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The Internet of Things: Sizing up the opportunity

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This connectivity trend is now recognized as a source of growth for semiconductor players and their customers. Here we consider the opportunities and constraints for components manufacturers.

The semiconductor industry has been able to weather the fallout from the global financial crisis and realize several years of healthy growth—in part because of the widespread adoption of smartphones and tablets, which created demand for mobile and wireless applications. The industry's average annual growth rate between 2010 and 2013 was about 5 percent. Could the same sort of growth result from widespread adoption of the Internet of Things? Many semiconductor players have been asking themselves just this question.

The Internet of Things refers to the networking of physical objects through the use of embedded sensors, actuators, and other devices that can collect or transmit information about the objects. The data amassed from these devices can then be analyzed to optimize products, services, and operations. Perhaps one of the earliest and best-known applications of such technology has been in the area of energy optimization: sensors deployed across the electricity grid can help utilities remotely monitor energy usage and adjust generation and distribution flows to account for peak times and downtimes. But applications are also being introduced in a number of other industries. Some insurance companies, for example, now offer plans that require drivers to install a sensor in their cars, allowing insurers to base premiums on actual driving behavior rather than projections. And physicians can use the information collected from wireless sensors in their patients' homes to improve their management of chronic diseases. Through continuous monitoring rather than periodic testing, physicians could reduce their treatment costs by between 10 and 20 percent, according to McKinsey Global Institute research—billions of dollars could be saved in the care of congestive heart failure alone.

In each of these cases, the connected devices that transmit information across the relevant networks rely on innovations from semiconductor players—highly integrated microchip designs, for instance, and very low-power functions in certain applications. The semiconductor companies that can effectively deliver these and other innovations to original-equipment manufacturers, original-device manufacturers, and others that are building Internet of Things products and applications will play an important role in the development of the market. That market, in turn, may represent a significant growth opportunity for semiconductor players.

Indeed, semiconductor executives surveyed in June 2014 as part of our quarterly poll of the components-manufacturing market said the Internet of Things will be the most important source of growth for them over the next several years—more important, for example, than trends in wireless computing or big data. McKinsey Global Institute research supports that belief, estimating that the impact of the Internet of Things on the global economy might be as high as $6.2 trillion by 2025.[1] At the same time, the corporate leaders polled admit they lack a clear perspective on the concrete business opportunities in the Internet of Things given the breadth of applications being developed, the potential markets affected—consumer, healthcare, and industrial segments, among others—and the fact that the trend is still nascent.

In this article, we take the pulse of the market for Internet of Things applications and devices. Where along the development curve are the enabling technologies, and where can semiconductor players insert themselves in the evolving ecosystem? We believe components manufacturers may be able to capture significant value primarily by acting as trusted facilitators—it is their silicon, after all, that can enable not just unprecedented connectivity but also long-term innovation across the Internet of Things.

Sizing the opportunity

Three years ago, industry pundits and analysts predicted that, by 2020, the market for connected devices would be between 50 billion and 100 billion units. Today, the forecast is for a more reasonable but still sizable 20 billion or 30 billion units. This leveling off of expectations is in line with what we have seen in past introductions of new technologies. Throughout the late 1990s and early 2000s, for instance, there was much discussion in the semiconductor industry about the potential benefits and implications of Bluetooth technology, but the inflection point for Bluetooth did not happen until 2003 or 2004, when a large enough number of industry players adopted it as a standard and pushed new Bluetooth-based devices and applications into the market. The market for Internet of Things devices, products, and services appears to be accelerating toward just such an inflection point, in view of four critical indicators.

Supplier attention. Internet of Things developer tools and products are now available. Apple, for instance, has released HealthKit and HomeKit developer tools as part of its latest operating-system upgrade, and Google acquired Nest to catalyze the development of an Internet of Things platform and applications.[2]

Technological advances. Some of the semiconductor components that are central to most Internet of Things applications are showing much more functionality at lower prices. Newer processors, such as the ARM Cortex M, use only about one-tenth of the power that most energy-efficient 16-bit processors used only two years ago. This leap forward in technological capabilities is apparent in the evolving market for smart watches. The first such products released in 2012

[1] For more, see *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013, on mckinsey.com.

[2] Aaron Tilley, "Google acquires smart thermostat maker Nest for $3.2 billion," *Forbes*, January 13, 2014, forbes.com.

boasted 400-megahertz single processors and simple three-axis accelerometers. Now a typical smart watch will include 1-gigahertz dual-core processors and high-end, six-axis devices that combine gyroscopes and accelerometers. Meanwhile, the prices of the chip sets used in these products have declined by about 25 percent per year over the past two years.

Increasing demand. Demand for the first generation of Internet of Things products (fitness bands, smart watches, and smart thermostats, for instance) will increase as component technologies evolve and their costs decline. A similar dynamic occurred with the rise of smartphone usage. Consumer demand for smartphones jumped from about 170 million devices sold annually just four or five years ago to more than a billion devices in 2014. The increase in orders coincided with a steep decline in the price of critical smartphone components.

Emerging standards. Over the past two years, semiconductor players have joined forces with hardware, networking, and software companies, and with a number of industry associations and academic consortiums, to develop formal and informal standards for Internet of Things applications. AT&T, Cisco, GE, IBM, and Intel, for instance, cofounded the Industrial Internet Consortium, whose primary goal is to establish interoperability standards across industrial environments so that data about fleets, machines, and facilities can be accessed and shared more reliably. Other groups have been focused on standardizing the application programming interfaces (APIs) that enable basic commands and data transfer among Internet of Things devices.

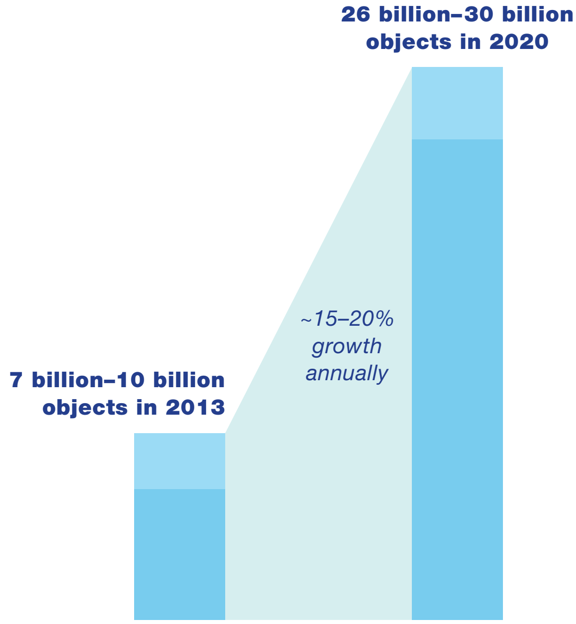
Implications for semiconductor players

Analysts have predicted that the installed base for Internet of Things devices will grow from around 10 billion connected devices today to as many as 30 billion devices by 2020—an uptick of about 3 billion new devices per year (exhibit). Each of these devices will require, at a minimum, a microcontroller to add intelligence to the device, one or more sensors to allow for data collection, one or more chips to allow for connectivity and data transmission, and a memory component. For semiconductor players, this represents a direct growth opportunity that goes beyond almost all other recent innovations—with the exception, perhaps, of the smartphone.

A new class of components will be required to address this opportunity: system on a chip–based devices produced specifically for the Internet of Things, with optimal power and connectivity features and with sensor integration. First-generation chips are already on the way, although it will probably be a few generations before chips can deliver all the functionality required. Intel, for instance, is releasing a low-power system on a chip designed for smaller products in automotive and industrial environments. This chip also can be used in fitness bands and other wearable devices. Additionally, sensors based on microelectro-mechanical-systems (MEMS) technology will continue to play a significant role in enabling Internet of Things applications.[3]

[3] For more, see Harald Bauer, Sebastian Schink, and Florian Thalmayr, "How big data and connected consumer products could boost the market for MEMS technology," *McKinsey on Semiconductors*, Number 4, Autumn 2014.

Exhibit Some 30 billion objects may be connected to the Internet of Things[1] by 2020.



[1]A networking of physical objects via embedded devices that collect and/or transmit information.

Source: Forecasts derived from ABI Research; expert interviews; Gartner; IDC; McKinsey analysis

It's worth noting that semiconductor players may also be able to profit indirectly from the Internet of Things, since the data generated from billions of connected devices will need to be processed—all those "little" data must be turned into big data—and users will require greater storage capacity, spurring new demand for more servers and more memory. Building on an existing market, semiconductor companies can continue to provide the critical devices and components that are at the heart of these products.

The question, then, is no longer if the Internet of Things can provide substantial growth for semiconductor players; the real consideration is how best to capitalize on the trend. What are the critical challenges or inhibitors? What are the possible enablers for growth and adoption? Our research and discussions with semiconductor executives have helped us identify potential challenges in two critical areas—technology and ecosystem development.

The technological challenges

Semiconductor players may need to invest heavily to adapt their chip designs and development processes to account for specific Internet of Things system requirements. For instance, because many applications would require devices that are self-sustaining and rely on energy harvesting or long-life batteries, semiconductor companies must address the need for optimal power consumption and outstanding power management in their products. Connectivity load will be another critical concern, since hundreds or even thousands of devices may need to be connected at the same time. The average smart home, for instance, may contain 50 to 100 connected appliances, lights, thermostats, and other devices, each with its own low-power requirements. Existing connectivity solutions such as standard Bluetooth or Wi-Fi will probably not be able to meet smart-home requirements given their power and network limitations.

Manufacturers may also need to emphasize flexible form factors to a greater degree than they currently do. Components must be small enough to be embedded in today's smart watches and smart glasses but also amenable to further shrinking for incorporation into still-unidentified future products. And security and privacy issues absolutely must be addressed. Internet of Things devices will not be used for critical tasks in, say, industrial or medical environments if connectivity protocols have not been established to prevent hacking, loss of intellectual property, or other potential breaches.

Semiconductor players are moving full steam ahead to address some of these challenges. Their efforts in two areas in particular are highly encouraging.

Increased integration. Some semiconductor players are already considering investing in new integration capabilities—specifically, expertise in packaging and in through silicon via, a connectivity technique in electronic engineering, as well as in software development. The emergence of more integrated system-in-package and system-on-a-chip devices is helping to overcome some of the challenges described earlier, in part by addressing power, cost, and size factors. The trend toward multidimensional chip stacking and packaging (2.5-D and 3-D integrated-circuit, or 2.5DIC and 3.0DIC, devices in particular) has resulted in integrated circuits that are one-third smaller than standard chips, with 50 percent lower power consumption and bandwidth that is up to eight times higher—at a cost that can be up to 50 percent lower when compared with traditional systems on a chip of the same functionality. Monolithic integration of MEMS sensor technologies with complementary metal-oxide semiconductors is considered unlikely for Internet of Things applications. In these instances, the integration of substrates with silicon requires making certain design trade-offs and optimizing both the sensor and the logic circuits. Instead, we expect to see 2.5DIC and 3.0DIC technologies being favored for Internet of Things–specific integrated circuits.

Connectivity standards. The current cellular, Wi-Fi, Bluetooth, and Zigbee specifications and standards are sufficient to enable most Internet of Things applications on the market. Some applications, however, will require low-power, low-data-rate connectivity across a range of more than 20 meters—an area in which cellular technologies and Wi-Fi often fall short. New technologies that target this need are emerging from players such as those in the Bluetooth and

Weightless interest groups. The latter is an industry group comprising technology companies that are exploring the use of free wireless spectrum to establish an open communications protocol. Such standardization efforts will enable Internet of Things applications that require broadly distributed sensors operating at low power over low-cost spectrum—for instance, temperature and moisture sensors used in agricultural applications.

The ecosystem challenges

As Joep van Beurden, the chief executive at CSR, notes, only about 10 percent of the financial value to be captured from the Internet of Things trend is likely to be in the "things"; the rest is likely to be in how these things are connected to the Internet (see "Making connections: An industry perspective on the Internet of Things," on mckinsey.com). The semiconductor players that focus primarily on the things themselves should therefore find ways to support the development of a broader ecosystem (beyond silicon) and find their niche as both enablers and creators of value for their customers and their customers' customers. This will mean developing partnerships with players further downstream, such as companies that are building and providing cloud-based products and services.

It will be important for semiconductor companies to remember that different industries are at different levels of maturity and complexity with respect to the Internet of Things—so the roles that components manufacturers can play in application development in certain industries will vary, as will the timing of growth opportunities. The market for home-automation tools, for instance, has established some common APIs, but competing standards remain. A number of application developers have already started generating monitoring products for consumers, and once standardization issues can be addressed, the market may experience significant growth rather quickly. By contrast, the markets for monitoring and control systems in factories and for beacon technologies in retail are much more fragmented and will therefore take longer to develop. In retail, for instance, all the players in the value chain—the stores, the data aggregators, the Internet service providers, and other partners—must sort out their roles and standards of operation before beacon-technology providers can approach them with a clear customer value proposition and business model.

In these instances, semiconductor companies may want to test the waters by forming alliances with hardware companies, systems players, and customers or by finding ways to assist in developing standards. In the factory-monitoring-systems market, for instance, players are attempting to create common standards (through the Industrial Internet Consortium initiative, for example, and the Europe-only Industry 4.0 initiative), even though most of the hardware platforms are still proprietary, as are the data, which reside in legacy systems. Semiconductor players that pursue alliances and standard-setting activities may be able to play an enabling role in defining best practices in Internet of Things privacy, security, and authentication—issues that will be critical in markets, such as healthcare and wearables, that are dealing with sensitive consumer data.

Given the potential 90 percent distribution of value to players that provide all the technologies "beyond" the silicon, there may never be a compelling enough business case for components manufacturers to develop individual chips and systems for hundreds of thousands of discrete Internet of Things industry applications. We believe semiconductor players should instead design a family of devices that are sufficiently flexible to cater to the needs of multiple industries—that can be used in industrial *and* consumer Internet of Things applications that boast similar characteristics. Our work suggests that these devices will probably fall somewhere along a continuum of application requirements—at one extreme, high-power, high-performance, application-processing Internet of Things devices, such as those embedded in smart watches, and, at the other extreme, low-cost, ultralow-power integrated sensors that support sufficient (but not excessive) functionality and autonomous device operation. To achieve this level of design flexibility and to address the opportunity properly, semiconductor players may need to rethink their approach to product and application development.

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The challenges associated with the Internet of Things are many; semiconductor executives should consider ways to integrate new development models, process capabilities, and go-to-market strategies in their existing operations. Success will require bold moves, boards that are willing to bet on unfamiliar models and activities, and collaboration with those that are developing industry standards. But the semiconductor industry should embrace this era of innovation and reinvention. The opportunities for growth outweigh the challenges, as components manufacturers explore the creation of a new class of Internet of Things–enabled semiconductors that can cut across a wider swath of potential customers than existing components can. The sector may be on the cusp of unit growth similar to the surge it experienced with the smartphone—and perhaps an even greater jump. □

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