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Chapter extract

Ambient computing

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Possibilities abound from the tremendous growth of embedded sensors and connected devices – in the home, the enterprise and the world at large. Translating these possibilities into business impact requires focus – purposefully bringing smarter "things" together with analytics, security, data and integration platforms to make the disparate parts work seamlessly with each other. Ambient computing is the backdrop of sensors, devices, intelligence and agents that can put the Internet of Things to work.

THE Internet of Things (IoT) is maturing from its awkward adolescent phase. More than 15 years ago, Kevin Ashton purportedly coined the term he describes as the potential of machines and other devices to supplant humans as the primary means of collecting, processing and interpreting the data that make up the Internet. Even in its earliest days, its potential was grounded in business context; Ashton's reference to the Internet of Things was in a presentation to a global consumer products company pitching RFID-driven supply chain transformation.[1] And the idea of the IoT has existed for decades in the minds of science fiction writers – from the starship *Enterprise* to *The Jetsons*.

Cut to 2015. The Internet of Things is pulling up alongside cloud and big data as a rallying cry for looming, seismic IT shifts. Although rooted more in reality than hype, these shifts are waiting for simple, compelling scenarios to turn potential into business impact. Companies are exploring the IoT, but some only vaguely understand its full potential. To realise that potential, organisations should look beyond physical "things" and the role of sensors, machines and other devices as signals and actuators. Important developments, no doubt, but only part of the puzzle. Innovation comes from bringing together the parts to do something of value differently – seeing, understanding and reacting to the world around them on their own or alongside their human counterparts.

Ambient computing is about embracing this backdrop of sensing and potential action-taking with an ecosystem of things that can respond to what's actually happening in the business – not just static, pre-defined workflows, control scripts and operating procedures. That requires capabilities to:

- Integrate information flow between varying types of devices from a wide range of global manufacturers with proprietary data and technologies

- Perform analytics and management of the physical objects and low-level events to detect signals and predict impact
- Orchestrate those signals and objects to fulfill complex events or end-to-end business processes
- Secure and monitor the entire system of devices, connectivity and information exchange

Ambient computing happens when this collection of capabilities is in place – elevating IoT beyond enabling and collecting information to using the fabric of devices and signals to do something for the business, shifting the focus from the novelty of connected and intelligent objects to business process and model transformation.

What is the "what"?

The focus on the "things" side of the equation is natural. Manufacturing, materials and computer sciences continuously drive better performance with smaller footprints and lower costs. Advances in sensors, computing and connectivity allow us to embed intelligence in almost everything around us. From jet engines to thermostats, ingestible pills to blast furnaces, electricity grids to self-driving freight trucks – very few technical constraints remain to connect the balance sheets of our businesses and our lives. The data and services available from any individual "thing" are also evolving, ranging from:

- **Internal state:** Heartbeat- and ping-like broadcasts of health, potentially including diagnostics and additional status reporting (for example, battery level, CPU/memory utilisation, strength of network signal, up-time or software/platform version)
- **Location:** Communication of physical location via GPS, GSM, triangulation or proximity techniques
- **Physical attributes:** Monitoring the world surrounding the device, including altitude, orientation, temperature, humidity, radiation, air quality, noise and vibration
- **Functional attributes:** Higher-level intelligence rooted in the device's purpose for describing business process or workload attributes
- **Actuation services:** Ability to remotely trigger, change or stop physical properties or actions on the device

New products often embed intelligence as a competitive necessity. And the revolution is already well underway. An estimated 11 billion sensors are currently deployed on production lines and in power grids, vehicles, containers, offices and homes. But many aren't connected to a network, much less the Internet.[2] Putting these sensors to work is the challenge, along with deciding which of the 1.5 trillion objects in the world should be connected and for what purpose.[3] The goal should not be the Internet of Everything; it should be the network of *some* things, deliberately chosen and purposely deployed. Opportunities abound across industries and geographies – connected cities and communities, manufacturing, retail, health care, insurance and oil and gas.

Beyond the thing

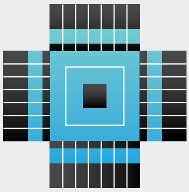
Deliberate choice and purpose should be the broader focus of ambient computing. Analytics is a big part of the focus – turning data into signals and signals into insight. Take transportation as an example. Embedding sensors and controls in 24,000 locomotives, 365,000 freight cars and across 140,000 miles of track supporting the United States' "Class I" railroads only creates the backdrop for improvement. Moving beyond embedding, companies such as General Electric (GE) are creating predictive models and tools for trains and stockyards. The models and tools optimise trip velocities by accounting for weight,

From the Internet of Things to ambient computing: A concentric system

The Internet of Things lives through sensors and actuators embedded in devices interacting with the world physically and functionally. Ambient computing contains this communication at the core and harnesses the environment for business processes and insights.

Sensors & connectivity

Underlying components allowing intelligence and communication to be embedded in objects.



SENSORS Temperature, location, sound, motion, light, vibration, pressure, torque, electrical current. ACTUATORS Valves, switches, power, embedded controls, alarms, intra-device settings. COMMMUNICATION From near- to far-field: RFID, NFC, ZigBee, Bluetooth, Wi-Fi, WiMax, cellular, 3G, LTE, satellite.

Device ecosystem

New connected and intelligent devices across categories making legacy objects smart.

CONSUMER PRODUCTS Smartphones, tablets, watches, glasses, dishwashers, washing machines, thermostats. INDUSTRIAL Construction machines, manufacturing and fabrication equipment, mining equipment, engines, transmission systems, warehouses, smart homes, microgrids, mobility and transportation systems, HVAC systems.

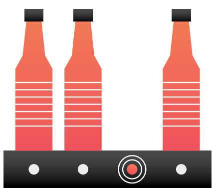
Ambient services

The building blocks of ambient computing and services powered by sensors and devices.

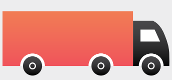
INTEGRATION Messaging, quality of service, reliability. ORCHESTRATION Complex event processing, rules engines, process management and automation. ANALYTICS Baselining and anomaly monitoring, signal detection, advanced and predictive modelling. SECURITY Encryption, entitlements management, user authentication, nonrepudiation.

Business use cases[a]

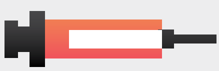
Representative scenarios by industry to harness the power of ambient computing.



BASIC Efficiency, cost reduction, monitoring and tuning, risk and performance management. ADVANCED Innovation, revenue growth, business insights, decision making, customer engagement, product optimisation, shift from transactions to relationships and from goods to outcomes.



LOGISTICS Inventory and asset management, fleet monitoring, route optimisation.



HEALTH & WELLNESS Personalised treatment, remote patient care.

MECHANICAL Worker safety, remote trouble-shooting, preventative maintenance.

MANUFACTURING Connected machinery, automation.

Source: [a] Deloitte Development LLC, *The Internet of Things Ecosystem: Unlocking the business value of connected devices*, 2014, http://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/internet-of-things-iot-enterprise-value-report.html, accessed January 7, 2015.

speed, fuel burn, terrain and other traffic. The gains include faster-rolling trains, pre-emptive maintenance cycles and the ability to expedite the staging and loading of cargo.[4]

The GE example highlights the need for cooperation and communication among a wide range of devices, vendors and players – from partners to competitors, from customers to adjacent parties (for example, telecommunication carriers and mobile providers). The power of ambient computing is partially driven by Metcalfe's Law, which posits that the value of a network is the square of the number of participants in it. Many of the more compelling potential scenarios spill across organisational boundaries, either between departments within a company, or through cooperation with external parties. Blurry boundaries can fragment sponsorship, diffuse investment commitments and constrain ambitions. They can also lead to isolationism and incrementalism because the effort is bounded by what an organisation directly controls rather than by the broader analytics, integration and orchestration capabilities that will be required for more sophisticated forays into ambient computing. Ecosystems will likely need to evolve and promote industry standards, encourage sharing through consortia and move away from proprietary inclinations by mandating open, standards-based products from third parties.

Ambient computing involves more than rolling out more complete and automated ways to collect information about real-world behaviour. It also turns to historical and social data to detect patterns, predict behaviours and drive improvements. Data disciplines are essential, including master data and core management practices[5] that allow sharing and provide strategies for sensing and storing the torrent of new information coming from the newly connected landscape. Objects can create terabytes of data every day that then need to be processed and staged to become the basis for decision making. Architectural patterns are emerging with varying philosophies: embedding intelligence at the edge (on or near virtually every device), in the network, using a cloud broker, or back at the enterprise hub. One size may not fit all for a given organisation. Use cases and expected business outcomes should anchor the right answer.

The final piece of the puzzle might be the most important: how to put the intelligent nodes and derived insights to work. Again, options vary. Centralised efforts seek to apply process management engines to automate sensing, decision making and responses across the network. Another approach is decentralised automation, which embeds rules engines at the endpoints and allows individual nodes to take action.

In many cases, though, ambient computing is a sophisticated enabler of amplified intelligence[5] in which applications or visualisations empower humans to act differently. The machine age may be upon us – decoupling our awareness of the world from mankind's dependency on consciously observing and recording what is happening. But machine automation only sets the stage. Real impact, business or civic, will come from combining data and relevant sensors, things and people so lives can be lived better, work can be performed differently and the rules of competition can be rewired.

My take

Richard Soley, PhD
Chairman and CEO, Object Management Group
Executive director, Industrial Internet Consortium

As head of the Object Management Group, one of the world's largest technology standards bodies, I'm often asked when standards will be established around the Internet of Things (IoT).[6] This common question is shorthand for: When will there be a language to ease interoperability between the different sensors, actuators and connected devices proliferating across homes, business and society?

In developing IoT standards, the easy part is getting bits and bytes from object to object, something we've largely solved with existing protocols and technologies. The tricky part relates more to semantics – getting everyone to agree on the meaning and context of the information being shared and the requests being made. On that front, we are making progress industry by industry, process area by process area. We're seeing successes in use cases with bounded scope – real problems, with a finite number of actors, generating measurable results.

This same basic approach – helping to coordinate industrial players, system integrators, start-ups, academia and vendors to build prototype test beds to figure out what works and what doesn't – is central to the charter of the Industrial Internet Consortium (IIC).[7] The IIC has found that the more interesting scenarios often involve an ecosystem of players acting together to disrupt business models.

Take, for example, today's self-driving cars, which are not, in and of themselves, IoT solutions. Rather, they are self-contained, autonomous replacements for drivers. However, when these cars talk to each other and to roadway sensors and when they can use ambient computing services like analytics, orchestration and event processing to dynamically optimise routes and driving behaviours, then they become headliners in the IoT story.

The implications of self-driving cars talking to each other are profound – not only for taxicab drivers and commuters, but also for logistics and freight transport. Consider this: Roughly one-third of all food items produced today are lost or wasted in transit from farm to table.[8]

We could potentially make leaps in sustainability by integrating existing data on crop harvest schedules, grocery store inventory levels and consumer purchasing habits, and analysing this information to better match supply with demand.

The example that excites and scares me the most revolves around maintenance. The IoT makes it possible to reduce – and potentially eliminate – unexpected maintenance costs by sensing and monitoring everything happening within a working device, whether it be a jet engine, medical device or distribution system. Rather than reacting to mechanical or system breakdowns, engineers could work proactively to address problems before they become full-blown malfunctions. Companies could deploy systems in which nothing fails. Imagine the impact on industry. Business models based on replenishment/replacement cycles would need to be overhauled. Manufacturers of spare parts and providers of repair services might potentially disappear completely, as the focus of maintenance shifts from objects to outcomes. The list of possible ramifications is staggering.

When the future-state level of interconnectivity is realised, who will own each step along the supply chain? End-to-end control affords significant opportunity, but it is rarely achieved. When the IoT evolves, I imagine it will resemble the newly integrated supply chains that emerged in the 1980s and 1990s. While no one controlled the entire supply chain, it was in everyone's interest along that chain to share and secure information in ways that benefited all parties.

My advice to companies currently considering IoT investments is, don't wait. Begin collaborating with others to build prototypes and create standards. And be prepared – your IoT initiatives will likely be tremendously disruptive. We don't know exactly how, but we do know this: You can't afford to ignore the Internet of Things.

Cyber implications

Enabling the Internet of Things requires a number of logical and physical layers, working seamlessly together. Device sensors, communication chips and networks are only the beginning. The additional services in ambient computing add even more layers: integration, orchestration, analytics, event processing and rules engines. Finally, there is the business layer – the people and processes bringing business scenarios to life. Between each layer is a seam, and there are cyber security risks within each layer and in each seam.

One of the more obvious cyber security implications is an explosion of potential vulnerabilities, often in objects that historically lacked connectivity and embedded intelligence. For example, machinery, facilities, fleets and employees may now include multiple sensors and signals, all of which can potentially be compromised. CIOs can take steps to keep assets safe by considering cyber logistics before placing them in the IT environment. Ideally, manufacturing and distribution processes have the appropriate controls. Where they don't, securing devices can require risky, potentially disruptive retrofitting. Such precautionary steps may be complicated by the fact that physical access to connected devices may be difficult to secure, which leaves the door open to new threat vectors. What's more, in order to protect against machines being maliciously prompted to act against the interests of the organisation or its constituencies, IT leaders should be extra cautious when ambient computing scenarios move from signal detection to actuation – a state in which devices automatically make decisions and take actions on behalf of the company.

Taking a broad approach to securing ambient computing requires moving from compliance to proactive risk management. Continuously measuring activities against a baseline of expected behaviour can help detect anomalies by providing visibility across layers and into seams. For example, a connected piece of construction equipment has a fairly exhaustive set of expected behaviours, such as its location, hours of operation, average speed and what data it reports. Detecting anything outside of anticipated norms can trigger a range of responses, from simply logging a potential issue to sending a remote kill signal that renders the equipment useless.

Over time, security standards will develop, but in the near term we should expect them to be potentially as effective (or, more fittingly, ineffective) as those surrounding the Web. More elegant approaches may eventually emerge to manage the interaction points across layers, similar to how a secured mesh network handles access, interoperability and monitoring across physical and logical components.

Meanwhile, privacy concerns over tracking, data ownership, and the creation of derivative data using advanced analytics persist. There are also a host of unresolved legal questions around liability. For example, if a self-driving car is involved in an accident, who is at fault? The device manufacturer? The coder of the algorithm? The human "operator"? Stifling progress is the wrong answer, but full transparency will likely be needed while companies and regulators lay the foundation for a safe, secure and accepted ambient-computing tomorrow.

Finally, advanced design and engineering of feedback environments will likely be required to help humans work better with machines, and machines work better with humans. Monitoring the performance and reliability of ambient systems is likely to be an ongoing challenge requiring the design of more relevant human and machine interfaces, the implementation of effective automation algorithms and the provisioning of helpful decision aids to augment the performance of humans and machines working together – in ways that result in hybrid (human and technical) secure, vigilant and resilient attributes.

Where do you start?

MANY don't need to be convinced of ambient computing's opportunities. In a recent survey, nearly 75 per cent of executives said that Internet of Things initiatives were underway.[9] Analysts and companies across industries are bullish on the opportunities. Gartner predicts that "by 2020, the installed base of the IoT will exceed 26 billion units worldwide; therefore, few organisations will escape the need to make products intelligent and the need to interface smart objects with corporate systems."[10] Other predictions measure economic impact at $7.1 trillion by 2020,[11] $15 trillion in the next 20 years,[12] and $14 trillion by 2022.[13] But moving from abstract potential to tangible investment is one of the biggest hurdles stalling progress. Below are some lessons learned from early adopters.

- **Beware fragmentation.** Compelling ambient computing use cases will likely cross organisational boundaries. For example, retail "store of the future" initiatives may cross store management, merchandising, warehouse, distribution centre, online commerce, and marketing department responsibilities – requiring political and financial buy-in across decision-making authorities. Because the market lacks end-to-end solutions, each silo may be pursuing its own initiative, offering at best incremental effect, at worst redundant or competing priorities.

- **Stay on target.** Starting with a concrete business outcome will help define scope by guiding which "things" should be considered and what level of intelligence, automation and brokering will be required. Avoid "shiny object syndrome," which can be dangerously tempting given how exciting and disruptive the underlying technology can seem.

- **User first.** Even if the solution is largely automated, usability should guide vision, design, implementation and ongoing maintenance plans. Companies should use personas and journey maps to guide the end-to-end experience, highlighting how the embedded device will take action or how a human counterpart will participate within the layers of automation.

- **Eyes wide open.** Connecting unconnected things will likely lead to increased costs, business process challenges and technical hurdles. Be thoughtful about funding the effort and how adoption and coverage will grow. Will individual organisations have to shoulder the burden, or can it be shared within or across industries and ecosystems? Additionally, can some of the investment be passed on to consumers? Although business cases are needed, they should fall on the defensible side of creative.

- **Network.** With the emphasis on the objects, don't lose sight of the importance of connectivity, especially for items outside of established facilities. Forrester Research highlights "a plethora of network technologies and protocols that define radio transmissions including cellular, Wi-Fi, Bluetooth LE, ZigBee, and Z-Wave."[14] Planning should also include IPv6 adoption,[15] especially with the public IPv4 address space largely exhausted and the aforementioned billions of new Internet-enabled devices expected in the next 10 years.

- **Stand by for standards.** Standards help create collaborative and interoperable ecosystems. We expect that IoT standards for interoperability, communication and security will continue to evolve, with a mix of governmental bodies, industry players and vendors solving some of the challenges inherent in such a heterogeneous landscape. Several IoT-focused standards bodies and working groups including the AllSeen Alliance, Industrial Internet Consortium Open Interconnect Consortium and Thread Group have formed in the last two years.[16] Having preliminary standards is important, but you shouldn't hold off on investing until all standards are finalised and approved. Press forward and help shape the standards that impact your business.

- **Enterprise enablement.** Many organisations are still wrestling with smartphone and tablet adoption – how to secure, manage, deploy and monitor new devices in the workplace. That challenge is exponentially exacerbated by ambient computing. Consider launching complementary efforts to provision, deploy policies for, monitor, maintain and remediate an ever-changing roster of device types and growing mix of underlying platforms and operating systems.

Bottom line

AMBIENT computing shouldn't be looked at as just a natural extension of mobile and the initial focus on the capabilities of smartphones, tablets, and wearables – though some similarities hold. In those cases, true business value came from translating technical features into doing things differently – or doing fundamentally different things. Since ambient computing is adding connectivity and intelligence to objects and parts of the world that were previously "dark," there is less of a danger of seeing the opportunities only through the lens of today's existing processes and problems. However, the expansive possibilities and wide-ranging impact of compelling scenarios in industries such as retail, manufacturing, healthcare and the public sector make realising tomorrow's potential difficult. But not impossible. Depending on the scenario, the benefits could be in efficiency or innovation, or even a balance of cost reduction and revenue generation. Business leaders should elevate discussions from the "Internet of Things" to the power of ambient computing by finding a concrete business problem to explore, measurably proving the value and laying the foundation to leverage the new machine age for true business disruption.

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Notes

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