analyze ball speed, spin, and impact location to improve their game.

approach enables a faster rate of applications development and system innovation as multiple entities contribute. It can also result in a de facto industry standard, but one from which no company gains a proprietary benefit.

While a closed system is possible for individual product systems, it is often impractical for systems of systems. Whirlpool, for example, realizes that its strong position in home appliances will not be sufficient to become the leader in the “connected home,” which includes not only connected appliances but also automated lighting, HVAC, entertainment, and security. Therefore, Whirlpool designs its appliances to be readily connectable to the variety of home automation systems on the market, seeking to retain proprietary control only over its product features. A hybrid approach, in which a subset of functionality is open but the company controls access to full capabilities, occurs in industries like medical devices, where manufacturers support an industry standard interface but offer greater functionality only to customers. Over time, closed approaches become more challenging as technology spreads and customers resist limits on choice.

4 Should the company develop the full set of smart, connected product capabilities and infrastructure internally or outsource to vendors and partners? Developing the technology stack for smart, connected products requires significant investment in specialized skills, technologies, and infrastructure that have not been typically present in manufacturing companies. Many of these skills are scarce and in high demand.

A company must choose which layers of technology to develop and maintain in-house and which to outsource to suppliers and partners. In utilizing outside partners, it must decide whether to pursue custom development of tailored solutions or license off-the-shelf, best-of-breed solutions at each level. Our research suggests that the most successful companies choose a judicious combination of both.

Companies that develop smart, connected products in-house internalize key skills and infrastructure and retain greater control over features, functionality, and product data. They may also capture first-mover advantages and the ability to influence the direction of technology development. The company gets on its own, steeper learning curve, which can help maintain its competitive advantage. For

example, while software skills are not well developed in most manufacturing companies, Jeff Immelt recently said that “every industrial company will become a software company.” The nature of technology for smart, connected products makes it clear why that might well be true and why building internal software capability is crucial.

Early pioneers AGCO and Deere have both taken a largely in-house route to develop smart farm equipment solutions for those reasons. GE has created a major software development center to build in-house capabilities it sees as strategic across business units.

However, as with the two previous IT waves, the difficulty, skills, time, and cost involved in building the entire technology stack for smart, connected products is formidable and leads to specialization at each layer. Just as Intel has specialized in microprocessors and Oracle in databases, new firms that specialize in components of the smart, connected products technology stack are already emerging, and their technology investments are amortized over many thousands of customers. Early movers that choose in-house development can overestimate their ability to stay ahead and end up slowing down their development time line.

But outsourcing can create new costs, as suppliers and partners demand a larger share of the value created. Companies that rely on partners also compromise their ability to differentiate going forward, and their ability to build and retain the in-house expertise required to set overall product design strategy, manage innovation, and choose vendors well.

In making these build-versus-buy choices, companies should identify those technology layers that offer the greatest opportunities for product insight, future innovation, and competitive advantage, and outsource those that will become commoditized or advance too quickly. For example, most companies should strive to maintain solid internal capabilities in areas such as device design, the user interface, systems engineering, data analytics, and rapid product application development.

These choices will evolve over time. In the early stages of smart, connected products technology, the number of capable and robust suppliers has been limited, and so companies have been faced with the imperative of in-house or custom development. Already, however, best-of-breed vendors with turnkey connectivity solutions and product clouds, secure high-performance application platforms, and ready-to-use

data analytics are emerging. This makes it increasingly challenging for in-house efforts to keep up and can turn an early lead into a disadvantage.

5 What data must the company capture, secure, and analyze to maximize the value of its offering? Product data is fundamental to value creation and competitive advantage in smart, connected products. But collecting data requires sensors, which add cost to the product, as does transmitting, storing, securing, and analyzing this data. Companies may also need to obtain rights to the data, adding complexity and cost. To determine which types of data provide sufficient value relative to cost, the firm must consider questions such as: How does each type of data create tangible value for functionality? For efficiency in the value chain? Will the data help the company understand and improve how the broader product system is performing over time? How often does the data need to be collected to optimize its usefulness, and how long should it be retained?

Companies must also consider the product integrity, security, or privacy risks for each type of data and the associated cost. The less sensitive data a company collects, the lower the risk of breaches and transmission disruptions. When security requirements are high, companies will need capabilities to protect the data and limit transmission risk by storing data in the product itself. (We will discuss security more extensively in part two of this series.)

The types of data a company chooses to collect and analyze also depend on its positioning. If the company's strategy is focused on leading in product performance or minimizing service cost, it must usually capture extensive "immediate value" data that can be leveraged in real time. This is especially important for complex, expensive products for which downtime is costly, such as wind turbines or jet engines.

For companies seeking leadership in the product system, there is a need to invest in capturing and analyzing more-extensive data across multiple products and the external environment, even for products the company does not produce. For example a smart, connected product system might need to capture traffic data, weather conditions, and fuel prices at different locations for an entire fleet of vehicles.

Different strategies involve different data-capture choices. Nest, which aims to lead in energy efficiency



Ralph Lauren

Ralph Lauren's Polo Tech Shirt, available in 2015, streams distance covered, calories burned, movement intensity, heart rate, and other data to the wearer's mobile device.

and energy cost, gathers extensive data on both product usage and peak demand across the energy grid. This has enabled the Rush Hour Rewards program, which raises residential customers' air conditioning thermostat temperature to reduce energy use during peak demand periods and precools a home before peak demand begins. By partnering with energy providers, securing the data they provide, and integrating it with customer data, Nest enables customers to earn discounts or credits from their energy provider and to use less energy when everyone else is using more.

6 How does the company manage ownership and access rights to its product data? As a company chooses which data to gather and analyze, it must determine how to secure rights to the data and manage data access. The key is who actually owns the data. The manufacturer may own the product, but product usage data potentially belongs to the customer. For example, who is the rightful owner of the data streaming from a smart, connected aircraft engine—the engine supplier, the airframe manufacturer, or the airline that owns and operates the planes?

There is a range of options for establishing data rights for smart, connected products. Companies may pursue outright ownership of product data, or seek joint ownership. There are also various levels of usage rights, including NDAs, the right to share the data, or the right to sell it. Firms must determine their approach to transparency in data collection and use. Rights to data can be laid out in an explicit agreement or buried in small print or hard-to-understand boilerplate documents. Although we are seeing the early stages of a movement toward more transparency in data gathering across industries, data disclosure and ownership standards often have yet to be established.

Another option for handling data rights and access includes the establishment of a data-sharing framework with component suppliers for providing information about the component's condition and performance but not about its location. Limiting suppliers' access to data, however, could reduce potential benefits if the supplier lacks a full understanding of how products are being used, slowing innovation.

Customers and users want a say in these choices. Some customers today are much more willing than others to share data on their product use. For example, part of Fitbit's value proposition is its ability



Medtronic

Medtronic's implanted digital blood glucose meter connects wirelessly to a monitoring and display device and can alert patients to trends in glucose levels requiring attention.

to share via social media the personal fitness information it collects. But not every customer wants to share this data. Likewise, cautious drivers may be willing to share data on their driving habits with insurance or rental car companies as a way to lower premiums or fees, but others may resist. Firms will need to provide a clear value proposition to customers to encourage them to share usage or other data. As consumers become more aware of the value that data generates across the value chain, they will become more active and demanding participants in decisions about what data is collected, how it is used, and who benefits.

Today it's common to see "click through" agreements giving broad consent to collect product data the first time a smart, connected product is used. This consent allows companies to indiscriminately collect product data and use it with few constraints. In time we expect that more-stringent contractual frameworks and mechanisms governing those rights will emerge to define and protect intellectual property associated with smart, connected product data. It behooves companies to get ahead of this trend, especially on the product data they truly need to collect in order to drive value.

Careful stewardship of data will also be essential, especially in highly regulated industries such as medical devices. Regulatory standards for data access and security are already in place in many such fields. Biotronik has created infrastructure that allows it to securely gather patient information, such as arrhythmia events or pacemaker battery status, and share it only with a specified audience—the patient's physician. Regardless of the industry, however, stewardship of data will be an essential capability, and data breaches will lead to serious consequences regardless of who is at fault. Ongoing security risk is part of the business case for which data to collect and how to manage it.

7 Should the company fully or partially disintermediate distribution channels or service networks? Smart, connected products enable firms to maintain direct and deep customer relationships, which can reduce the need for distribution channel partners. Companies can also diagnose product performance problems and failures and sometimes make repairs remotely, reducing reliance on service partners. By minimizing the role of the middlemen, companies can potentially capture new

revenue and boost margins. They can also improve their knowledge of customer needs, strengthen brand awareness, and boost loyalty by educating customers more directly about product value.

Tesla, for example, has disrupted the status quo in the automotive industry by selling its cars directly to consumers rather than through a traditional dealer network. This has simplified the firm's pricing—consumers pay full sticker price, avoiding the haggling common at dealerships—greatly improving customer satisfaction. By eliminating third-party involvement in repairs, Tesla captures revenue and deepens its relationship with customers. The firm transmits software upgrades to its cars, continually improving the customer experience and giving drivers the equivalent of the "new car smell" with each update. When monitoring detects that a Tesla vehicle is due for repairs, the car either autonomously calls for a remote repair via software or sends a notification to the customer with an invitation to request that a valet deliver it to the Tesla facility. The firm was recently rated number one in customer satisfaction by *Consumer Reports*.

While disintermediation has definite advantages, some level of physical proximity to customers is still required and desirable in most industries. Customers must take delivery of and sometimes install a physical product, and some types of service visits are still necessary. In addition, customers may have strong relationships with resellers and channels that offer them a broader product line and deep and local field-based expertise. When manufacturers diminish the role of valuable channel partners, they risk losing them to competitors whose strategy is to embrace partners. Also, assuming roles formerly handled by partners—such as direct selling or service—can be challenging, involving high start-up costs and major new investments in value chain functions such as sales, logistics, inventory, and infrastructure.

The choice of whether or not to disintermediate a channel or service partner will depend in large part on the type of partner network the firm manages. Do partners simply distribute products, or are they critical to delivering training and service in the field? What percentage of partner activities can be replaced through smart, connected product capabilities? Do customers understand the value of eliminating the middleman? Do customers understand that traditional relationships with established channels are no longer necessary and involve extra cost?

MISTAKES TO AVOID

Smart, connected products offer a rich new set of value creation and growth opportunities. However, efforts to seize those opportunities will not be without challenges. Some of the greatest strategic risks include the following:

Adding functionality that customers don't want to pay for. Just because a feature is now possible does not mean there is a clear value proposition for the customer. Adding enhanced capabilities and options can reach the point of diminishing returns, due to the cost and complexity of use.

Underestimating security and privacy risks. Smart, connected products open major new gateways to corporate systems and data, requiring stepped-up network security, device and sensor security, and information encryption.

Failing to anticipate new competitive threats. New competitors offering products with smart, connected capabilities (such as connectivity and embedded software) or performance- or service-based business models can emerge quickly and reshape competition and industry boundaries.

Waiting too long to get started. Moving slowly enables competitors and new entrants to gain a foothold, begin capturing and analyzing data, and start moving up the learning curve.

Overestimating internal capabilities. The shift to smart, connected products will demand new technologies, skills, and processes throughout the value chain (for example, big data analytics, systems engineering, and software application development). A realistic assessment about which capabilities should be developed in-house and which should be developed by new partners is crucial.

8 Should the company change its business model?

Manufacturers have traditionally focused on producing a physical good and capturing value by transferring ownership of the good to the customer through a sales transaction. The owner is then responsible for the costs of servicing the product and other costs of use, while bearing the risks of downtime and other product failures and defects not covered by warranties.

Smart, connected products allow the radical alteration of this long-standing business model. The manufacturer, through access to product data and the ability to anticipate, reduce, and repair failures, has an unprecedented ability to affect product performance and optimize service. This opens up a spectrum of new business models for capturing value, from a version of the traditional ownership model where the customer benefits from the new service efficiencies to the product-as-a-service

model in which the manufacturer retains ownership and takes full responsibility for the costs of product operation and service in return for an ongoing charge. Customers pay as they go, not up front. Here, the value of product performance improvements that reduce operating cost (such as better energy efficiency) and service efficiencies are captured by the manufacturer.

Smart, connected products create a dilemma for manufacturers, particularly those that make complex, long-lived products for which parts and service generate significant revenue and often disproportionate profit. Whirlpool, for example, currently has a healthy business selling spare parts and service contracts—a model that can dull incentives to make products more reliable, more durable, and easier to fix. If, instead, Whirlpool moved to a product-as-a-service model, in which it maintained ownership of the product and the customer simply paid for the use of the machine, the economic incentives would be turned upside down.

The profitability of product-as-a-service models depends on the pricing and terms of contracts, which are a function of bargaining power. Product-as-a-service models can increase buyers' power, because customers may be able to switch after the contract period (if the product is not embedded as with an elevator), unlike with perpetual ownership.

Product sharing, a variation of the product-as-a-service model, focuses on more efficient utilization of products that are used intermittently. Customers pay for the use of the product (such as cars or bikes) when they need it, and the company (such as Zipcar or Hubway) is responsible for everything else. Product sharing is spreading to nonmobile products such as houses.

Companies can also pursue hybrid models between the extremes of product-as-a-service and conventional ownership, such as product sales bundled with warranty or service contracts, or product sales bundled with performance-based contracts. Service contracts allow the manufacturer to keep service in-house and capture more of the value from service efficiencies. In a performance-based contract, the manufacturer sells the product along with a contract that promises that the product will perform to certain specifications (such as percentage of uptime). Here, ownership is transferred, but the manufacturer maintains responsibility and bears the risk of product performance.

9 Should the company enter new businesses by monetizing its product data through selling it to outside parties?

Companies may find that the data they accumulate from smart, connected products is valuable to entities besides traditional customers. Companies may also discover that they can capture additional data, beyond what they need to optimize product value, that is valuable to other entities. In either case, this may lead to new services or even new businesses.

Data about the performance of a product's components, for example, could be valuable to suppliers of those components. Data about driving conditions or delays gathered by a fleet of vehicles could be valuable to other drivers, to the operators of logistical systems, or to road repair crews. Data about driving characteristics could be valuable to fleet operators or insurance companies.

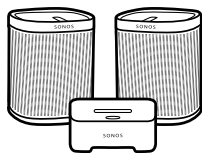
Again, in choosing how to capture new value from product data, companies must consider the likely reaction of core customers. While some of them may not care how their data is used, others may feel strongly about data privacy and reuse. Companies will need to identify mechanisms to provide valuable data to third parties without alienating customers. For example, a company might not sell individual customer data but rather blinded or aggregate data on purchasing patterns, driving habits, or energy usage.

10 Should the company expand its scope?

Smart, connected products not only transform existing products but often broaden industry boundaries. Products that have been separate and distinct can become parts of optimized systems of related products, or components of systems of systems. Shifting boundaries mean that companies that have been industry leaders for decades may find themselves playing more of a supporting role in a broader landscape.

The emergence of product systems and systems of systems raises at least two types of strategic choices about company scope. The first is whether a company should expand into related products or other parts of the system of systems. The second is whether a company should seek to provide the platform that connects the related products and information, even if it does not make or control all the parts.

Companies may be tempted to enter into related products in order to capture the big opportunity, but entry into related products always involves risk



Sonos

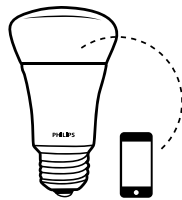
The company's wireless music systems place the user interface in the cloud, enabling users to control the portable device from a smartphone.

and the need for new capabilities. Companies must identify a clear value proposition before entering. Expanding product scope will be most attractive where there are major performance improvement opportunities through co-designing the related products to optimize the system. Alternatively, if optimization is not dependent on individual product designs, a company may be better off sticking to its knitting and providing open connectivity to related products produced by others. Success is less a function of traditional product design than systems engineering.

Companies whose products (and associated technological capabilities) are central to overall product system operation and performance, such as Joy Global's mining machines, will be in the best position to enter related products and integrate the system. Manufacturers that produce less system-critical machines, such as the trucks that move the material extracted from underground, will have less capability and credibility in customers' eyes to take on a broader system provider role.

The choice of whether or not to develop the technology platform that connects a product system or system of systems depends on some related questions. The first is whether the company can assemble the necessary IT skills and technology, which are quite different from those required in product design and manufacturing. Another key question is where system optimization takes place. "Inside product" optimization involves integrating individual product designs so that products work better together. "Outside product" optimization takes place through the algorithms that connect products and other information, where products themselves are modular. Inside product optimization creates the strongest rationale for expanding into related products and offering a proprietary platform. Outside product optimization favors an open platform, and the platform may be offered by a company that does not produce products at all.

Carrier Corporation offers an example of these choices. It has a 100-year history of innovation in the design of a full range of HVAC equipment such as furnaces, air conditioners, heat pumps, humidifiers, and ventilators. Carrier optimizes its HVAC product system performance by integrating individual designs across products, and its smart Infinity heating and cooling system platform connects them. However, HVAC is part of a broader home automation system.



Philips Lighting

Users can control Philips Lighting hue lightbulbs via smartphone, turning them on and off, programming them to blink if they detect an intruder, or dimming them slowly at night.

Smart, connected products will give rise to the next era of IT-driven productivity growth at a time when the impact of earlier waves of IT has largely played itself out.

Carrier has not entered other product areas within home automation because of the need for very different capabilities. Rather, its Infinity platform provides interfaces to allow the HVAC product family to be integrated into the system of systems.

Finally, as smart, connected products expand industry scope and the boundaries of competition, many companies will need to rethink their corporate purpose. The focus is shifting to the broader need companies meet, rather than their traditional product definition. For example, Trane has moved from seeing itself as an HVAC equipment producer to a company that makes high-performance buildings better for everyone inside. As products continue to communicate and collaborate in networks, which are expanding both in number and diversity, many companies will have to reexamine their core mission and value proposition.

A company must make a clear choice in each of these dimensions of strategy but ensure that each choice is consistent with and reinforces the others. For example, a company pursuing product system leadership will enter related product categories, pursue inside product design integration, capture extensive product usage data, and develop more intensive internal capabilities across the technology stack. In contrast, a company that focuses on a single part of a product system will need to become best-of-breed in terms of features and functionality and provide transparent and open interfaces so that its product can be readily integrated into and becomes a valuable part of other companies' systems and platforms. Ultimately, competitive success will arise not by imitating rivals but by defining a distinctive value proposition that the company can realistically achieve.

The Larger Opportunity

Smart, connected products are changing how value is created for customers, how companies compete, and the boundaries of competition itself. These shifts will affect virtually every industry, directly or indirectly. But smart, connected products will have a broader impact even than this. They will affect the

trajectory of the overall economy, giving rise to the next era of IT-driven productivity growth for companies, their customers, and the global economy at a time when the impact of earlier waves of IT has largely played itself out and productivity growth has slowed down.

This third wave of IT not only will create step function improvements in product capability and performance but will radically improve our ability to meet many business and human needs. Across many fields, products will be far more efficient, effective, safe, reliable, and more fully utilized, while conserving scarce natural resources such as energy, water, and raw materials.

This opportunity to drive rapid innovation and economic growth, and with it a return to prosperity growth, comes none too soon. The past decade has been characterized by internal cost reduction, cautious investment, higher corporate profitability, rising M&A, and muted innovation across large parts of the economy. This path has resulted in slower job growth, slower improvements in wages and living standards for the average citizen, a diminished sense of economic opportunity, doubts about capitalism, and reduced public support for business.

The era of smart, connected products can change this trajectory, provided that companies move aggressively to embrace the opportunity. Business and government together will need to equip workers across all groups with the skills to participate, and agree on the rules and regulations needed to set standards, enable innovation, protect data, and overcome efforts to block progress (such as auto dealers' political opposition to Tesla).

The United States stands to lead and benefit disproportionately in a smart, connected products world, given America's strengths in the core underlying technologies, many of the skills required, and key supporting industries. If this new wave of technology allows the U.S. to reinvigorate its capacity as a technology leader in the global economy, it will breathe new life into the American dream while contributing to a better world. ♥

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