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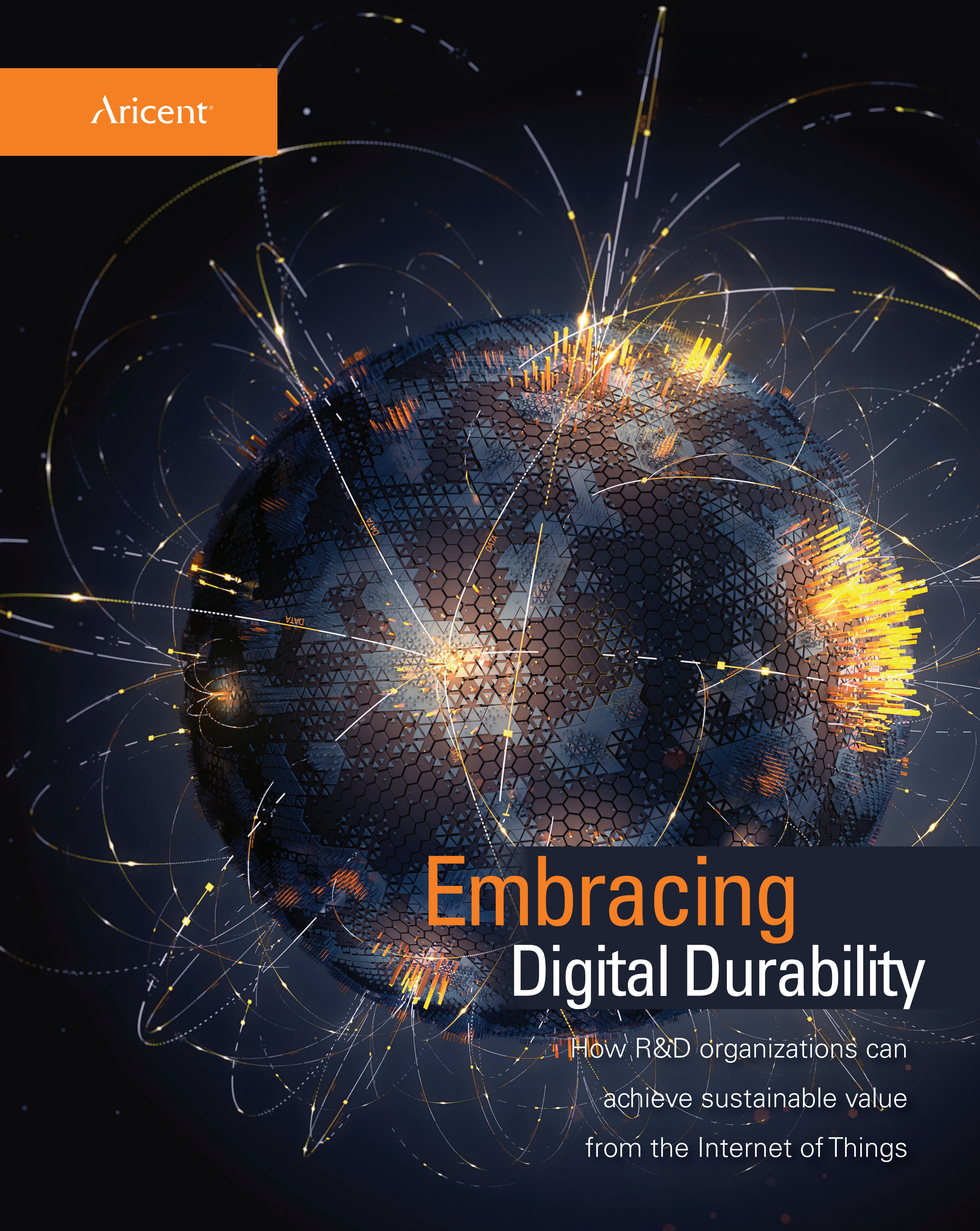


Embracing Digital Durability

How R&D organizations can achieve sustainable value from the Internet of Things

Foreward

It's not enough to embrace the new digital era. The existential challenge for companies today is to become digitally durable—to anticipate disruption and to be prepared to transform processes and products to compete on outcomes.[1] Whether it's understanding the profound impact of self-driving cars on transportation or being a part of the smart-energy revolution, simply closing the digital gap is no longer sufficient.

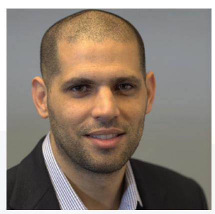
At the epicenter of the transformation is the R&D organization. R&D is responsible for innovating the design, development, and support of the company's products and services as the implications of Industry 4.0[2]—specifically the Internet of Things (IoT)—become a reality. Designers and engineers must not just stumble on a hit but systematically arrive at compelling offerings that generate sustainable value from digital technology.

Evidence of the digital disruption is all around us. Light bulbs, for example, are intelligent nodes in our homes and offices that help us save on energy costs. Meanwhile, the auto industry is scrambling to prepare for a future where vehicle ownership is a service. General Motors' response: a $500 million investment in the Lyft peer-to-peer ride-sharing network and a new strategic focus on creating an on-demand network for autonomous vehicles.[3]

In the telecommunications sector, companies such as AT&T, Verizon and Vodafone are reacting to fierce competition from the likes of Apple, Alphabet and Samsung as they vie for control of the customer experience both at home and on the road. US cable and satellite operators are on the defensive as "unlock the box" proposals are emboldened through digital services as an alternative to costly leased set-top boxes.[4]

Aricent's research, detailed in "Technology Vision 2016," shows that successful companies are pursuing an R&D paradigm that allows them to compete aggressively on outcomes.[5] These companies have a culture that anticipates disruption to create sustainable value from Internet of Things. They are digitally durable.

Frank Kern, CEO



Walid Negm, CTO

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The Pillars That Define the Digitally Durable Culture

The most innovative companies have an R&D organization that operates as part of a circular value chain. By closing the loop among sales, manufacturing and operations, these companies stimulate the evolution of products through market feedback, among other things. Now, leaders are not only gaining insights from the market but also developing cultures that enable anticipatory senses—and, hence, their companies are becoming more digitally durable.

In its most recent annual report, Amazon reminded its shareholders of its three "dreamy" businesses: Amazon Marketplace, Amazon Prime and Amazon Web Services. These offerings have a number of traits—customers love them, they are capable of growing and show a "potential to endure for decades."[6]

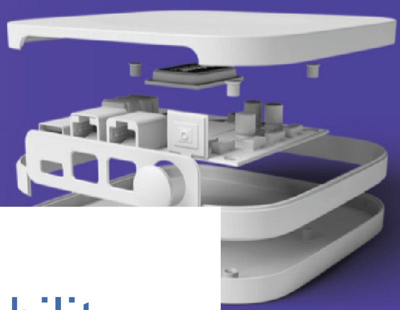
Winning offerings must also be agile and proactive. Aricent's experience in R&D and product development for some of the world's most pioneering companies reveals a culture that anticipates disruption in an era that is inherently digital and shaped by the Internet of Things (see figure 1 on page 4). Such a culture demonstrates:

Intense customer affinity. Products and services must exceed customer expectations, offering richer, deeper, more personal experiences that lead to long-term relationships. Arguably the most enduring example of intense customer affinity in the last decade is the Apple iPhone. Today, Apple is extending the iPhone's reach into the automotive market with CarPlay.[7]

Nimble product development. The R&D organization must be ready and willing to change direction quickly in response to markets that are increasingly digitally contestable.[8] The news today includes countless examples of anticipatory business reorganizations. One that stands out is General Electric's bet on the Industrial IoT and its creation of GE Digital.[9] The new unit, led by a chief digital officer, brings together GE's software center and its global IT and commercial software teams with its Wurldtech unit, which provides industrial security systems.

R&D learning loops. Value needs to be delivered on software-centric, programmable and connected platforms so digital services can be launched quickly and upgraded seamlessly. Tesla Motors epitomizes the idea of R&D learning loops. In 2014, the electric car company issued a recall notice to its 29,000-plus Model S owners for overheating charger plugs, and then applied the fix over the air.[10] Around the same time, GM issued a similar fire-related safety recall that required a software update. However, despite OnStar telematics, these owners had to take their vehicles into a dealership for the update. As a result, GM incurred a warranty labor expense on all 370,000 recall service appointments.

Long-tail innovation versatility. Finding success in IoT requires a willingness to experiment in niche and industry-specific applications. Moreover, in these early days, pioneers are thinking very differently to uncover niche opportunities. Today, for example, 95% of the world's population is covered by cellular networks, representing just 10% or about 15 million square kilometers of the earth's land area. Beyond this, expanding coverage through conventional terrestrial cell towers does not make commercial or financial sense to service providers. One novel approach to extending LTE connectivity to remote and underserved markets is Google's Project Loon. In partnership with telecommunications companies, Google is experimenting with a network of high-altitude balloons to connect people and things to the Internet.[11]



Four R&D Trends That Enable Digital Durability

Intel, GE, Tesla and Google are among the many companies that embody digitally durable culture. Aricent's "Technology Vision 2016" highlights four R&D trends that innovators are pursuing to shape their R&D agenda and create sustainable value.

01. Drive smart outcomes with smart services. Smart outcomes are about delivering exceptional customer experiences that create affinity and set the course for business growth. Two essentials for delighting the customer are pervasive platform thinking and human-centered design.

02. Design for billions of things. Building the infrastructure for hyper-scaled IoT means that suppliers and vendors must take full advantage of software-definition and open hardware, which accelerate time to market, upgrade services quickly and seamlessly, and focus on software-defined security.

03. Navigate unconventional connectivity. There is no dominate architecture for IoT. Survival of the fittest is how the market will select the standards and protocols that will orchestrate IoT devices and applications. It's imperative to participate in fast-moving technology developments, from high-altitude drones and narrow-band, low-latency spectrum options to the choice of custom chips.

04. Innovate beyond silicon. The exponential growth of smaller, faster and cheaper chips is showing signs of diminishing marginal rates of return. Companies can continue to accelerate the pace of innovation by tapping complementary technologies, such as specialized chips, sensors

Because they are in step with the pillars shaping corporate culture, Aricent believes these trends will enable companies to exceed customer expectations and to architect dynamic infrastructures, networks and components that will lead to digital durability. Taken individually, these R&D practices are valuable tools that help technology leaders focus on keeping pace with change. Taken together, they are the foundation on which R&D organizations and product development processes are built to be digitally durable.

Figure 1

The R&D Framework for Achieving Digital Durability

01

Drive Smart Outcomes With Smart Services

The Internet of Things matters because it enables companies to apply machine learning models and algorithms to large data sets to derive insights that generate new revenue streams.[12] Whether it's ccorrelating multiple sensor data streams to detect the onset of engine failure, optimizing the energy usage of a building's HVAC system or understanding the tone of a driver's voice while the vehicle is moving, the value is in the data. It takes smart services to interpret both sparse and rich data then turn it into actionable insights that solve industry-specific challenges.

> "At the heard of the outcomes economy are smart services that enhance the relationship between people and machines"

Entirely new business models are emerging, where the customer pays for these actionable insights—the outcomes—rather than for a product or service. One company that is embracing this trend is General Electric.[13] GE Digital is working on technology solutions that analyze streams of data collected from sensors attached to industrial equipment. Customers take advantage of algorithms that understand and explain the performance of their assets and operations, and then take automated actions that optimize that performance and improve productivity.

For example, GE estimates that its airline customers can save, on average, $7 million worth of jet fuel annually because the information it provides makes jet engines more efficient. GE's Predix machine-learning platform determined that washing these engines more frequently in hot climates reduces maintenance and increases their lifespan. The company believes it can move to outcomes-based pricing for such services and away from today's break-fix business model. Moreover, if GE can keep a customer's equipment running at a certain agreed upon threshold—providing a smart outcome—that customer would be willing to pay GE a bonus. GE would benefit from outcomes-based pricing even if the company doesn't make the equipment it monitors.

At the heart of the outcomes economy are smart services that enhance the relationship between people and machines. Wearable devices, for example, help workers in hazardous locations understand and monitor their surroundings to keep them safe.[14] Artificial and virtual reality devices for gaming and productivity applications provide fully immersive experiences that blur the physical and the virtual. Consider the heads-up displays (HUDs) that automakers and aftermarket companies are developing. HUDs must be designed to minimize driver distractions while providing actionable information on the windscreen. In some cases, voice-activated commands may be the optimal interface for safe driving. HeadsUP!, a startup working with Amazon, has launched an aftermarket HUD that collects data through a driver's smartphone, and then projects speed, weather and navigation information on the windscreen.[15]

These types of smart services must be engineered from the customer to the chip. The service's design must be inspired by the human experience and in the context of the user's environment and needs. To achieve this, technology leaders must embrace two phase shifts in their product development: pervasive platform thinking and human-centered design.

Pervasive Platform Thinking

AT&T, BMW, GE, IKEA, Intel and other digitally durable companies know they must turn products into digital platforms. These platforms combine hardware, software, connectivity and intelligence, and they are connected through open and extensible application programming interfaces (APIs). Although APIs are nothing new, they are now a must-have for an R&D roadmap that can anticipate the future sources of value in a digital ecosystem.

For example, Honeywell recently introduced an API program that enables its connected products to talk to other IoT devices and the cloud.[16] Intel's RealSense developer library for visual analytics enables the underlying chip to become the platform on which developers build applications.[17] Similarly, Apple's HomeKit for smart-home application developers has been gaining adherents among chip companies such as Broadcom and MediaTek, both of which have released software development kits for their hardware platforms that are compliant with HomeKit.[18] GE, too, has introduced IoT-enabled LED bulbs that are HomeKit compatible.[19]

Of course, APIs must be locked down with strong authentication and encryption. There are growing examples of connected products becoming a window of opportunity for adversaries that find their way into a home camera, an assembly line or a car's power train. Any company that wants to succeed in the Internet of Things, should see itself as a leader in three security & privacy capabilities: digital trust, safety standards, cyber-physical security-- all in the context of hyper-scale connectvity.

Design Inspired by the Human Experience

Hardware and software are the building blocks of IoT, but good design is the differentiator that delivers a compelling user experience. Good design resonates with customers on a very fundamental level—it's about personalization, simplicity and intuitive interactions. If it's done well, design will drive both customer engagement and sustainable growth. Good design puts humans at the center of the product development process and starts by an immersive assessment of the ecosystem's people, processes, culture and technologies to support customer engagement.

Over the last 10 years, design-led companies have maintained a significant stock market advantage, outperforming the S&P by 219% in 2014, according to an annual report by the Design Management Institute.[20] The report also noted the emergence of a new set of potential design leaders, including Amazon, GE, Google, Honeywell and SAP.

Honeywell, for example, collaborated with third-party design firms to develop Lyric, a connected temperature control system that competes against Google's Nest automatic thermostat [21]. Lyric connects to a user's smartphone and uses geofencing to automatically set the home's temperature. By tracking the phone's location, Lyric knows when to turn down the heating or cooling; it then brings the home back to a set temperature when the user returns. The display turns on when Lyric's proximity sensor detects the user's approach, showing the current temperature and the pre-set temperature. It casts a blue glow when cooling, an orange glow when heating and a green glow when in energy-saving mode.

A key challenge for R&D leaders is to find ways to mesh the user experience with engineering know-how.

Takeaways

01. — Put the user experience at the center of the product development life-cycle.

02. — Expect no dominant IoT architecture for engineering IoT products and services.

03. — Get ahead of cyber-physical threats and build digital trust into connected products and smart services

02

Designing for Billions of Things

Soon billions of devices will sense, analyze, communicate and transact with each other and with us.[22] Gartner estimates that more than 20 billion connected devices will exist by 2020, exchanging what some say will be 1,000 exabytes of information over networks.[23] That's not so farfetched when you factor in video and virtual reality, as well as sensors in traffic lights, elevators, home appliances and smart factories.[24]

Designing for IoT requires innovation across silicon vendors, equipment makers and service providers that are on the receiving end of large volumes of interactions.

Even today we have glimpses of the scale of things. Consider Visa's Ready Program, a contextual commerce service that enables everyday things, such as automobiles, home appliances, clothing and other connected devices, to pay for services.[25] Medical equipment company Proteus Digital Health has developed an ingestible sensor that measures whether patients' have taken their medication.[26] View, a smart window maker, uses sensors and a smartphone app to tint window glass on demand, reducing energy use and the need for blinds.[27]

Regardless of the projections, such hyper-scale systems must be factored into the design and development of the infrastructure that will support the IoT economy. Much has been written about the design of hyper-scaled systems. Take, for example, the need to get work done by designing through micro-services—small pieces of software that talk to talk more efficiently to each other. Or leveraging the design principles of compute and network virtualization so a cellular core packet network architecture can be designed to handle millions of smartphones and billions of IoT endpoints.

Designing for billions of devices (and connections) requires innovation across the ecosystem of silicon vendors, equipment makers and service providers that are on the receiving end of large volumes of interactions. The future of the systems and the infrastructure for all of these sectors depends on expertise in designing three fundamental capabilities: software-definition, open hardware and service velocity.

Design for Software-Definition

Today, owners of smart homes can use the IFTTT language to create a rule that instructs a window to open if the temperature rises above a certain threshold. Amazon's Alexa digital assistant can do the same thing using voice commands.[28] The potential of defining everything—hardware, services and equipment—as programmable and versatile software assets started almost a decade ago, when Amazon Web Services introduced the world of IT to "elastic" CPUs, networks, compute cycles and storage that maximize utilization according to varying workloads.[29] Now, AT&T and other telecommunications providers are banking on software-defined networking (SDN) as the lynchpin to their success in IoT. In fact, AT&T has stated that by 2020, 75% of its network will be not only virtualized but also programmable.[30] The anticipation of billions of things means software-centric architectures will greatly influence R&D road-maps. That includes the next generation of switching and routing, data center operating systems or container services that orchestrate IoT applications which expect very large work-loads.

There is, however, a downside when everything is programmable; everything becomes hackable—from nuclear power plants to cars and baby monitors. Consider the smart thermostat, which is reachable at a distance through an API over the Internet. The fact that a hacker can find a way into the embedded operating system need not translate into a takeover, though. The onboard software can take advantage of virtualization to compartmentalize critical functions, such as resetting the firmware. An industrial equipment field device, such as a programmable logic controller, also can defend itself, incorporating intrusion tolerance techniques to deceive an attacker. The introduction of these and other more advanced software-defined security countermeasures will be necessary when billions of things are turned on.

Design for Open Hardware

The idea of taking advantage of commodity hardware has been driven in large part by Facebook, Yahoo and Google in their efforts to bring down datacenter costs.[31] The approach is to abstract complexity through software, and then leverage application-specific integrated circuits (ASICs) to build simple, standards-based hardware. Hyper-scaled datacenters are being constructed using clusters of x86 CPUs that are connected by enormously scalable networks and powered by SDN controllers and standard arrays of storage. Microsoft and others are using open hardware as a leverage point in their cloud businesses.[32]

At Facebook, the company depended on inflexible, expensive proprietary systems and hardware. It launched the Open Compute Project to power its datacenters using less expensive, interoperable building blocks. Recently, Facebook co-founded the Telecom Infra Project (TIP) to reimagine global connectivity by opening up the deployment of telecom infrastructure from access, back-haul and core systems.[33]

Every service provider, device maker and OEM should take a cue from the open hardware movement to find ways to differentiate their products and services by decoupling software and hardware. AT&T, for example, has already built out white-box networking nodes that are a hybrid of open-source and off-the-shelf technology. The company believes the economics, scale, performance and programmability of bare metal switching makes sense for its customers.[34]

Open hardware links directly to open-source software. Indeed, open source is a significant technology disruptor and proof that vendors are rethinking their business models for hardware platforms. Open-source communities managed by the Linux Foundation and others have seen tremendous growth—and acceptance—within both software and hardware development communities to deliver network solutions.[35] OpenStack, an open-source software platform for cloud computing, has developed as an industry-accepted cloud platform that works across multiple hypervisor environments.[36]

Design for Service Velocity

Thinking and acting fast has always been a competitive advantage. Both will be paramount as we look to the promise of 20 billion connected devices and their insatiable data consumption. Deploying software infrastructure and digital services in an optimally controlled and risk-free manner is necessary to meet the scalability and growing demands networks face. The philosophy of continuous delivery and integration, while ingrained in the cultures of software companies, is still nascent in other industries, such as telecommunications, industrial equipment and automotive.

To support the scalability of millions, if not billions, of virtual things into their business models, R&D organizations need to think about how they can accelerate service introduction. There will be complexity in the integration and interoperability of these systems.

The architecture of end-to-end solutions through third-party IoT platforms can facilitate smoother service lifecycle management. For example, Verizon's ThingSpace is designed to make it easier for developers to roll out IoT devices and applications.[37]Cisco's recent acquisition of Jasper Technologies, another IoT platform that targets service providers, will help the company launch, manage and monetize IoT services on a global scale.[38]

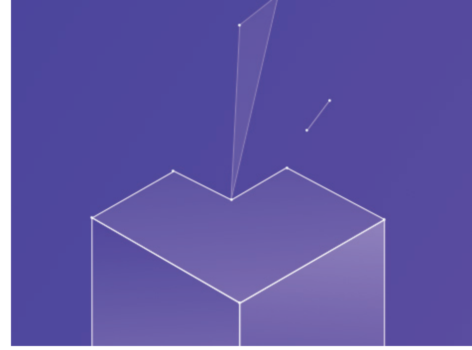
Takeaways

01. Make the end customer experience the source of differentiation in products and services.

02. Revisit supply chain risk management for disaggregated open hardware and software components.

03. Understand the impact on R&D processes of closed-loop learning mechanisms.

03



Navigate Unconventional Connectivity

The playbook for a hyper-connected world is still under construction. With nearly two-thirds of the world's 7 billion people already connected—and about half of those by smartphones—the next big growth opportunity is to connect people and things.[39] One challenge for service providers like AT&T, Verizon, and Vodafone that are connecting devices to their networks is that things don't communicate the same way humans do. This is prompting a change in the roles and relationships among the companies competing for long-term relationships with their customers.

> "Although 5G is expected to address millions of low-power devices, it's still a few years away from standardization and deployment."

AT&T Digital Life, BMW Connected Drive and Google Fiber are blurring industry lines. AT&T is a telecommunications company that has become a credible content provider with its DirecTV acquisition.[40] BMW is an automaker that is becoming a digital platform company.[41] Google now finds itself providing telecomservices.[42] As industry lines dissolve, each participant's value in the chain will be redistributed as the digital technologies lower the barriers to entry.

Engineers and designers will be faced with often competing alternatives to connect the Internet of Things. They must be nimble enough to anticipate the evolution and intersection of at least these three scenarios: heterogeneous connectivity expansion, telecom model dominance and novel connectivity options.

Open Connectivity Will Win

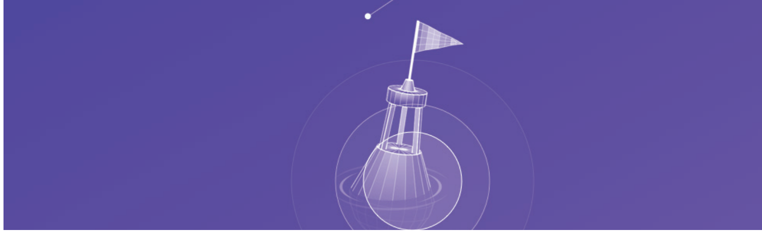
Spectrum wars may be somewhat moot when it comes to IoT. One reason is that the high power requirements of conventional cellular connectivity make the owned spectrum impractical for low-power, low-latency applications. Another gating factor is that conventional cellular networks are not optimal for short-range connectivity, where a significant percentage of IoT devices will operate.

Consider the automotive industry's approach to the short-range connectivity challenge. Cars are being designed to talk to nearby cars (vehicle-to-vehicle) and to road infrastructure (vehicle-to-infrastructure) such as smart connected traffic lights and road signage. This is happening now, not on conventional cellular networks but over unlicensed spectrum in the upper 5 GHz band using an extension of the IEEE 802.11 standard, which is also the basis for Wi-Fi.

In addition, the rising volume of things that need to connect are not yet compatible with traditional carriers' business models, specifically in terms of pricing. One company that is navigating this roadblock is Proton. This IoT startup has developed an IoT communications module called Electron, which includes a cellular radio and a built-in data plan. By positioning itself as a mobile virtual network operator, Proton has negotiated data plans on behalf of customer companies that need to ship connected products.[43]

Although 5G is expected to address millions of low-power devices, offering speeds 100 times faster than LTE, it's still a few years away from standardization and deployment.[44] In the meantime, a variety of low-power, wide-area (LPWA) alternatives are vying for attention, including LTE Category 0, Ingenu, Sigfox and Zigbee. Ingenu plans to cover 30 US metro markets with its machine network, which uses random phase multiple access (RPMA) technology, by the end of 2016[45] (see figure 2, on page 10).

Being open to a variety of connectivity alternatives is prudent. For example, industrial companies typically have an installed base of equipment that lasts for decades. Vintage equipment requires custom sensor networks and industrial strength Ethernet to monitor turbines, mining equipment or assembly lines. New additions require newer connectivity solutions.



Telecom Model Dominates

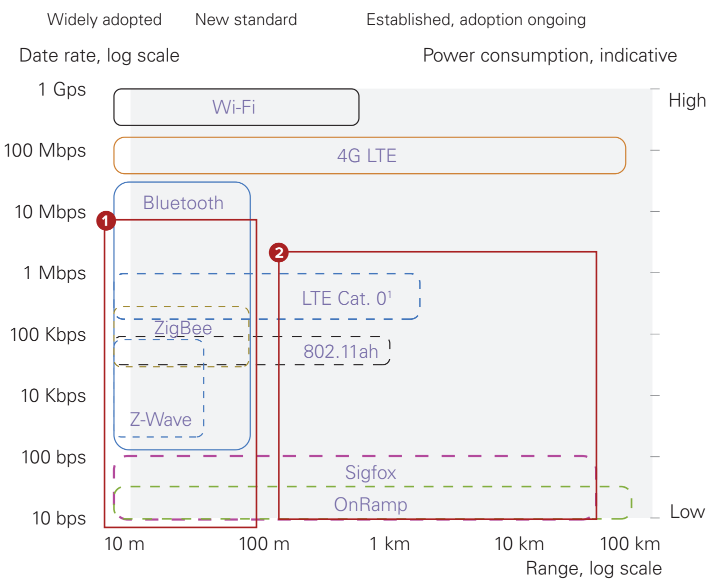
As IoT use cases emerge in smart factories, as well as in connected homes and cars, the telecom industry is finding itself operating on a number of fronts to both defend its turf and expand its reach. In the future, 5G will be perhaps the most attractive connectivity platform offered by carriers because it promises to take latency down to 1 millisecond. This will be essential in financial transactions, as well as in telepresence for medical applications, social virtual reality platforms and self-driving cars.

Until 5G is available, carriers have a strong value proposition in 4G/LTE. This includes an unconventional game plan that takes advantage of the extremely low data usage patterns of low-power devices by pulling together techniques that enable IoT data to piggyback on existing spectrum. By using slow transmissions—data rates measured in bits per second—connections can be established across long distances by operating on limited power. Asset tracking, fleet management and security alerts are some of the target.

Figure 2

Stiff Competition for IoT Connectivity Standards

Standards for the Internet of Things (IoT) are not mature in many categories, including connectivity.



1 Many competing standards for low-range, medium-low data rate hinder growth for many IoT applications
- Interoperability missing
- Consortia wars might be emerging
- Additional incompatibilities in higher communication layers, eg, 6LoWPAN vs ZigBee

2 Standard white space for low-data-rate, low-power, high-range applications such as smart grid
- Wi-Fi and LTE have high power consumption
- Alternatives with low power and wide range (eg, LTE Cat. 0, 802.11ah, Sigfox and OnRamp) are in very early stages and compete against each other

* Preliminary specifications.

Source: Company websites; expert interviews; GSA and McKinsey IoT collaboration; press research

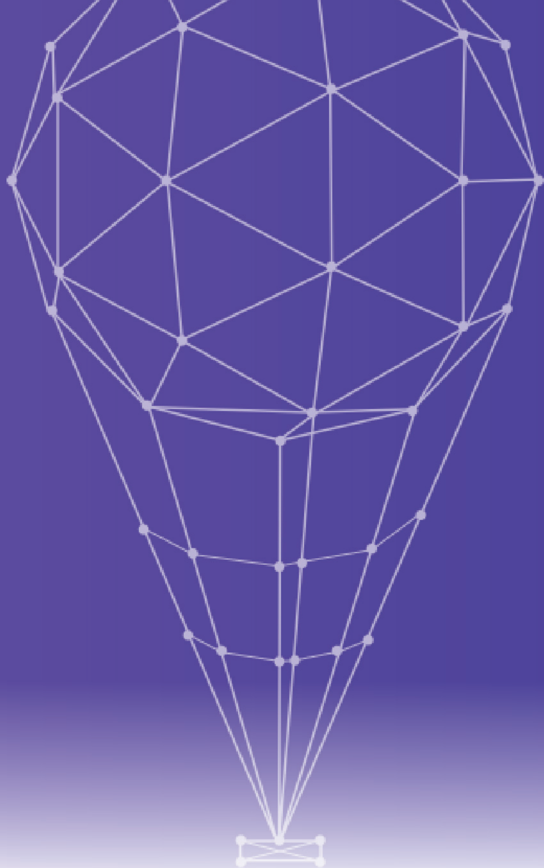
McKinsey & Company

The 3rd Generation Partnership Project (3GPP) has nearly completed its NarrowBand-IOT (NB-IOT) specification, which can handle about 100,000 devices per cell and is 100 times better than standard LTE capacity.[46] NB-IOT features narrowband-based LTE technology with extremely low power consumption, deep coverage and multiple points of connection. The approach is expected to take the cost per connection to a level that is profitable for carriers.

On yet another front, carriers are vying to coexist with Wi-Fi. LTE-Unlicensed (LTE-U) and LTE-License Assisted Access (LAA) tap into the Wi-Fi spectrum within factories, venues and office buildings.[47] License-exempt strategies are a way for carriers to keep their customer relationships. For example, Verizon is running LTE-U tests with chipmaker Qualcomm and Deutsche Telekom completed a trial using LTE-LAA in Nuremberg last year.[48]

Novel Connectivity Options

Not all innovation revolves around telcos and their core networks. Facebook, Google, OneWeb, SpaceX and others are experimenting with alternatives to terrestrial cell towers, as a way to eventually connect every person—and thing—on the planet to the Internet.[49] Both Facebook and Google are exploring high-altitude platforms (HAPs) that operate in the stratosphere, well above the flight patterns of aircraft. Facebook is testing a Boeing 737-sized drone called Aqila, while Google's Loon project is using helium balloons equipped with solar-powered wireless transmitters.



OneWeb and SpaceX have plans to launch constellations of very small, very low-earth orbit Internet satellites—about 750 miles above the planet. That's a fraction of the distance from earth of the current generation of Internet-specific satellites. The lower orbit will improve latency.

IoT growth also requires innovation in micro-electronics. System-in-a-Package (SiP) and System-on-a-Chip (SoC) technologies are the leading contenders for delivering life support in very small form factors for IoT devices that require ultra-low power for long battery life (see "Trend #4: Innovating Beyond Silicon," on page 12).

The semiconductor industry will continue to search for killer apps built around common standards that justify the risk and cost of investing in new design capabilities and fab capacity.[50] As an example, consider the number of competing connectivity standards on the market for devices with a low range and a medium-to-low data rate: Bluetooth, LTE Category 0, ZigBee, and others.

All of the key players across the IoT value chain need to experiment and accept a degree of uncertainty. They must plan for a scenario in which niche and vertical applications do not produce a dominant architecture for IoT in the foreseeable future.

Takeaways

01. — Experiment with emerging technologies and monitor where consensus is building around technologies and standards.

02. — Find the opportunities in low-power, wide-area, low-latency and close-proximity connectivity.

03. — Expect a proliferation of competing standards and protocols before the market coalesces.

04

Innovate Beyond Silicon

Recently, Marc Andreessen projected that within 20 years ambient computing will be a reality. Every physical item—every table, every wall, every surface—will be sensing, computing and connecting.[51]

Such ubiquity will require a new generation of semiconductor devices, because semiconductor manufacturing technology is hitting a wall. The laws of physics and economics are imposing limitations on the pace and cost-benefit tradeoff of further transistor scaling. The industry is finding it challenging to make chips smaller and faster, which is the essence of Moore's law.[52]

A new roadmap, called More than Moore (MtM), is gaining momentum.[53] It encourages chip and hardware developers to think beyond the complementary metal-oxide semiconductor (CMOS) trajectory and to consider other technologies in their product development roadmaps. MtM is particularly relevant for IoT application development, given the inclusion of analog sensing technologies and the low-power, low-latency requirements of connected things (see figure 3).

For example, micro-electro-mechanical systems (MEMS)—such as gyroscopes and pressure and motion functions, among others—are critical for virtually all IoT applications. Also, new and innovative packaging technologies, such as layered silicon, will reduce the size of devices and the time circuits need to wait for instructions.

To take full advantage of MtM, the R&D organization should watch three value-seeking opportunities: chip specialization, algorithms and ecosystems.

Find Value in Specialized Chips

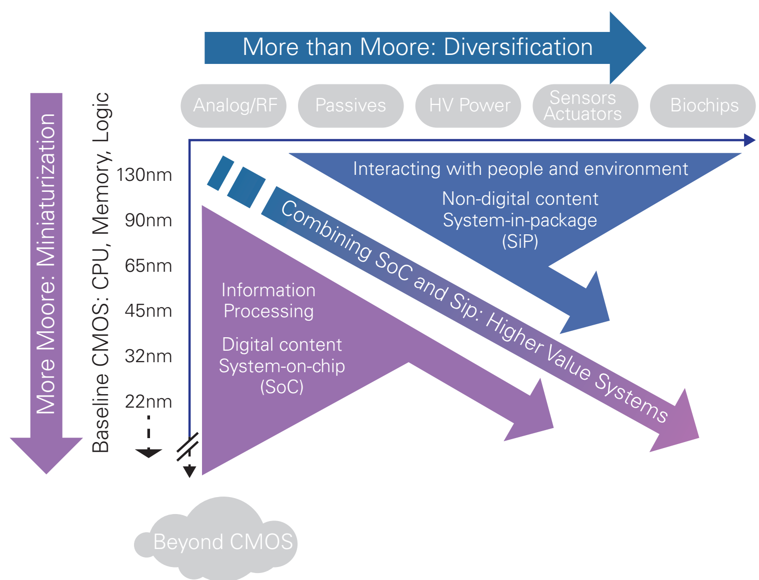
Semiconductor innovation will continue to be a building block for the Internet of Things. Take, for example, Intel's Curie chip, which could be the next 'Intel Inside' product breakthrough. Curie is Intel's answer to the consumer wearables market, a button-sized SiP that includes a processor, flash memory, sensors and Bluetooth low-energy connectivity. Company CEO Brian Krzanich said he thinks Intel can sell hundreds of millions of Curie chips in the athletics sector alone.[54]

Increasingly, the focus is shifting from high-volume ASIC and SoC market opportunities—which were the traditional focus of previous digital eras—to fashioning specialized chips from existing design libraries for niche applications. In 2015, for example, ARM introduced a high-performance 64-bit CPU core, called the Cortex-A35, that is capable of running advanced operating systems such as Google Android, Linux and Microsoft Windows. The company followed up with a 32-bit stripped-down version that targets low-power IoT devices like wearables.[55]

Similarly, Qualcomm recently announced a power-efficient version of its Snapdragon SoC for wearables that combines Wi-Fi, LTE and an integrated sensor hub for richer algorithms.[56] Adesto Technologies re-

Figure 3

Future IoT Chips Require Both More Moore and More Than Moore



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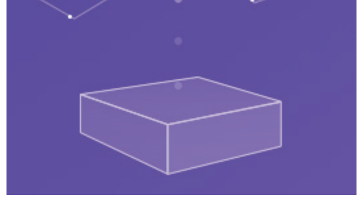

leased a low-power conductive bridging RAM (CBRAM) chip for battery-operated or energy-harvesting devices that temporarily stores data before transmitting it.[57] Niche markets for these products include medical devices, industrial machinery and HVAC systems.

Embedded systems are becoming a major new source of value in the transformation of products into smart services.

Complementing chip specialization is a need to ensure greater security. Anything that is connected can be reached, and potentially breached. Manufactures of IoT devices and systems are right to demand that chipmakers ensure high security standards for semiconductors. A major security breach, such as the widely reported 2015 Jeep Cherokee hack, could slow down IoT adoption.[58] NXP's latest chip, a low-power 64-bit ARM-based processor, comes with built-in networking-grade security.[59]

Finally, a new breed of merchant ASICs is driving low-cost specialization. These chip suppliers, including Arista, help networking gear makers design their own chips using off-the-shelf silicon from Intel, Cavium and Broadcom.[60] Downstream in the value chain, service providers, network equipment providers and enterprises are loading software—primarily open source—onto the merchant silicon-built hardware.

Find Value in Algorithms

In the 1990s, Rolls-Royce changed its business model from selling jet engines to selling miles and competing on outcomes. Algorithms ingested streams of data from a multitude of sensors to forecast the likelihood of wear and tear, to anticipate the maintenance of individual engine components and to calculate the cost per mile for the customer. In so doing, the company transformed its engagement with customers from a product relationship to a service relationship.[61]

Although embedded systems are nothing new for industrial equipment makers, they are becoming a major new source of value in the transformation of products into smart services. Companies that think they sell hardware should shift to selling services, which will require developing new business models, talent and partnerships.

The value creation opportunity in software lies squarely in the realm of artificial intelligence and proprietary algorithms. Advanced Driver Assistance Systems are a good example of algorithms that learn, reason, experiment and act with a goal in mind. Apple's HomeKit, ARM's mbed, Google's Brillo and Samsung's Artik exemplify pioneering IoT platforms that take advantage of machine learning.

A recent Accenture study captured the power of algorithms for managing costs, improving the customer experience and increasing revenue.[62] The company analyzed 30 pilot projects at early technology adopters that were using machine-learning algorithms, including anomaly detection, natural language, predictive analytics and visual sensing. In one pilot, a consumer food company machine-reengineered the delivery of its products using a collision avoidance system with an intelligent vision sensor. The system scans the road while applying computer-vision algorithms, and then sends alerts to the driver. The project resulted in a marked reduction in accidents and delays, with implications for cost, revenue and on-time delivery.

Artificial intelligence makes up a significant strategic push for industry pioneers. For instance, SpaceX and Tesla founder Elon Musk, LinkedIn's co-founder Reid Hoffman and corporate backer Amazon, among others, have contributed to a $1 billion investment in a new Artificial Intelligence Research Center.[63] The goal, Musk said, is to create "artificial general intelligence," where a machine would be capable of performing any intellectual task that a human can.

Find Value in Ecosystems

As companies find their place in the IoT market, the development of ecosystem partnerships is proving to be vital for success. Look at any of the major use cases to date—Intel's IoT developer's kit and Microsoft's Azure, for example—and the importance of the ecosystem becomes apparent. Whether companies are developing software, hardware or connectivity, it takes a community to create smart services that deliver smart

outcomes. Having a strong anchor company with clear goals at the center of the ecosystem is a necessary, if not sufficient, condition for success.

GE Digital is a good example.[64] Its Alliance program was initiated to drive development of the company's Predix IoT platform. GE has been developing Alliance since the new unit was announced in September 2015. Cisco, Accenture, AT&T and Vodafone were early partners, and Intel, Infosys, TCS, Deloitte Digital, Softtek and Wipro have recently joined. Alliance members will be able to work much closer with GE's Predix platform as a service for the more industrial Internet of Things. ■

Takeaways

01. — Leverage Moore's law but exploit complementary technologies to power IoT developments.

02. — Develop expertise in algorithms for IoT applications that deliver compelling services.

03. — Build and participate in the development ecosystem to seed and grow new markets.

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