Internet of Things – Analysis and Challenges

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Summary: A new concept associated with the "Future Internet" is "Internet of Things" (IoT). IoT describes the idea in which objects become part of the Internet. Every object is uniquely identified and accessible to the network, its position and status are known. In this environment services and intelligence are added to this expanded Internet, mixing the digital and physical world, ultimately impacting on our professional, personal and social environments.

The current article presents an overview and summary of the Internet of Things, its application and potential benefits to society and economy, based on emerging publications in Internet. It has to be regarded as an introductory paper to a wide audience ranging from strategic research managers, business IT managers and other interested indivisuals.

Key words: Internet of Things, IoT, M2M, sensor, object, society, economy.

JEL: C87, D01, D8.

1. Introduction

Connectivity is fast becoming a standard feature of consumer and industrial devices allowing such products to become part of a future "Internet of Things" (IoT). This network of billions of mobile and static devices – each uniquely identifiable and able to communicate with any other device on the network – is mooted as the next stage of development for the Internet.

According to analyst Analysys Mason, in a report entitled "Internet 3.0: the Internet of Things", the consumer IoT alone will grow to encompass 16 billion connectable devices worldwide by 2020 – and that may be a big underestimate [4].

"16 billion connectable consumer devices by 2020 may actually be a conservative [forecast]," Jim Morrish, Principal Analyst at Analysys Mason and author of the report, said [5]. "Taking into account the uncertainties inherent in forecasting new technologies 10 years out, we believe that a realistic maximum number of devices may be 44 billion, and 6 billion a realistic minimum. That's a worldwide average of between 0.8 and 5.8 devices for each person alive in 2020." "The most direct potential consequence of the IoT is the generation of huge quantities of data," Morrish added. "In a hypothetical

IoT environment, every physical object (and many virtual objects) may have a virtual twin in 'the cloud', which could be generating regular updates."

In addition to the expansion of connectable consumer devices, the industrial machine-to-machine (M2M) sector is also growing fast. According to Morrish, as the prices of M2M communications equipment have fallen, manufacturers have installed the technology in an increasing amount of consumer energy "smart" meters, and have started to install it in a range of household equipment, cars and security systems.

In a separate report, Analysis Mason forecasts that the number of M2M device connections will grow from 62 million last year to 2.1 billion devices in 2020, at a 36 per cent year-on-year growth rate. The company said that the automotive and transport sector accounts for the most M2M device connections today, but other sectors, such as utilities, healthcare and security, will have overtaken it by 2020.

Every human being is surrounded by 1,000 to 5,000 objects, as per a rough estimate [1]. Each of these items is electronically tagged and linked through a wireless network to a central system which will enable us to track them as an when needed. In fact IoT aims to do exactly that. It refers to a network of objects, such as household appliances, organised as a self-configuring wireless network. The concept of the Internet of things is attributed to the original Auto-ID Center, founded in 1999 at MIT. While the idea is very straight forward, its implementation is complex.

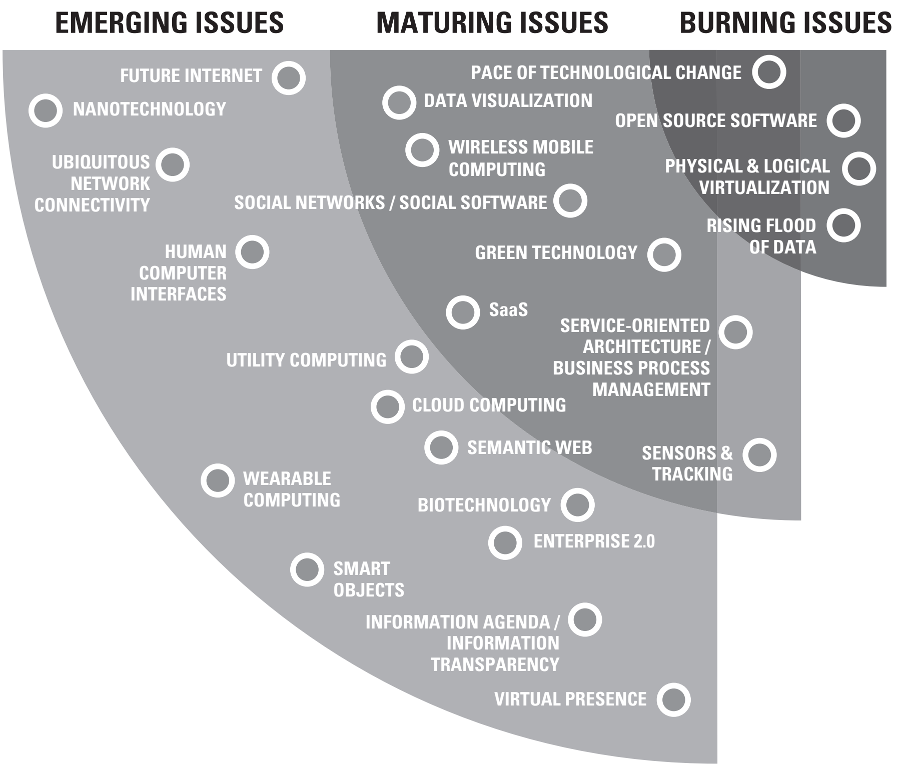
If all objects in the world were equipped with miniature identifying devices, such as RFID tags, they can be identified and managed by computers leading to a total transformation in daily life. Such a system could greatly reduce the chances of a business running out of stock of an item or identifying the items approaching expiry date. Mislaid items, parcels in transit through post or courier, physical theft etc. could also be monitored by computers better than humans, as the location of items would be known at all times.

Over the past decade, billions of people have connected to the Internet via the computer and mobile devices, leading a communication revolution. If all objects in the world have the necessary information to function optimally by adjusting themselves, IoT will extend this principle exponentially, providing for an unprecedented control over the objects that surround humans.

2. Internet of Things

Internet of Things (IoT), also known as ubiquitous computing, ambient intelligence and distributed electronics, is the name given to the idea of connecting everyday objects to the internet, creating smart networks comprised of devices that communicate with one another [10, 11]. Large-scale deployments of similar technologies are already emerging in a range of industrial sectors, with companies such as IBM, Cisco Systems and General Electric developing applications for everything from smart grid to real-time transportation management and optimisation. What makes Internet of Things distinct is the fact that it refers specifically to objects.

In most organizations, information travels along familiar routes. Proprietary information is lodged in databases and analyzed in reports and then rises up the management chain. Information also originates externally – gathered from public sources, harvested from the Internet, or purchased from information suppliers.



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However the predictable pathways of information are changing: the physical world itself is becoming a type of information system [11]. In what's called the Internet of Things, sensors and tiny devices (actuators) embedded in physical objects—from roadways to pacemakers—are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet. These networks produce large volumes of data that flow to computers for analysis. When objects can both sense the environment and communicate, they become tools for understanding complexity and responding to it swiftly. What's revolutionary in all this is that these physical information systems are now beginning to be deployed, and some of them even work largely without human intervention.

Business models based on today's largely static information architectures face challenges as new ways of creating value arise [15]. When a customer's buying preferences are sensed in real time at a specific location, dynamic pricing may increase the odds of a purchase. Knowing how often or intensively a product is used can create additional options—usage fees rather than outright sale, for example. Manufacturing processes equipped with a multitude of sensors can be controlled more precisely, raising efficiency. When operating environments are monitored continuously for hazards or when objects can take corrective action to avoid damage, risks and costs diminish.

The implementation of IoT in large scale would need encoding 50 to 100 trillion objects and follow their movement. The Internet Protocol Version 4 (IPv4) in use today has limitation in its addressing capacity. The next generation IPv6 would be able to communicate with devices attached to virtually all human-made objects because of its extremely large address space.

IoT encompasses a number of research disciplines that enable the Internet to reach out into the real world of physical objects. Technologies like RFID, short-range wireless communications, realtime localization and sensor networks are now becoming increasingly common, bringing IoT into commercial use [9, 12]. They foreshadow an exciting future interlinking the physical world and cyberspace – a development that is not only relevant to researchers, but to corporations and individuals alike.

The Internet of Things refers to a network of objects not historically connected. Four kinds of objects can be considered [2, 8, 11]:

1. The device containing electronics in order to fulfil its primary function (eg, washing machine, car, aircon unit);
2. The electrical device traditionally absent of sophisticated electronics (eg, lighting, heating, power distribution);
3. Non-electrical objects (eg, food and drink packages, animals, clothing);
4. Environmental sensors (eg, for variables such as temperature, ambient sound and moisture).

IoT has potential for societal, environmental as well as economic impact. Accurate information about the status, location and identity of things, which forms part of and impacts on the environment, allows for smarter decision making and appropriate action taking. IoT concepts have been demonstrated in a variety of domains, ranging from logistics, transport and asset tracking, smart environments (homes, buildings, infrastructure), to energy, defence and agriculture. In essence, IoT impacts and certainly has the potential to significantly influence all facets of society.

According to Elgar Fleisch [16], IoT is relevant in every step in every value chain. He has identified seven main value drivers. The first four based on value from machine-to-machine communication, while the last three create value with the integration of users. The drivers as identified by Fleisch are:

- Simplified manual proximity trigger – things can communicate their identity when they are moved into the sensing space of a sensor. Once the identity is known and communicated, a specific action or transaction can be triggered.
- Automatic proximity trigger – an action is triggered automatically when the physical distance of two things drops below a threshold. The identity of the thing is known, which when combined with the physical location and action allows for better processes.
- Automatic sensor triggering – a smart thing can collect data via any type of sensor including temperature, acceleration, orientation, vibration and humidity. The thing senses its condition and environment, communicates the information which enables prompt (and global) decision making.
- Automatic product security – a thing can provide derived security (information) based on the interaction between the thing and its cyberspace representation (e.g. a QR-code containing a specific URL pointing to relevant information).
- Simple and direct user feedback – things can incorporate simple mechanisms to provide feedback to a human present in the environment. Often these feedback mechanisms are in the form of audio (audible beep) or visual (flashing light) signals.
- Extensive user feedback – things can provide rich services to a human (often the thing is linked to a service in cyberspace through a gateway device such as a smart phone). Augmented

product information is a good example of extensive user feedback.

- Mind changing feedback – the combination of real world and cyberspace might generate a new level of changing behaviours in people. One possibility is changing the driving behaviour as sensors in the vehicle communicate driving patterns to an outside agency.

The widespread adoption of the Internet of Things will take time, but the time line is advancing thanks to improvements in underlying technologies. Advances in wireless networking technology and the greater standardization of communications protocols make it possible to collect data from these sensors almost anywhere at any time. Ever-smaller silicon chips for this purpose are gaining new capabilities, while costs, following the pattern of Moore's Law, are falling. Massive increases in storage and computing power, some of it available via cloud computing, make number crunching possible at very large scale and at declining cost. As the technology develops and matures, the range of corporate deployments will increase. Now is the time for executives across all industries to structure their thoughts about the potential impact and opportunities likely to develop from the Internet of Things. Six distinct types of emerging applications, which fall in two broad categories, have been identified so far [2, 14]:

a) information and analysis, and
b) automation and control.

I. Information and analysis

As the new networks link data from products, company assets, or the operating environment, they will generate better information and analysis, which can enhance decision making significantly. Some organizations are starting to deploy these applications in targeted areas, while more radical and demanding uses are still in the conceptual or experimental stages [14].

I.1. Tracking behavior

When products are embedded with sensors, companies can track the movements of these products and even monitor interactions with them. Business models can be fine-tuned to take advantage of this behavioral data. Some insurance companies, for example, are offering to install location sensors in customers' cars. That allows these companies to base the price of policies on how a car is driven as well as where it travels. Pricing can be customized to the actual risks of operating a vehicle rather than based on proxies such as a driver's age, gender, or place of residence.

In retailing, sensors that note shoppers' profile data (stored in their membership cards) can help close purchases by providing additional information or offering discounts at the point of sale.

In the business-to-business marketplace, one well-known application of the Internet of Things involves using sensors to track RFID (radio-frequency identification) tags placed on products moving through supply chains, thus improving inventory management while reducing working capital and logistics costs. The range of possible uses for tracking is expanding. In the aviation industry, sensor technologies are spurring new business models. Manufacturers of jet engines retain ownership of their products while charging airlines for the amount of thrust used. Airplane manufacturers are building airframes with networked sensors that send continuous data on product wear and tear to their computers, allowing for proactive maintenance and reducing unplanned downtime.

I.2. Enhanced situational awareness

Data from large numbers of sensors, deployed in infrastructure (such as roads and buildings) or to report on environmental conditions (including soil moisture, ocean currents, or weather), can give decision makers a heightened awareness of real-time events, particularly when the sensors are used with advanced display or visualization technologies.

Security personnel can use sensor networks that combine video, audio, and vibration detectors to spot unauthorized individuals who enter restricted areas. Some advanced security systems already use elements of these technologies, but more far-reaching applications are in the works as sensors become smaller and more powerful, and software systems more adept at analyzing and displaying captured information. Logistics managers for airlines and trucking lines already are tapping some early capabilities to get up-to-the-second knowledge of weather conditions, traffic patterns, and vehicle locations. In this way, these managers are increasing their ability to make constant routing adjustments that reduce congestion costs and increase a network's effective capacity. In another application, law-enforcement officers can get instantaneous data from sonic sensors that are able to pinpoint the location of gunfire.

I.3. Sensor-driven decision analytics

The Internet of Things also can support longer-range, more complex human planning and decision making. The technology requirements – tremendous storage and computing resources linked with advanced software systems that generate a variety of graphical displays for analyzing data – rise accordingly.

In the oil and gas industry, for instance, the next phase of exploration and development could rely on extensive sensor networks placed in the earth's crust to produce more accurate readings of the location, structure, and dimensions of potential fields than current data-driven methods allow. The payoff: lower development costs and improved oil flows.

As for retailing, some companies are studying ways to gather and process data from thousands of shoppers as they journey through stores. Sensor readings and videos note how long they linger at individual displays and record what they ultimately buy. Simulations based on this data will help to increase revenues by optimizing retail layouts.

In health care, sensors and data links offer possibilities for monitoring a patient's behavior and symptoms in real time and at relatively low cost, allowing physicians to better diagnose disease and prescribe tailored treatment regimens. Patients with chronic illnesses, for example, have been outfitted with sensors in a small number of health care trials currently under way, so that their conditions can be monitored continuously as they go about their daily activities. One such trial has enrolled patients with congestive heart failure. These patients are typically monitored only during periodic physician office visits for weight, blood pressure, and heart rate and rhythm. Sensors placed on the patient can now monitor many of these signs remotely and continuously, giving practitioners early warning of conditions that would otherwise lead to unplanned hospitalizations and expensive emergency care. Better management of congestive heart failure alone could reduce hospitalization and treatment costs by a billion dollars annually in the United States.

II. Automation and control

Making data the basis for automation and control means converting the data and analysis collected through the Internet of Things into instructions that feed back through the network to actuators that in turn modify processes. Closing the loop from data to automated applications can raise productivity, as systems that adjust automatically to complex situations make many human interventions unnecessary. Early adopters are ushering in relatively basic applications that provide a fairly immediate payoff. Advanced automated systems will be adopted by organizations as these technologies develop further [14].

II.1. Process optimization

The Internet of Things is opening new frontiers for improving processes. Some industries, such as chemical production, are installing legions of sensors to bring much greater granularity to monitoring. These sensors feed data to computers, which in turn analyze them and then send signals to actuators that adjust processes – for example, by modifying ingredient mixtures, temperatures, or pressures. Sensors and actuators can also be used to change the position of a physical object as it moves down an assembly line, ensuring that it arrives at machine tools in an optimum position. This improved instrumentation, multiplied hundreds of times during an entire process, allows for major reductions in waste, energy costs, and human intervention.

In the pulp and paper industry, for example, the need for frequent manual temperature adjustments in lime kilns limits productivity gains. One company raised production 5 percent by using embedded temperature sensors whose data is used to automatically adjust a kiln flame's shape and intensity. Reducing temperature variance to near zero improved product quality and eliminated the need for frequent operator intervention.

II.2. Optimized resource consumption

Networked sensors and automated feedback mechanisms can change usage patterns for scarce resources, including energy and water, often by enabling more dynamic pricing. Utilities such as Enel in Italy and Pacific Gas and Electric (PG&E) in the United States, for example, are deploying "smart" meters that provide residential and industrial customers with visual displays showing energy usage and the realtime costs of providing it. Based on time-of-use pricing and better information residential consumers could shut down air conditioners or delay running dishwashers during peak times. Commercial customers can shift energy-intensive processes and production away from high-priced periods of peak energy demand to low-priced off-peak hours.

Data centers, which are among the fastest-growing segments of global energy demand, are starting to adopt power-management techniques tied to information feedback. Power consumption is often half of a typical facility's total lifetime cost, but most managers lack a detailed view of energy consumption patterns. Getting such a view isn't easy, since the energy usage of servers spikes at various times, depending on workloads. Furthermore, many servers draw some power 24/7 but are used mostly at minimal capacity, since they are tied to specific operations. Manufacturers have developed sensors that monitor each server's power use, employing software that balances computing loads and eliminates the need for underused servers and storage devices. Greenfield data centers already are adopting such technologies, which could become standard features of data center infrastructure within a few years.

II.3. Complex autonomous systems

The most demanding use of the Internet of Things involves the rapid, real-time sensing of unpredictable conditions and instantaneous responses guided by automated systems. This kind of machine decision making mimics human reactions, though at vastly enhanced performance levels. The automobile industry, for instance, is stepping up the development of systems that can detect imminent collisions and take evasive action. Certain basic applications, such as automatic braking systems, are available in high-end autos. The potential accident reduction savings flowing from wider deployment could surpass $100 billion annually. Some companies and research organizations are experimenting with a form of automotive autopilot for networked vehicles driven in coordinated patterns at highway speeds. This technology would reduce the number of accidental jams caused by small disturbances that cascade into traffic bottlenecks.

Scientists in other industries are testing swarms of robots that maintain facilities or clean up toxic waste, and systems under study in the defense sector would coordinate the movements of groups of unmanned aircraft. While such autonomous systems will be challenging to develop and perfect, they promise major gains in safety, risk, and costs. These experiments could also spur fresh thinking about how to tackle tasks in inhospitable physical environments (such as deep water, wars, and contaminated areas) that are difficult or dangerous for humans.

3. Current Significant IoT Activities

IoT is fast becoming an important priority, not only for academia, but also industry and governments. Multinational companies have recognised the commercial potential of a IoT. Examples include [2, 4, 13]:

- IBM's Smarter Planet initiative aims to add intelligence to systems and processes that interface with the world. To utilise the data collected from things such as clothes, appliances, the natural environment, road infrastructure, and the electrical grid to make a difference in energy, banking, healthcare and cities.
- Microsoft's Eye-On-Earth platform creates and environment where water and air quality of a large number of European countries can be viewed, thus aiding in climate change research.
- HP is researching IoT based infrastructure in their Central Nervous System for the Earth initiative. Their aim is to populate the planet with billions of small sensors aimed at detecting vibrations and motion.

Similarly, IoT has been placed on the research agendas of countries and regions:

- The European Commission has recognised the importance of addressing the challenges in IoT. Their Cluster of European Research Projects on the Internet of Things (CERP-IoT) comprises of many (in excess of 30) research activities, platforms and networks focused on the "Internet connected and inter-connected world of objects".
- The Chinese Government is investing in IoT and sees it as a vehicle for economic growth.
- Worldwide a lot of research groups address problems in IoT:
- The MIT Auto-ID Laboratory is focusing on RFID and wireless sensor networks to drive IoT and is recognised as being one of the early adopters of IoT.
- In Europe, large scale involvement is driven through the CERP-IoT.
- In South Africa, the Internet of Things Engineering Group at the CSIR Meraka Institute, is focused on creating a framework allowing for channel agnostic communication between things and applications in IoT. Applications which demonstrate IoT concepts while utilising the framework have been developed. They

include an application to serve as an indigenous knowledge repository (Urban Memory) where physical objects are linked to cultural events of significance which have been captured and are living in cyberspace.

4. IoT Challenges

A number of challenges need to be overcome in order IoT to achieve its vision. They challenges range from applications to new technical developments [10, 14].

A world where all things are connected, communicating information and data about its local environment to a central location opens the door for "Big Brother". The individual's right to privacy needs to be protected. The individual's trust in the IoT should be fundamental and complete, knowing that information will not impact negatively on any individual or society. Principles of informed consent, data confidentiality and security must be safeguarded. Trust raises an interesting technological challenge: how and when can sensors in an environment be controlled? Governance in the IoT is crucial. Policy makers and public authorities have a responsibility to ensure that IoT will create impact, from economic growth to addressing societal problems.

Standardisation of technologies is important, as it will lead to better interoperability, thus lowering the entry barriers. Currently, many manufacturers are creating vertical solutions, using their own technologies and inaccessible services. Standards need to be created to change IoT into the more complete model.

One significant aspect in IoT is the large number of things being connected to the Internet, each one providing data. Finding ways to reliably store and interpret the masses of data through scalable applications remain a major technological challenge.

The following key IoT challenge areas have been identified [3, 6, 7, 10] :

a) Privacy, Identity Management, Security and Access control – IoT presents significant challenges in terms of who can see what with which credentials (recalling that the entities are no longer only people, but might be any form of IoT "appliance".
b) Standardisation and Interoperability – How to guarantee that hugely diverse technology platforms continue to act in a platform manner.
c) Data deluge – The IoT shares many of the key challenges similar to large scale data initiatives as identified in the e-Infrastructure domain. How to deal with the data stream of billions of "actors" and how to ensure the data remains usable for future generations?

A number of applications were listed above that would find a home in many situations on the continent. In addition to these, a number of relevant application areas might present unique opportunities and are listed below [8, 11, 13]:

a) Food security: The ability to measure and respond appropriately to issues affecting food security, such as droughts, pests, and lack of knowledge of proper farming methods in different circumstances may have a significant implication for food security. Interventions may take the form of large scale fusion of remotely sensed information mixed in with in-situ, cost effective sensors and the necessary information and communication infrastructures to alert a small scale farmer through a mobile phone text message that certain portions of his land need particular attention. On the small scale, it may include "smart packaging" of seeds, fertiliser and pest control mechanisms that respond to specific local conditions and indicate actions by, for instance changing colour. Monitoring on a

continuous basis the fertilisers and pesticides used on export-based products enables a small scale farmer to have their produce "certified" for an export market in a cost effective manner.
b) Natural disasters: Through the combination of sensors and simulation, many a life could be spared if, for instance, the occurrence of land-slides may be predicted in time for villages to take appropriate actions. Often the remotely sensed data that may be used together with simulation tools (including PC based tools right up to supercomputer applications) do not provide the real-time information and resolution necessary to take appropriate action in time. Flash floods present another example where in-situ monitoring is very important.
c) Water: With the importance of water for both human and economic development in the region and its scarcity in many places, networks of sensors, tied together with the relevant simulation activities might not only monitor long term water interventions such as catchment area management, but may even be used to alert users of a stream, for instance, if an upstream event, such as the accidental release of sewage into the stream, might have dangerous implications.

The list can easily be extended to cover areas such as health, the environment, the state of road infrastructures and other areas of importance to the emerging and developing economies of the world.

There are some problems for which answers need to be found out [7, 15]:

a) Can the infrastructure support such a huge expansion of the Internet?
b) Can everything be entrusted to a technology that can easily crash? Reliability of the systems is in question.
c) From the privacy angle, IoT will allow companies and governments to collect unprecedented amounts of information about its citizens, with its repercussions.
d) What about catastrophic failures of the systems? The more data is submited bt users to the Internet, the more dependent they are on it. The more interconnected the world becomes, the more users have to lose from catastrophic failures. Terrorist attacks, hackers' intrusions and plain old disasters could wreak havoc on a world where everything is connected to a giant electronic brain.

5. Future of IoT

The Internet of Things has great promise, yet business, policy, and technical challenges must be tackled before these systems are widely embraced [1, 4]. Early adopters will need to prove that the new sensor- driven business models create superior value. Industry groups and government regulators should study rules on data privacy and data security, particularly for uses that touch on sensitive consumer information. Legal liability frameworks for the bad decisions of automated systems will have to be established by governments, companies, and risk analysts, in consort with insurers. On the technology side, the cost of sensors and actuators must fall to levels that will spark widespread use. Networking technologies and the standards that support them must evolve to the point where data can flow freely among sensors, computers, and actuators. Software to aggregate and analyze data, as well as graphic display techniques, must improve to the point where huge volumes of data can be absorbed by human decision makers or synthesized to guide automated systems more appropriately.

Within companies, big changes in information patterns will have implications for organizational structures, as well as for the way decisions are made, operations are managed, and processes are conceived. Product development will need to reflect far greater possibilities for capturing and analyzing information [11, 15].

Companies can begin position themselves for these changes by using new technologies to optimize business processes in which traditional approaches have not brought satisfactory results. Energy consumption efficiency and process optimization are good initial targets [13]. Experiments with the emerging technologies should be conducted in development labs and in pilot trials. Companies can seek partnerships with innovative technology suppliers creating Internet-of-Things capabilities for the corresponding industries.

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