Productivity Leap with IoT

Visions of the Internet of Things with a special focus on Global Asset Management and Smart Lighting

VISIONS • SCIENCE • TECHNOLOGY • RESEARCH HIGHLIGHTS

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VTT

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Dependency ratio increases **to 70%** in Finland by 2025

50 billion connected devices in 2020

IoT world is **10^{27} bytes** tomorrow

Annual productivity leap **from 2.5% to 3.9%**

ICT enabler **of 40%** of productivity improvement

Annual budget **13-15 M€**

Smart lighting market rises from **0.4 B$ to 11.4 B$** by 2020

Additional **$15 trillion** in global GDP by 2030

Welcome to see the opportunities in IoT!

Heikki Ailisto
Programme Manager

VTT VISIONS 3

Productivity Leap with IoT

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PUBLISHER
VTT Technical Research Centre of Finland
P.O. Box 1000 (Tekniikantie 4 A, Espoo)
FI-02044 VTT, Finland
Tel. +358 20 722 111, fax +358 722 7001

EDITORS: Marko Jurvansuu and Kaisa Belloni
GRAPHIC DESIGN: Kaisa Kuisma, VTT, and ID BBN

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Editors view

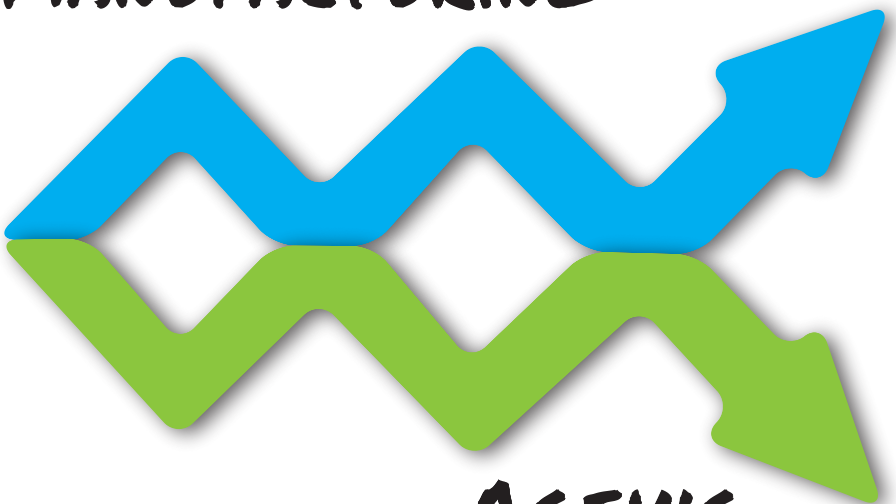
To many of us, the Internet of Things (IoT) is still an emerging concept. To cast a clear light on this new landmark in technology, in this edition of Visions our multidisciplinary team of experts shares its latest insights on the IoT and on its implications for productivity. Tomorrow, the Internet of Things will be a seamless part of everyday life, just as the Internet and smart phones are today.

Let's be at the forefront!

Dr. Marko Jurvansuu, editor

1 Why do we need a productivity leap?

Flight of manufacturing



Ageing population

Depleting natural resources

1.1 Three key threats to our wellbeing

Europe is facing major challenges to its way of life and to the very foundations of its society. From a technological perspective, VTT pinpoints three key threats.

Flight of manufacturing. Loss of manufacturing capability leads to chronic trade balance deficit and a diminishing tax base. A further key threat is the loss of R&D, finance and governance functions in the wake of manufacturing to the newly industrialised countries. As these high added-value services are lost, per capita income decreases and current levels of public services and spending become unsustainable. In Finland, during 2008–2013 the number of people employed in industry fell from 420,000 to 355,000, i.e. 15%. The Nokia cluster alone has lost 14,000 jobs in the past three years, while the forest industry has cut 20,000 well-paying industrial jobs since 2000. In the UK this development has been even more drastic – a 40% loss in manufacturing jobs since the turn of the millennium. Research and development work is following the production as standard of education and competence is increasing in the third countries. Emerging and developing countries are growing faster than advanced economies, steadily closing the income gap.

Ageing population. Early retirement combined with increased life expectancy results in a diminished workforce. The challenge of providing the elderly with the care they need and deserve is placing increasing demands on society's resources, with a growing proportion of the workforce and public money being allocated to elderly care. In Finland, the ratio of non-working age (15 or younger, 65 and older) to working age people will increase from 51% in 2010 to as much as 70% by 2025. In rural areas it can be over 100%. Similar trends are being seen in all European countries as well as in Japan and Korea.

Depleting natural resources, increasing pollution. Energy and raw materials are limited, yet demand for them is constantly increasing. Growing price pressure is inevitable as China, India and other countries increase their consumption. Europe is committed to CO_2 restrictions and

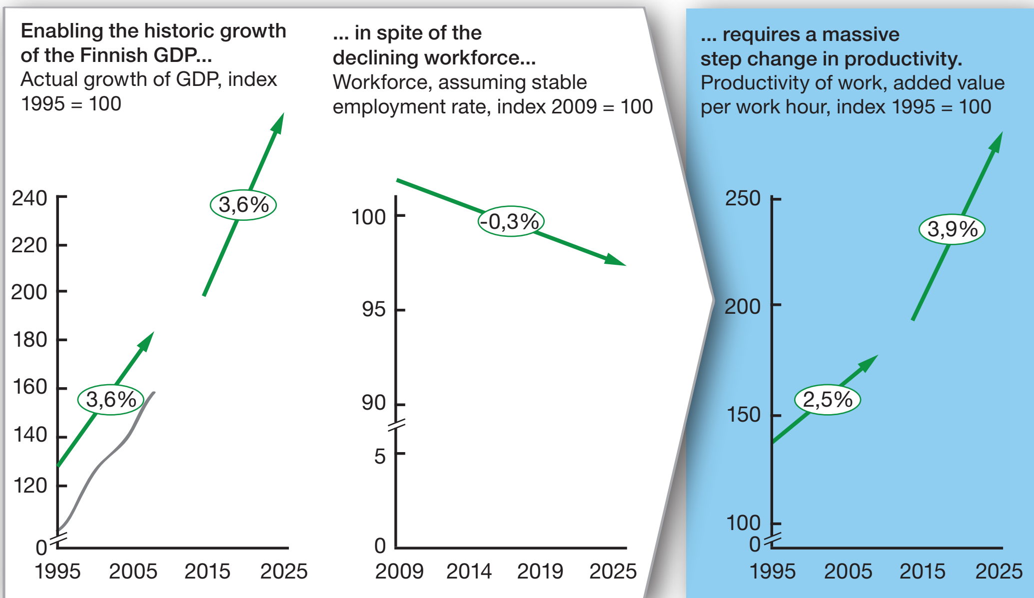


FIGURE 1.1. To maintain the 3,6% growth of the Finnish GDP, despite the declining workforce, calculations show that annual productivity growth should leap from 2.5% to 3.9%. Source: Economist Intelligent Unit; Statistics Finland.

FIGURE 1.2. ICT technologies, from Morse's telegram to Internet and smart devices, have fundamentally changed the way we live and have had a massive impact on the productivity.

other environmental policies that may handicap its competitiveness. Sudden political changes driven by popular opinion, such as changes in attitude towards nuclear energy following the Fukushima disaster, may cause unforeseeable risks for European industry.

A range of measures are needed to manage and counter these challenges. According to Finnish authorities actions must be directed towards productivity improvement and success in the global market. All of the above key challenges can be addressed by improving productivity. By improving manufacturing productivity, we can gain competitive edge and improve Finland's attractiveness to manufacturers as a place to invest. Likewise, better productivity enables greater output with fewer work-years. The same principle applies to the elderly care sector, which will need to be able to produce high quality care services with less input. Productivity also means more value with less raw materials and energy, thus helping achieve sustainability.

In recent years, the competitiveness of Finnish industry has waned, leading to significant loss of export revenues. As the graphs in Figure 1.1 show, in order for Finland to achieve the level of GDP growth needed to sustain public expenditure according to the Nordic welfare model, annual productivity growth must leap from 2.5% to 3.9%.

This edition of VTT Visions presents VTT's vision of how the 'Internet of Things' (IoT) as a set of technologies and as an enabler can increase productivity and thus help tackle these three key challenges.

1.2 Internet of Things is the next enabler for productivity leap

The past 150 years have been a triumph of electronic communications and computing, see Figure 1.2. From Morse's telegram to telephone, radio and TV, mainframe computers, PCs, mobile phones, the Internet and social media – ICT technologies have brought fundamental changes to the way we live, work, and do business.

ICT is the primary enabler of 80% of innovations and 40% of productivity improvement (A Digital Agenda for Europe, EU 2010). During the past three decades, the development and deployment of the personal computer, the Internet, ERP systems, and mobile communications have been the flagships of ICT-driven productivity. During the mobile communications boom, Finland focused so strongly on mobile communications that it can be claimed that the role of ICT as a source of productivity improvement in other industries was overshadowed by the Nokia cluster.

Yet, we can find cases where Finland has pioneered ICT-enabled productivity leaps. In the 1990s, Finnish banks introduced net banking and customers were quick to adopt the new technology. During the decade to follow, productivity, as measured by banking transactions per employee, almost ten-folded. A similar productivity leap and business transformation has been encountered in the travel agency sector due to web services. As an example from the public sector, web tools (Helmi; Wilma) for teacher–pupil–parent interaction and co-operation have shown similar ICT-enabled productivity gains.

In the ongoing decade, productivity will be driven by the Internet of Things. Successful deployment of the IoT is therefore crucial to the survival and thriving of companies and societies. Our goal is to help industry and the public sector to improve productivity by leveraging Internet of Things technologies in the areas important for industry in global competition.

1.3 From the Internet as we know it, to the Internet of Things

The Internet, as we know it now, is oriented towards consumers. People use the Internet for information, entertainment and social networking, as well as for transactions, such as shopping and banking. About a third of the world's population, 2.5 billion people, have access to the Internet and the information and services it makes available. The number of Internet users is growing by 15% per year. The stereotypical image of the web user as someone bent over a laptop or PC is already outdated. In the developed world, tablets have been fast changing the way people 'surf', but an even more significant change has been seen in the developing countries, where ordinary people can now access the Internet with an affordable smartphone. Mobile devices are making the Internet truly ubiquitous.

A major aspect of communication technology, though largely invisible to the average consumer, is computer-to-computer traffic and activity, i.e. the moving, refining, managing, presenting and storing of information. Machine-to-machine, or "M2M", communication is often considered "non-Internet" based, i.e. using either proprietary or switched telecom communication infrastructure, but M2M is, in fact, a sub-set of the Internet of Things. Figure 1.3

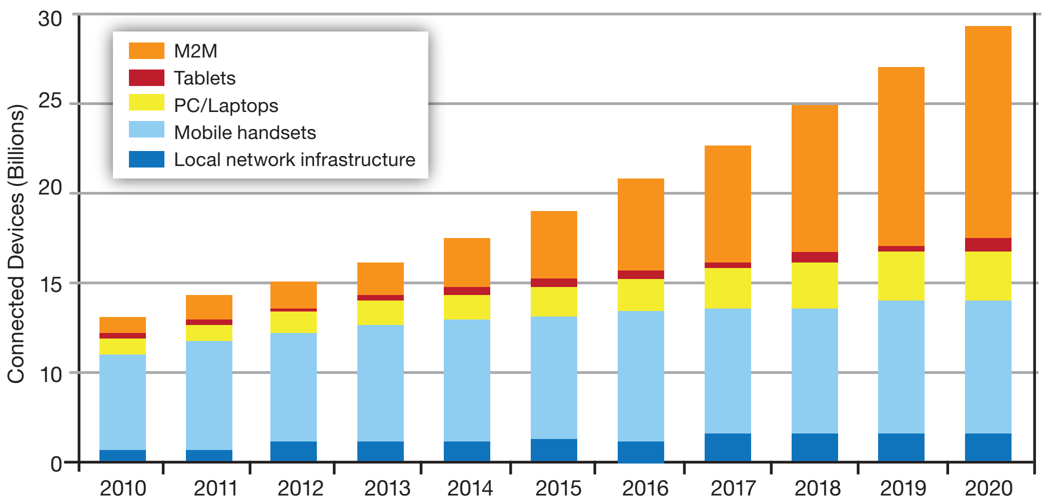


FIGURE 1.3. "The fast growth of M2M devices is a clear indication of rise of IoT. GSMA (2011) Connected Life – GSMA Position Paper, GSMA white paper. http:// www.gsma.com/documents/gsma-connected-life-position-paper/20440"

illustrates the growing importance of machine-to-machine communication as reflected by the rapid rise in numbers of M2M devices. This increase also shows that the expansion of the Internet from a technology for exchanging information rapidly between people to a technology enabling also communication between all kinds of physical items is already well underway.

1.4 What is the IoT?

The Internet of Things (IoT) escapes any clear definition, consisting as it does of a combination of technologies and a collection of applications and business opportunities, rather than any definable architectures or communication protocols. Different viewpoints result in different ways of defining IoT. For example, an identification of objects oriented definition states "The Internet of Things refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure." (Wikipedia, Internet of Things). An infrastructure oriented definition states "A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities." (CASAGRAS project). A business / physical objects and network oriented definition states "A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these 'smart objects' over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues." (Stephen Haller, SAP).

In this Visions publication, we see the IoT as a set of enabling technologies that can be used by almost all areas of business and society to improve productivity. The core enabling technologies are sensing, processing, communication, refining and managing information, while the supporting enabling technologies are energy harvesting and low-power embedded systems. The enabling technologies are, in principle, application and domain independent, which is the key advantage of IoT

> OUR DEFINITION OF THE IOT FROM A PRODUCTIVITY PERSPECTIVE IS AS FOLLOWS:
> THE INTERNET OF THINGS IS A DIGITAL REPRESENTATION OF THE REAL WORLD, ENABLING PRODUCTIVITY ENHANCEMENT THROUGH OPTIMAL USE OF REAL-WORLD ASSETS.

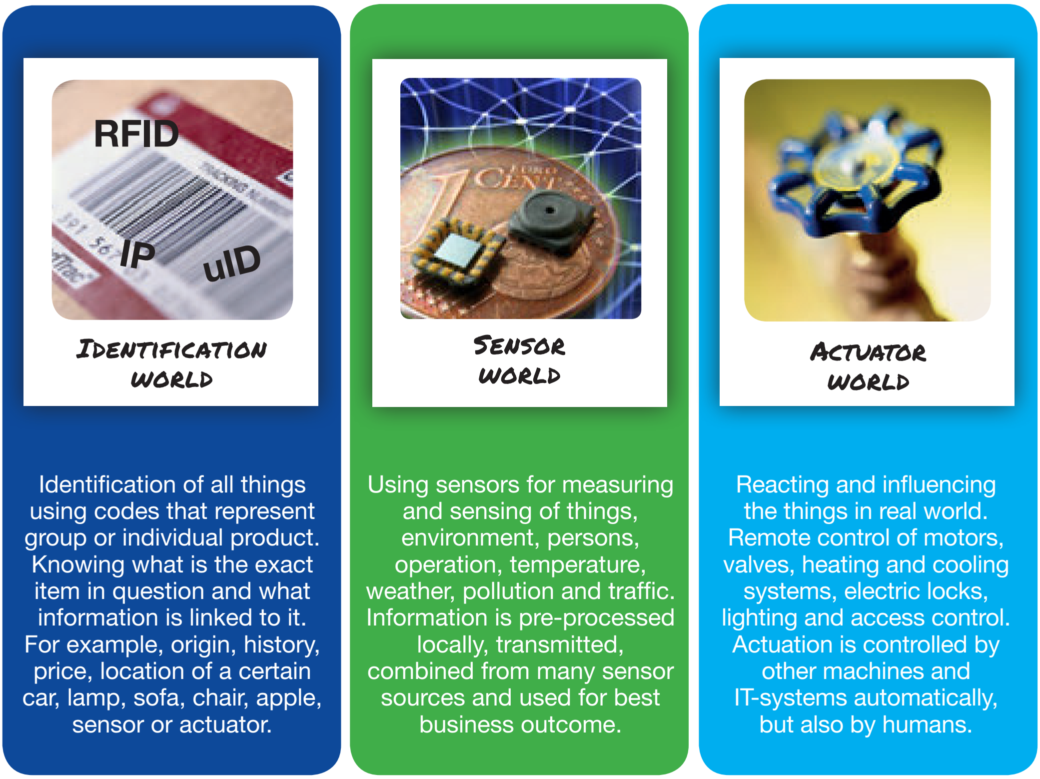


FIGURE 1.4. Internet of things consists of three "worlds" that are interconnected. Identification of objects is a fundamental extension from IP-addresses. Sensors are needed to provide real time information on the objects and actuators are needed to act upon the information.

over domain-, application- or proprietary-specific solutions, which in many cases still dominate today.

As interaction between smart devices and machines takes an increasingly central role, the Internet of Things will progressively take form. The IoT will bring together the physical and digital worlds. Firstly, in the Internet of Things, literally all objects can, and probably will, have a unique digitally readable identifier linking them to information stored in the digital domain. This information does not have to be static, it can be updated and modified to represent, for example, the current location, use, ownership and condition of objects.

Secondly, most measurable phenomena and conditions in the physical world will be measured or observed by sensors, which will refine and then communicate or even publish the information for specific uses. Innovative ways of combining such information from several sources to create additional value are likely to emerge. As an example, combining real-time traffic information with real-time weather information and forecasts may be used for forecasting traffic congestion.

Thirdly, remotely controlled actuators will be used to affect the real world on a much larger scale than today. While the extent of their impact is currently difficult to foresee, these three key aspects of the IoT – the identification world, the sensor world and the actuator world – will have a fundamental impact on business and everyday life as we know it. These three 'worlds' of the IoT are briefly described in Figure 1.4.

The Internet of Things is regarded as a disruptive technology and game changer by many industry leaders and prominent thinkers. They expect major business transformation and growth of productivity:

John Chambers, CEO of Cisco envisions **“connecting every device in the world, this would create a $14 trillion business”.** (Time Magazine Feb 4, 2013, p. 42)

Peter Hartwell, HP, “One trillion nanoscale sensors and actuators will need the equivalent of 1000 Internets: **the next huge demand for computing!”**

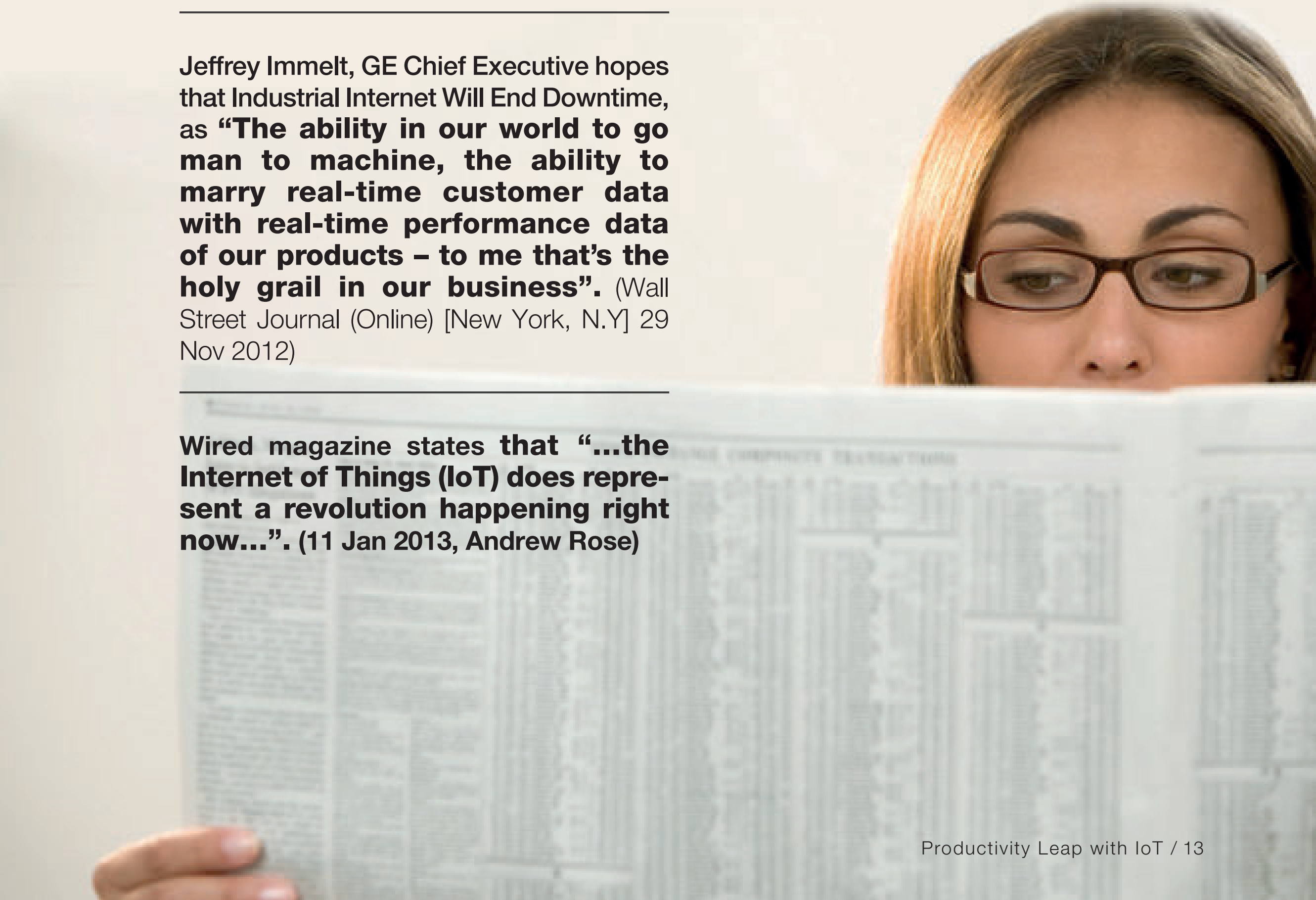
John Flower, EVP, Sun, sees two mega-trends: Reduced costs have brought with them the viability of connecting almost anything to the network. This ubiquity of access will make it so that people’s notions about what they interact with will change dramatically.

Jeffrey Immelt, GE Chief Executive hopes that Industrial Internet Will End Downtime, as **“The ability in our world to go man to machine, the ability to marry real-time customer data with real-time performance data of our products – to me that’s the holy grail in our business”.** (Wall Street Journal (Online) [New York, N.Y] 29 Nov 2012)

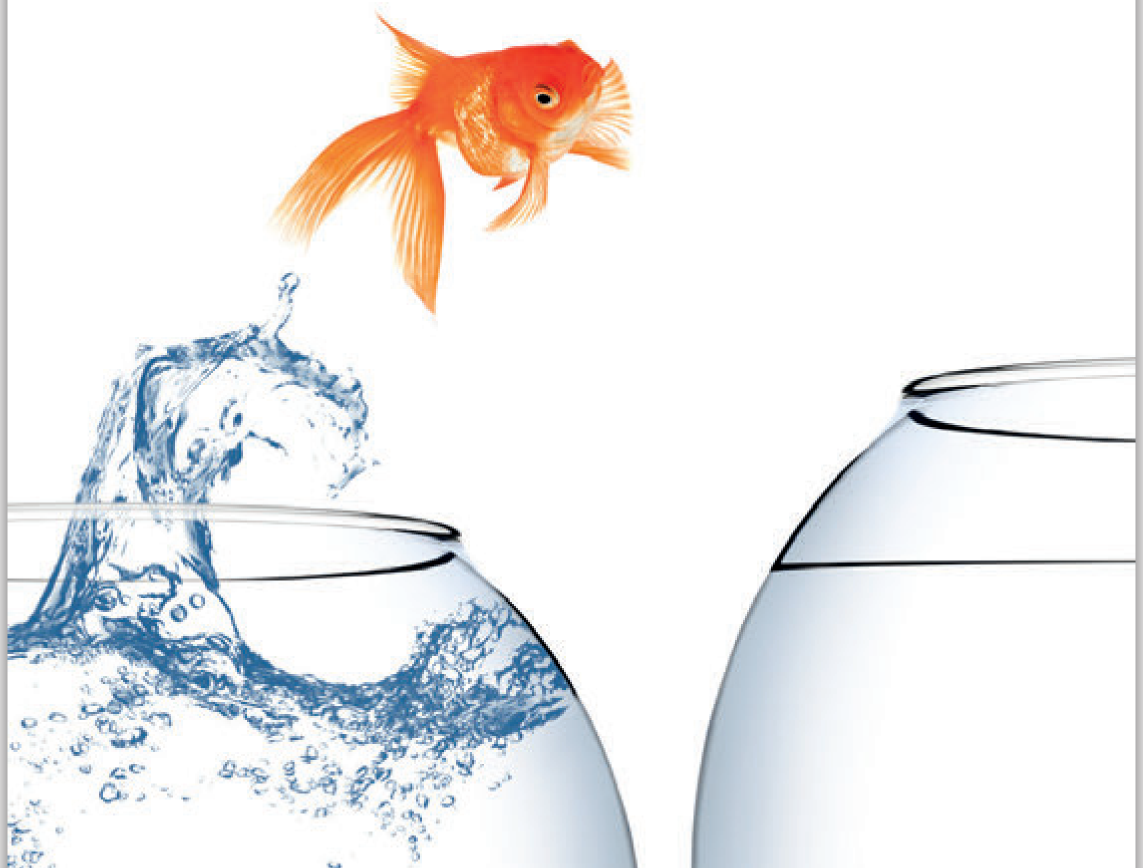
Wired magazine states that “...the Internet of Things (IoT) does represent a revolution happening right now...”. (11 Jan 2013, Andrew Rose)

“2013: **The year of the Internet of Things –** The Internet of Things probably already influences your life. And if it doesn’t, it soon will, say computer scientists”. (MIT Technology Review)

General Electric (GE) expects process has kick-started connecting machines to internet – to **generate an additional $15 trillion in global GDP by 2030** by helping to trim costs and wastages. GE calls it the “industrial internet”, to drive home the difference with consumer internet where people, not machines, are connected to the World Wide Web. (The Economic Times (Online) 17 Dec 2012.)



2 Elements of productivity disruption



The importance of increasing productivity and ICT's significant role in this endeavour are apparent. Increased productivity is being enabled by the changing structures within industry and society, wider implementation of Internet of Things (IoT) technologies, and the new business models that these facilitate. Security and privacy issues may, however, slow this development.

2.1 What is productivity?

Let us begin by defining the concept of productivity in more detail. There are numerous definitions of productivity, but we shall draw here on the OECD definition, as follows:

> **PRODUCTIVITY IS THE RATIO OF A VOLUME MEASURE OF OUTPUT TO A VOLUME MEASURE OF INPUT.**

The choice of measure depends on the purpose of measurement and, in many cases, on the availability of data. Productivity output is either gross output or value added. The required input may be, for example, capital, labour, land, energy, materials, services or knowledge. Even though some of these may seem practically immeasurable, there are several ways of calculating these values. Of the productivity measures, labour productivity is particularly important and is often seen as a dynamic measure of economic growth, competitiveness, and living standards. A common, but by no means only, measure of labour productivity is the GDP growth per hours worked. Some examples based on OECD data are illustrated in Figure 2.1. Finland scores close to average, while South Korea leads the table.

2.2 Productivity through new structures

According to the Finnish Ministry of Employment and the Economy [1], structural changes in ways of doing business are central to achieving productivity growth. Finnish economic policy therefore strongly promotes changes aimed at restructuring the economy and improving labour productivity. In the electronics industry, for example, assembly is no longer a significant part of total output, with the majority of value added arising from other activities, while also in the machinery industry two-thirds of jobs in Finland are not directly related to manufacturing. The highest productivity expectations are today related to brand management, product development, or product innovation related deployment tasks. Finland's vision for strong competitiveness stresses the development of new expertise in high productivity areas allowing the best possible use of labour input.

The importance of ICT technology in improving overall productivity is strongly emphasized by the Ministry of Employment and Economy. Already today, about one third of turnover and exports of the Finnish industrial sector are dependent on information technology. Remarkable growth is expected in this area.

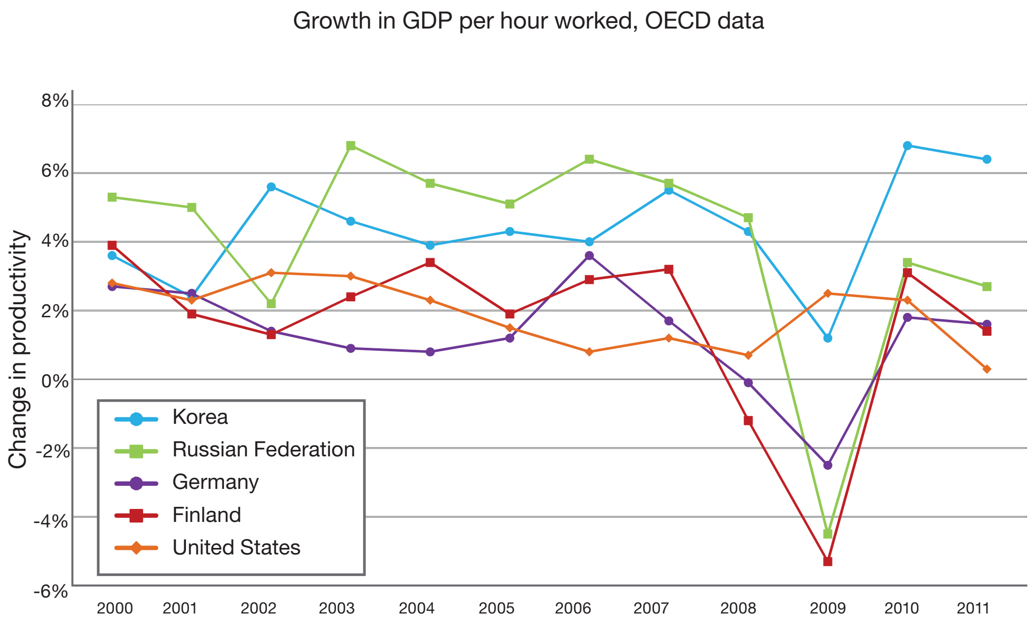


FIGURE 2.1. Growth in GDP per hour worked, OECD data (OECD Factbook, © OECD, 2012).

2.3 Productivity originates from the IoT

Companies are catching on to the business possibilities that IoT technologies enable, and some are already exploiting their benefits. They are recognizing the potential for faster decision making, real-time control, service time reduction, process optimization, new business models, enhanced operational efficiency, resource conservation, and the capability to do all of this location-independently, and moreover, globally.

The Internet of Things connects physical items, such as sensors, mobile phones and other consumer devices, or even enterprise assets, to the Internet and to each other. This allows these items to broadcast their status, context, or any other needed information either publicly or privately. The decreasing price of hardware components and new manufacturing methods, such as printed electronics, are allowing IoT technologies to expand into everyday objects, for example, in the form of printed antennas, sensors, energy and memory storages, and wireless power harvesting components. Further fuelling this growth are cloud services and 4G mobile communication standards enabling more fluent wireless traffic.

The above-described changes throughout the technology arena present boundless business opportunities. This provides unparalleled possibilities for companies to develop new services, improve current practices or implement new business formulas.

However, according to Gartner [2], "the Internet of Things will take more than 10 years to reach the Plateau of Productivity. Despite this, within business verticals there are many pacesetters that are already snatching business benefits. Well-known examples of these include energy companies entering smart metering (a fundamental part of smart grids) or transportation enterprises using RFID (Radio Frequency IDentification) controlled logistics and transportation systems.

In the future, most, if not all, everyday items will have unique identificators or IP addres and will create significant amounts of data or transactions generated by millions of endpoints. The Big Data concept is expanding and data will be referred to in terms of brontobytes (10^{27}). Mobile operators carrying this exponentially growing traffic have already innovated novel data plans for new business conditions and customers. In addition, savvy companies have recognized that a business possibility can be found in having the capability to rigorously analyse this vast data.

2.4 Productivity gains from new business models

The steadily increasing availability of data on customer behaviour is creating opportunities to fine tune current business practices or to innovate novel services and business models. ‘Time is money’ thinking is taking on a totally new dimension in the IoT world. The ability to react quickly is becoming a success factor in all areas of business, as real-time data flows enable rapid decision making and action-taking. Fast access to data enables, for example, system alarms to be generated autonomously, faster and automatically, including exact location information, allowing operational processes to become more efficient.

Technology developments are not only improving current business efficiency, but allowing new user-centric business models. New business models are being introduced in the manufacturing sector, with manufacturing being provided to customers as a service. Customers are being given a new, focal role as co-designers. As an example, US-based car company Local Motors allows customers to participate in producing their own unique car design. Another US company, MFG, provides a marketplace for buyers and suppliers. It acts globally as a bidirectional gateway between buyers and manufacturing service providers. Cubify provides an online 3D printing service that allows cloud consumers to produce their own parts via mobile devices. Customers are being increasingly invited into the driver’s seat of product development. This kind of user-centric business model is the embodiment of the larger service-oriented cloud manufacturing model, the goal of which is to utilize existing resources as efficiently as possible.

Usage-based pricing models are commonly used by mobile operators where the exact service usage is known. Now, IoT technologies are enabling the use of similar business models also in other fields, such as the traditional packaged goods business area. Car insurance companies have shown increasing interest in utilising car usage pattern based models to make personalized offers to drivers where the agreement offered is influenced by the actual behaviour of the driver.

Another illustrative, perhaps surprising, example is lawn-mowing. Currently, for a homeowner to be able to mow their lawn as and when they please, they need to own a lawn-mower. Sound obvious? But what if, instead of having to buy an entire mower, you could simply buy some mowing time, as and when you need it? This may sound like an unexpected business scenario, but from the technology point of view it is fully realizable.

When looking at the IoT world from a service development point of view, we can see that an open IoT data model has already been adopted in the development of new services. Open source developer communities are vital to the ICT technology business, as the examples of Linux, Open Office and MySQL show. In the IoT world, Cosm, previously known as Pachube, is a developer community that emphasizes openness and sharing. Currently, Cosm is moving from a non-commercial orientation towards a more professional business oriented approach. Cosm claims to be a secure, scalable platform that connects devices and products with applications to provide real-time control and data storage (www.cosm.com). Using Cosm's open API, individuals and companies can create new devices, develop prototypes, and bring products to market in volume. Cosm is closely linked to open source electronic hardware platforms such as Arduino (www.arduino.cc/) and Nanode (www.nanode.eu/), which considerably lower the threshold for experimenting with and prototyping new electronic devices, such as sensors and controllers. Since developer communities are crucial to the success of ecosystems, as demonstrated by the Android, iPhone and Windows mobile platforms, the industry would be well advised to follow Cosm and Arduino with interest.

IoT-enabled business models are becoming part of business as usual. The changes in the ways companies are doing business are already becoming visible to customers in many ways. They are taking the form of customer-tailored service options, or the possibility to be part of production or participate in product development. These examples give only a glimpse of the IoT-enabled services to come. One unifying factor in the above examples is that the user has a new, active and central role within the company's business model. Companies adopting new business models such as these are increasingly popping up as enabling IoT technologies emerge and their potential is recognized. As already noted, business models may arise from surprising directions too.

2.5 Security and privacy – obstacles to productivity?

As IoT technologies are applied more and more in business, security threats will become a constant concern. Set of interlinked sensors provide the basis for IoT applications. These sensors are used to measure and often automatically control system parameters. In this environment, even a benign intrusion can cause serious problems, let alone a hostile attack.

Whereas a broad spectrum of security protocols and defence measures have been developed and tested to secure traditional wireless data transfer, so far the retrieval and transfer mechanisms of sensor data have received much less attention. This security challenge will become even steeper as the diversity of sensors and wireless technologies used increase.

Security failures can cause immeasurable harm to businesses and result in widespread, potentially disastrous, damage. As a sinister example, in a targeted attack, the notorious Stuxnet cyber worm, which targets industrial software and equipment used to control and monitor industrial processes, infiltrated an Iranian nuclear facility in 2010. The full extent of the damage caused is still unknown, but the potential consequences are catastrophic [3].

Privacy is the other main concern when end users are considered. Reliable data confidentiality and security are concerns of most users when they allow an application to track their movements or other habits, or data transactions related to health or financial status.

In addition to unauthorized use of data, the question of data ownership will continue to be relevant. A constant exchange of data between things and between things and people may take place without any knowledge of the originators of the data. The concern of the user is wholly justified. As privacy is a multiform attribute, a holistic approach, from discussions on ethics to regulatory decisions, may be needed in solving privacy-related issues.

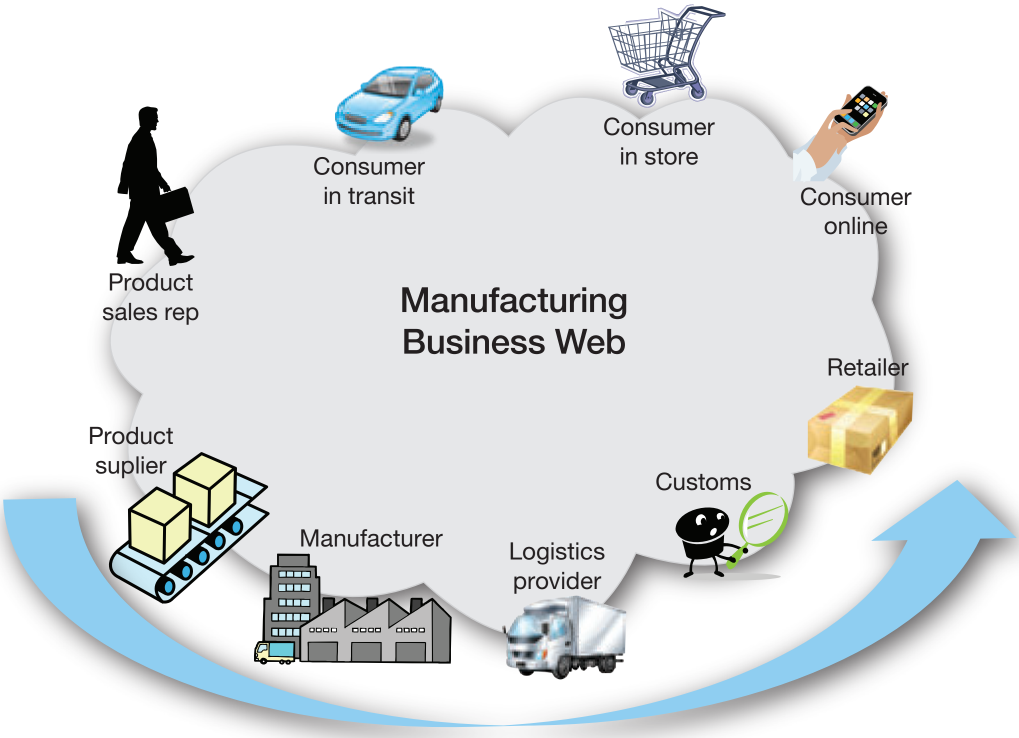


FIGURE 2.2. Manufacturing 2.0 scenario involving different stakeholders in the supply chain of a future enterprise.

2.6 IoT technologies drive the fourth industrial revolution

In Europe, manufacturing has been recognized as a key pillar for growth, and ICT as a key enabler in renewing manufacturing chains. The European vision for ICT and the Internet of Things in the manufacturing sector is well described in the EFFRA road-map [4], where ICT and the Internet are seen as leading factors in creating smart, digital and virtual factories. In manufacturing, the IoT connects the real, digital and virtual worlds of production and serves to bridge and link real-world entities and their digital representations. While the IoT concept has its origins in radio frequency identification (RFID), it now encompasses all networked devices, both within and external to manufacturing operations.

Internet of Things technologies contribute to manufacturing in several ways. For example, they enable smart manufacturing, flexible, self-organized factories, and self-configuration of automation equipment at the work-cell level (Figure 2.2). The key benefit, however, is in making all relevant information about the actual state of a manufacturing plant available in real time, providing the foundation for revolutionary production enhancements. This information can be used for operative and analytical purposes and for supporting high-resolution management. In addition, connecting factories in production networks that traverse country and company borders enables virtual factories where agility, process performance and value creation can be maximized throughout the system life cycle.

Another benefit that the IoT brings to manufacturing is that it enables the customization of even the smallest volumes to a high degree while retaining optimum productivity, thereby optimizing multi-variant series production. It allows companies to involve their customers more closely in the design and production process and to react faster to changing market requirements. Experts are already talking about **A FOURTH INDUSTRIAL REVOLUTION.** In the manufacturing sector, the Internet of Things enables improved business performance, production efficiency, and asset optimization.

INDUSTRIAL IOT EXAMPLES

IoT in assembly control: The basic idea is to provide context and location specific information in a user friendly way, i.e., the right information to the right user/place at the right time. Agro-SISU Power manufactures customized diesel engines with more than 300 configurations. An assembly control system is used to integrate various existing manufacturing ICT systems and the real-time data they provide: RFID product tracking, part ordering, automatic electronic tools parameters setting, detailed instructions of the task and parts, and historic data. The information is shown in a user-friendly touchscreen display interface. The system shortens the learning time of operators and increases quality in production when new products and tasks are introduced. Due to real-time production data collection, quality problems can be solved almost in real time.

IoT in operator support: Volvo Trucks is testing a mobile solution for assembly operators (Figure 2.3). Mobile and cloud-based work instructions accompanied by teaching and demonstration tools reduce operation times by 30% and error rates by 50% for new operators. Paperless and location-aware instructions have been demonstrated to vastly reduce changeover time.

FIGURE 2.3. Mobile operator support for Volvo truck manufacturing (photo: Johan Stahre, Chalmers University)

IoT in system self-configuration: the IoT can reduce operational costs when configuring, commissioning and maintaining manufacturing solutions by shortening disruption times due to reconfigurations or other changes in the production system. The IoT can even enable self-configuration of a device in an automatic plug and play manner – the device is simply plugged into the production system and to the network, and the network takes care of the rest, until the device is made ready for operation. This is a major research area today.

Examples of typical factory tasks include monitoring, controlling and planning production work cells and line operations using digital data. The IoT provides detailed real-time data from the job shop or factory floor which can be used for supporting analysis, for planning in-sync with various simulation and optimization techniques, or for equipment configuration management as described in the infoboxes.

2.7 Power delivery, traffic and health among the first exploiters of IoT

The term "smart grid" has been in stable use since at least 2005, when it appeared in the article "Toward a Smart Grid" by Amin and Wollenberg in 2005 [5]. There are many smart grid definitions. Common to most is the application of digital processing and communications to the power grid to enable new kinds of business possibilities for network operators, power suppliers, electric power market players, and consumers; see Figure 2.4.

The key concepts in current **smart grid development** are new automation, especially in low and medium voltage grids; improved reliability of power delivery; efficient integration of distributed energy resources; vast increases in data and communications; more active end-users; and new digital services for different actors in the value chain. A major challenge is seen to be ensuring information security while on the other hand ensuring the reliability of energy distribution networks.

As we progress toward a smart grid, with the aim of achieving intelligent, more real-time management of grids, more measurement and control possibilities at different grid levels will be needed. This means a huge increase in IoT components in the future. The first embodiment of these is Automated Meter Reading (AMR) systems, which are under installation around the world. At the same time, development steps are taken in building automation, power distribution automation, and in the field of electric vehicles. All this development means more data and communication, most of which will be handled by IoT systems.

Efficient transport is seen as a precondition for maintaining and improving EU prosperity with less congestion, fewer emissions, better employment and more growth. New innovations and business opportunities are being opened up as large sectors, such as transportation, energy and ICT, cooperate together. The major challenges are related to urban mobility, integration of transport at the regional level, and the development of intelligent transport corridors for optimization of efficient transport networks. In recent years, research and development in the transportation field have been directed at cooperative systems, advanced autonomous vehicle systems, systems and technologies towards green mobility, safety systems and applications, as well as security and privacy issues.

Today, about 8–10% of GDP in most Western countries is spent on **healthcare** (up to 16.5% in the US). This translates into 2,500–8,000 euros per citizen per year, which amounts to trillions of euros globally. Health care costs are rising, while at the same time the population is aging and public spending is being reduced – this has created a financially unsustainable situation. With an aging population and unhealthy lifestyles, the prevalence of chronic diseases is increasing at alarming rates. Due to increased health care costs, there is pressure to improve the processes to deliver right results to right places and at the right time for people seeking health care services. IoT technologies are among the core enablers of new services for the wellbeing of people in modern society.

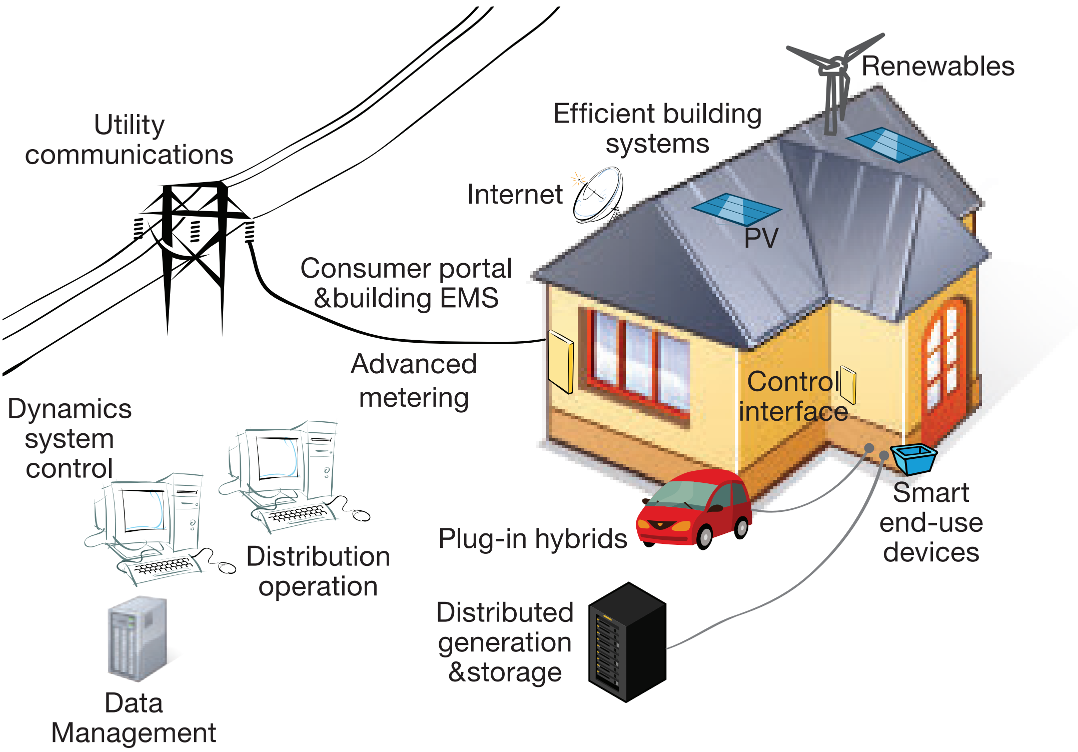


FIGURE 2.4. Smart grid environment.

Until now, however, ICT solutions in healthcare have tended to mirror the current state of care management, which is often too much focussed on providing acute and curative care rather than preventive actions or support. Examples include hospital IT systems that improve professionals' workflow, but are limited to the hospital environment, and, increasingly, telehealth services which support the daily management of patients in the community or at home. Existing ICT-based systems target specific patient populations (e.g., cardiac patients), but lack the crucial ability to personalize care to the continuously changing needs of individual patients. Personalization is needed to deliver precision health care, and to obtain desperately sought-for costs savings. In light of the above, the health care system will inevitably see a shift towards inexpensive, prevention-based, individual approaches – the IoT paradigm plays a key role in enabling this transform.

IoT in system self-configuration:

CASE-EXAMPLE 1: AUTOMATIC READING OF ELECTRICITY METERS

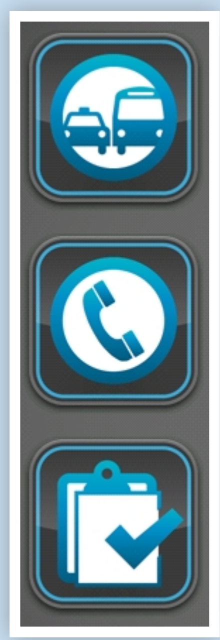
The energy sector is one of the IoT forerunners in automating work processes using sensor and wireless technologies for collecting energy consumption data from customers. Traditionally, meter reading requires labour-intensive on-site visits by utility personnel. Billing is based on rough yearly consumption estimates and the resulting compensatory payments may sometimes be high. In addition, consumers have no access to their actual energy consumption information. The need for remotely readable meters has been recognized for some time. Recent improvements in telecommunication and metering techniques as well as reductions in telecommunication costs have finally enabled this service.

Automatic meter reading (AMR) systems improve efficiency through reduced labour costs, improved information on energy network status, and improved outage management. Furthermore, accurate information and better estimation of customer energy usage helps to optimize energy markets and network management. AMR systems also provide huge advantages in terms of resolving major disturbances or locating faults in low-voltage distribution networks. For the end customer, the transition from estimate billing to direct billing is a major improvement and, in the near future, economic aspects will be more underlined as we progress towards use of dynamic tariffs, varying according to the energy system and market situation. Consumers are also being empowered by being able to monitor their energy usage in real time and make informed energy use decisions.

However, the penetration of AMR technologies still varies considerably geographically. Finland has set high objectives for introducing AMR in all households, and similar progress has been witnessed in many other European countries. The global potential, including developing countries, is significant. The current development of next-generation meters is rapid in countries where the technology is already established.

CASE-EXAMPLE 2: INTELLIGENT TRAFFIC WITH VEDIA

The device-independent Vedia system allows the use of several interactive location-based information services on a smart phone, tablet or other mobile device. The idea of a Vedia is to create a virtual one-stop shop where users have easy access to services through their terminal devices while on the move – on foot, on public transport or in a car. (See Figure 2.5.)



The Vedia provides drivers with real-time information on traffic congestion, slippery roads, the best deals on petrol, and so on. The system also instructs the driver on how to drive eco-efficiently. When approaching the city centre, the driver can use the service to find a free parking space, and to book and pay for it. Furthermore, the driver can check public transport timetables and routes to help plan their journey. Examples of services for commercial transportation include automatically generated driving logs and travel reports, as well as transport monitoring and control, and updated maintenance.

Consumer privacy is of prime importance. The service provider cannot use customer data for any purpose other than that agreed between the partners. Vedia is developed by VTT and leading Finnish companies (for more information, see http://www.vedia.fi/ or http://www.vtt.fi/sites/pastori/pastori_vedia.jsp?lang=en)

FIGURE 2.5. Parts of Vedia main menu.

CASE EXAMPLE 3: PREVENTIVE HEALTH CARE IS DATA-DRIVEN

Technological advancements have influenced the way we live our lives – the 'Four Cs': constant connectivity, collaboration and crowdsourcing, customized consumption, and cloud computing, have paved the way for a data-driven culture in which data-driven healthcare plays a crucial part. A concrete productivity-enhancing example application lies in the early diagnosis and screening of diseases, such as in the case of, enormously costly, dementia. Early diagnoses can be made based on a wealth of "cheap data" obtained from everyday objects. This information can be used to trace changes in behaviour as an alternative to hospital tests, which are typically carried out when symptoms are already too far advanced, thus saving millions per year nationwide by allowing earlier intervention and thereby reducing the strain on care facilities and staff as well as improving the quality of life – and thus also productivity – of patients and their caregivers. The tool developed by VTT takes several inputs (e.g. blood test results, MRI measurements) and compares patient data with database information for healthy and diagnosed people. Based on this data, the tool analyses the probability of Alzheimer's disease (Figure 2.6).

ICT makes it possible to cut the cost of existing services while preserving or improving the level of their quality. In practice, the gaps between research and industrial implementation, such as legislative issues, need to be resolved. As a small, technologically highly developed and well-educated nation, Finland has a unique opportunity to contribute to global efforts towards developing effective healthcare solutions.

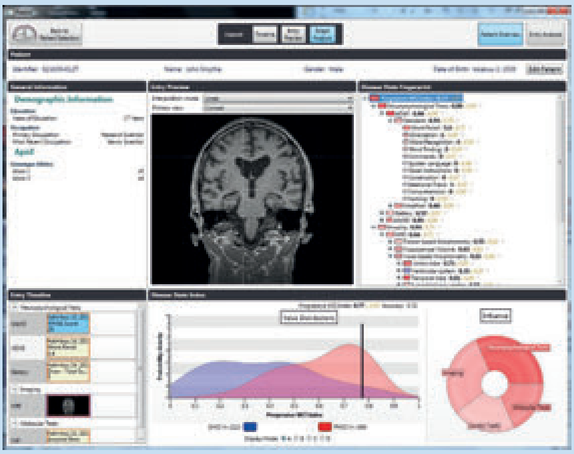


FIGURE 2.6. Screenshot from a preventive tool for early diagnosis of Alzheimer's disease.

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[3] http://csrc.nist.gov/publications/nistpubs/800-82/SP800-82-final.pdf, p. 16.

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Productivity Leap with IoT – VTT's spearhead programme targets tomorrow's challenges

Increased productivity is vital to the future of Finland and Europe. "Securing and increasing our industrial base is vital to both Finland and Europe. We can sustain the western living standards and contribute to the global future only by being the home to world-class industry. VTT's spearhead programme 'Productivity Leap with Internet of Things' (Pro-IoT) seeks to capture the opportunities presented by the Internet of Things as a powerful enabler of productivity gains. Pro-IoT is one of VTT's four spearhead programmes and represents an important strategic path decision in our operation.

> I SEE IOT AS A KEY TECHNOLOGICAL TOOL FOR IMPROVING PRODUCTIVITY, WHICH IS THE MOST FUNDAMENTAL MEANS OF ENSURING THE COMPETITIVENESS OF OUR INDUSTRY AND SOCIETY AS A WHOLE. VTT AS A MULTIDISCIPLINARY RESEARCH ORGANISATION IS IN AN EXCELLENT POSITION TO DRIVE THE ADOPTION OF IOT TECHNOLOGIES IN DIFFERENT FIELDS."
>
> **HEIKKI AILISTO, PROGRAMME MANAGER**

To achieve the desired impact – maximal improvement in industry and public sector productivity – two target areas were selected for the Pro-IoT programme: **Global Asset Management (GAM)** and **Smart Lighting (SL)**. These key business areas are of significant importance to Finland, as the machine and vehicle industry, a heavy user of global asset management technologies, accounts for a major part of Finnish export income. Smart lighting is also a highly promising new industry and a new business area in its own right. In addition, ICT and electronics as productivity enablers are also important elements in the programme. VTT has a strong background in the development of all of these areas.

The following chapters give a closer glance at how IoT increases productivity, especially in Global Asset Management (Chapter 3) and Smart Lighting (Chapter 4). During the course of the four-year programme, new business and application areas are expected to emerge, of which those offering the highest potential are identified and briefly presented in Chapter 5. For more information, contact Heikki Ailisto at heikki.ailisto@vtt.fi or visit www.vtt.fi/programmes.

Productivity improves when downtime of production assets decreases.

Productivity improves when unnecessary service calls and work hours are eliminated.

Productivity improves when lighting is where the people are.

Productivity improves when there is right kind and right amount of light.

Increasing the productivity of our clients

Strong industry in Finland going through transformation

Decreasing machine and vehicle breakdowns, avoiding high maintenance and service costs.

Application area Global asset management

- **Solution:** Optimal use of industrial and machine assets utilizing powerful measurement units and condition recognition algorithms
- **Opportunity for business transformation:** From one-time sale to service based revenue, creation of new service-based ecosystem.

Removing unnecessary costs and discomfort caused by excess, non-optimized lighting.

Application area Smart lighting

- **Solution:** Better lighting experience with 70% less energy using sensor information, novel luminaires and smart control of light
- **Opportunity for business transformation:** New business model: "light as a service" and emergence of new "smart light companies"

Potential for a new smart lighting industry and an ecosystem.

Our technology competencies form the basis

- VTT Node, a powerful and robust wireless sensor node
- Tolkku toolbox, algorithms that process sensor data
- Condition Based Maintenance competence
- Global Asset Management process understanding
- LED luminaires, wireless control and sensor solutions
- Printed intelligence luminaires and sensors
- Context detection
- Smart lighting pilot environment

…IoT communication infra, interoperability, IT security,...

3 The future of maintainance business

CONDITION MONITORING

> SENSE CONTEXT
> ANALYSE CONDITION
> PREDICT LIFETIME

SPARE PARTS

> TRANSPORT DIGITALLY
> PRODUCE LOCALLY
> MOUNT ON DEMAND

3.1 Enhanced productivity by service ecosystems for asset management

In the most elementary definition, asset management means getting the best value out of a company's assets [1]. What constitutes the value gained from these assets depends on the company's objectives as well as the nature and purpose of the organization and the needs and expectations of its stakeholders.

Obtaining customer commitment to a product or product line is challenging in today's world. Most of the businesses consider customer loyalty an essential part of their business strategy. Committed customers will create competitive edge and will be sought after. Performance based services that support end customers' business needs will be offered more than just producing sophisticated products more efficiently. These services must be tightly integrated with top quality products and will be necessary for a company's competitiveness and ability to obtain loyal customers in the global market. These services may include, for example, maximising the operational up-time of machinery through suitable maintenance strategies such as condition-based maintenance (CBM), on-demand production, supply and assembly of spare parts, and optimizing process capacity and quality by controlling and tuning based on real-time information obtained from the process and the surrounding environment. A typical example of management of distributed assets is fleet management where vehicles' location, usage level and condition are tracked globally on-line.

ADDED VALUE FROM ASSETS COMES IN SEVERAL FORMS. IN ADDITION TO ECONOMIC VALUES SUCH AS BUSINESS PROFITABILITY OR HIGH PRODUCTIVITY, IT CAN BE RELATED TO ENVIRONMENTAL, SOCIAL OR OTHER DESIRED OUTCOMES. ASSET MANAGEMENT IS A STRUCTURED APPROACH THAT SUPPORTS THE ACHIEVEMENT OF ADDED VALUE WHILE BALANCING COST, RISK AND PERFORMANCE CRITERIA.

It's strongly indicated that manufacturing companies are focusing on the development and provision of services to increase attractiveness of their offering. This interest is also fed by the new business opportunities that emerge from such service integration. However, as manufacturing companies continue to focus increasingly on their core business – the development and manufacturing of their products – the above development will not be achievable unless these additional services are provided by partner networks via an industrial ecosystem whose future operation will be increasingly enabled cost-efficiently by Internet of Things (IoT) technologies.

THERE IS AN ON-GOING TRANSITION GLOBALLY FROM PURE IN-HOUSE MAINTENANCE ORGANISATION MODELS TOWARDS DEEP PARTNERSHIPS IN COMPLEX COMPANY NETWORKS SUPPORTED BY RAPID DEVELOPMENT OF IOT TECHNOLOGIES.

3.2 Why does asset management need service ecosystems?

In terms of asset management, productivity is a complex equation and has a multitude of contributing factors. For example, optimal performance and reliability in demanding operating conditions requires active tuning of machines or processes as well as continuous monitoring of critical components to prevent unplanned service breaks. Systems are also bound to become ever more complex, as more technology is needed to fulfil the constantly tightening requirements and limits for quality, energy consumption and emissions.

These changes are leading to a situation where users can no longer maintain the systems by themselves for technical or economic reasons and are looking for new service-based operating models. Such services could be provided by a manufacturer of an asset or third party to enable the users to concentrate on their core business. New technologies are changing ways of thinking regarding these types of models, partly because they enable the provision of such services at reduced cost, but also because they open up totally new possibilities for increasing productivity through new business models and operational improvements. The logic for increasing productivity through global asset management is depicted in Figure 3.1.

Service models are also becoming attractive to regular consumers for the same reasons. More and more technology is being embedded in our everyday lives, and maintaining it is far beyond our ability. For the modern consumer, ease of use and attractiveness of a product remain of key importance, but environmental awareness is also increasing. Services bringing added value to products will form the markets of the future. The winners in this tight competition will be alliances that promote the most interesting and valuable services on the top of their products. Maintenance and updating of products must therefore be made as easy as possible for consumers, whose time and knowhow may be limited.

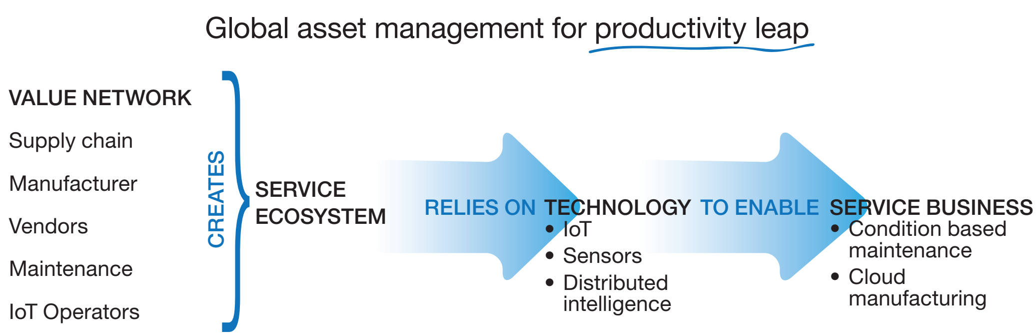

FIGURE 3.1. In the future, IoT operators are increasingly included thus enabling the exploitation of IoT in asset management. This basically means that, for example, one office can be dedicated to monitor the condition of an entire fleet of trucks on different routes around the world and use the service ecosystem of partners to perform maintenance.

VISION

Equipment in the field will constantly monitor and report their state and efficiency via remote connection to the service ecosystem. They will adapt themselves to changes in context by updating their control software and operating instructions via a configuration management service. In the case of mechanical failure, they are able to replace the outworn parts with the latest models by ordering virtual spare parts in digital form through a remote connection and make them concrete by deploying a local manufacturing service close to the site offered by a service partner. This all will be offered and controlled from the service ecosystem within a single service agreement.

3.3 Internet of Things is a platform for sophisticated services

Imagine a situation where your equipment tells you when it needs servicing and all the spare parts it needs are stored in digital form, transferred by email, and manufactured and installed locally, as and when needed, by a service ecosystem partner located close to site. This revolutionary approach will transform the market positions of the current stakeholders. Embedding more intelligence and sensing technology in products will open the bottlenecks in automated diagnostics and prognostics, even though today these technologies are priced too high to be able to create all-inclusive systems for most target applications. Local spare parts manufacturing will come into its own with breakthroughs in additive manufacturing and material technologies.

In the near future, a similar revolution to that seen in the telecom sector some years ago can be expected within the manufacturing industry. Services and related ecosystems that currently bring added-value and commercial benefit to mobile operators and mobile device

In traditional manufacturing and sales, customers often see products as one-time investments that are easily redeemable. Instead, when a product comes with a service, such as maintenance or optimization, the product becomes much more attractive and harder to replace with other products. *If the product is, in addition, connected to an ecosystem of other products and services as a seamless part, it is almost impossible for competitors to intervene in the value chain.* When such an ecosystem works optimally, there should be no economic or technological reasons for breaking the chain.

manufacturers will be adopted and developed by other industries too. For example, the network equipment vendor NSN not only produces base stations and related systems, it also provides operators with network planning, installation and maintenance services. This allows operators to concentrate on serving their end-user subscribers. Another example from the telecom world is Apple, who has successfully integrated a full ecosystem of supporting services into their devices including music, applications and electronic books.

For the manufacturing industry the impact will be three-fold. On the one hand, companies will need to provide ecosystem services to customers buying their products. On the other hand, companies themselves will benefit from the services provided by the ecosystem, which manufactures all of their operational equipment. Thirdly, manufacturing companies will need to learn how to integrate third-party service providers, such as operators, from other levels of the value network into their operational model in order to provide the best service for their customers.

As seen before in the telecom industry, such transitions and market changes are based on the evolution of enabling technologies, which have opened up totally new market opportunities for different stakeholders. Even today, almost any machine or device can be equipped with Internet access and a range of sensors without technical challenges. In fact, in future, IoT technologies will provide an ideal platform for sophisticated services that will emerge in, and blur the boundaries between, the real and virtual worlds.

YOUR EQUIPMENT TELLS YOU PRECISELY WHAT KIND OF SERVICE IT NEEDS, WHERE, WHY, AND WHAT ITS ESTIMATED LIFE TIME WILL BE WITHOUT THAT SERVICE.

3.4 Machines connecting the real and virtual worlds through IoT and sensoring

The huge steps taken in communication, sensing and data processing technologies in the consumer markets have enabled the rapid evolution of technologies supporting service ecosystems in recent years. Sensors for typical measurements have become everyday tools, and communication technologies have enabled Internet access almost everywhere, to almost everyone, and by almost

SERVICE ECOSYSTEMS LEAD TO NEW BUSINESS MODELS:

- **Service ecosystems provide a very different business model to traditional one-time investments where the customer purchases, for example, an engine. In service-based ecosystems, the monetary flow related to a purchase is more towards a continuous revenue stream.**
- **Asset ownership may be totally or partly replaced by performance-based contracts, access rights, leasing, sharing or other forms of collaboration. The supplier companies guarantee a certain level of performance, response time or some other mutually agreed set of Key Performance Indicators.**
- **An example of the transition from ownership to access is the cost per performance agreement. When ownership is replaced by access to the product and service (e.g. performance), new innovative business models emerge and these can, for instance, be the basis for new kinds of knowledge-based companies.**
- **New business models also boost the technological development of manufacturing companies towards more reliable and maintainable systems.**

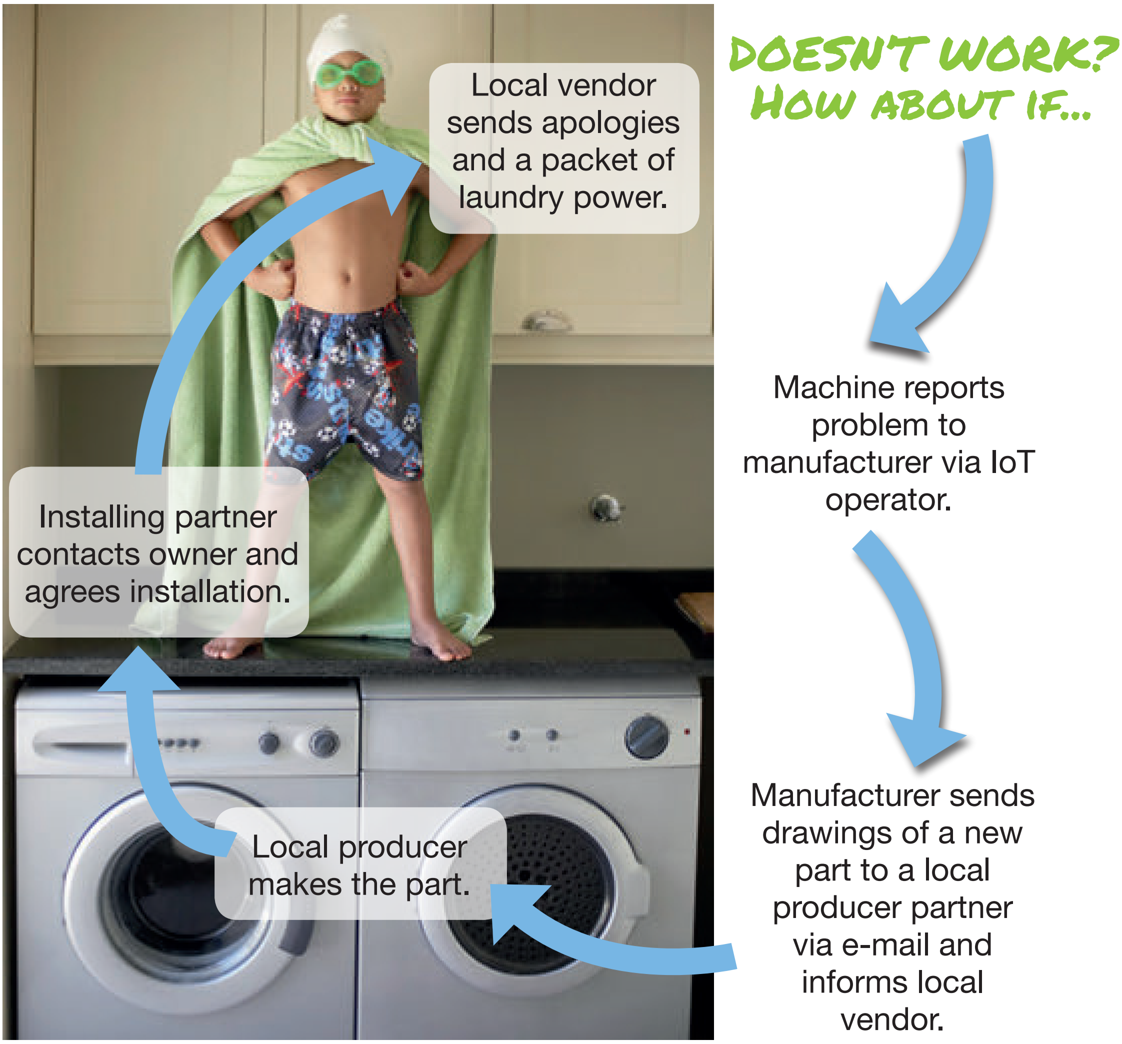

FIGURE 3.2. In the future, home appliance maintenance could be as simple as this. The picture shows the information loop for condition-based maintenance and describes the actions taken by actors in the service ecosystem of a laundry machine manufacturer.

everything, in the world. The IoT is expected to extend connectivity and Internet access from consumer devices to all items and components having enough capacity for information processing. Machines and vehicles will have connectivity and virtual identity and will interact with the physical world by sensing the context in which they are being used and by sensing the state of their critical components to optimize their performance.

Sensing technology will be integrated directly into structures and will exchange information about the state of critical components. In the future, sensors will be integral parts of machinery, enabling constant real-time monitoring without the need to stop the process or open up equipment. Energy harvesting from the environment together with robust wireless communication enables sensor installations in even the hardest to reach places, such as inside engines. Once sensor manufacturing technologies are ready to integrate sensing elements directly into parts cost-efficiently on production lines, the major markets will open. A more practical example is given in Figure 3.2.

> ICT HAS A CRUCIAL ROLE IN MANAGING THE VARIETY OF SERVICE REQUESTS, MATERIAL SUPPLY CHAINS AND COMPLEX PLANNING AND SCHEDULING INFORMATION CHAINS IN ALL SERVICE SYSTEMS. INFORMATION TECHNOLOGY IS SEEN TO LEAD TO IMPROVEMENTS IN PRODUCTIVITY AND IN EQUIPMENT UPTIME. CURRENTLY, THE UTILISATION OF INFORMATION PRODUCED IN THE MAINTENANCE FUNCTION IS TOO RESTRICTED TO OPERATIONAL CONTROL, AND ITS FULL POTENTIAL IN OVERALL MAINTENANCE DECISION SUPPORT REMAINS UNREALISED.

3.5 Roadmap towards IoT-enabled service ecosystems

IN THE SHORT TERM, there is a need for robust sensing technology that can be cost-effectively integrated into products. Novel manufacturing methods, such as additive manufacturing, or 3D printing, the process of creating three-dimensional solid objects from a digital model through a sequential layering process, are of key interest with regard to this kind of structural integration because they allow, for example, cost-effective integration of sensors during the manufacturing process as opposed to adding sensors manually afterwards. In addition, robust secure communication solutions are needed to provide reliable remote access to sensors and enable data transfer from them. Energy-efficient data processing needs to be developed to reduce the amount of measured data before transmission. Better utilization of usage information collected from control systems will also have a remarkable role in remote services. The first global implementations of all of the above are already being carried out by several companies. The near future will reveal the trends and major challenges as the first large-scale remote service installations are rolled out.

IN THE NEXT PHASE, after remote monitoring services are up and running, processes will need to be optimized by sensing the process itself as well as its surrounding environment. Optimization may also involve input from other objects and operators working nearby. This is where the IoT comes into the picture. Machines and devices will communicate with other objects, collecting and providing information about condition, efficiency, context and joint activities; for example, tractors in the field may exchange information with a combine harvester to optimize joint grain harvesting operations. Machines will have the ability to adapt themselves to changes in context and optimize the performance of the process. The status of the operation, overall efficiency, condition information and remaining life-time of critical components will be delivered to the service ecosystem via remote connection.

IN THE LONG TERM, we see an ecosystem where machine fleets are able to analyse and optimize their state and the whole process they are a part of based on globally collected information from similar processes. This process optimization will utilize information from public sources as well as from other devices nearby; for example, train traffic control that uses weather information together with information on current snow conditions on tracks to predict snow and ice loads and to optimize traffic. System user behaviour will also be analysed and considered in the optimization to

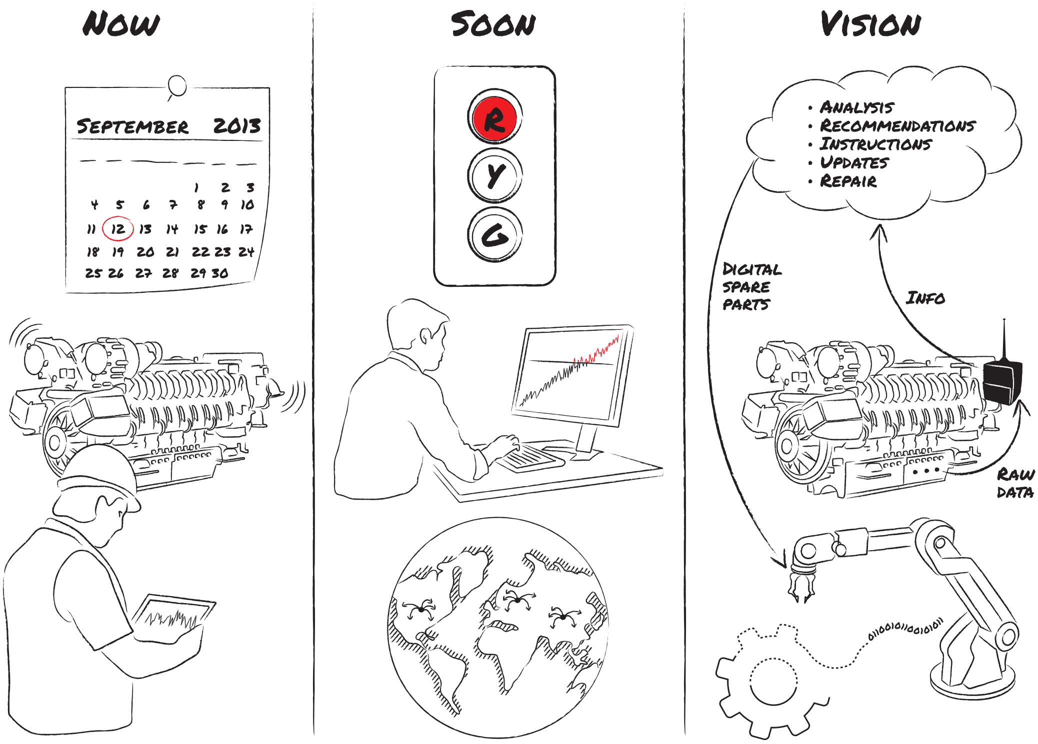

FIGURE 3.3. The transition from scheduled to condition-based maintenance opens new opportunities for service business. In the long run, this evolution will lead to ecosystems providing all-inclusive maintenance, from sensors to intelligence and personalized spare parts.

identify possible misuse or abnormal behaviour causing safety risks. The system will perform self-diagnostics on its condition and report to the remote service. In addition, the system will be able to order spare parts in digital form from the provider as parts approach the end of their life time. The required spare part design files will be transferred in a secured form to a preferred local manufacturer who will produce the components and forward them to the local maintenance partner for assembly, as depicted in Figure 3.2.

3.6 Challenges on the way

The main future challenge lies in the vast amount of data collected from devices and sensors in the field and finding methods for its wise deployment. This leads to a strong need for embedding intelligence in the immediate vicinity of equipment, and for developing processes that analyse the information locally before transmitting it over wireless or wired media for final use.

Once the physical information has been converted into digital form, there will be a need for data processing. In the vision of a comprehensive system with hundreds or thousands of sensors per machine, the amount of raw data will be enormous. The local-level system will need to have enough computational capability to process this raw data into a sophisticated form. The processed data could be used at the local level for optimization purposes in automation systems and, finally, sent via suitable media to a monitoring service.

The real challenge is distributed automatic decision making that boosts the cost efficiency of the service ecosystem.

Information security must be taken seriously in order to guarantee the authenticity of information and the privacy of systems connected to the Internet. There will be an increasing number of attacks in the future on public infrastructure and commercial operators, for example in the fields of energy production and transport.

3.7 Service providers must have the capability, technologies and skills to collaborate

When there are millions of intelligent devices equipped with control and monitoring functionalities operating in the field, there will also be a need for a comprehensive management infrastructure that governs the whole service ecosystem. Only in this way can the optimal up-time, performance and desired properties of machinery be guaranteed throughout their lifetime.

Networked and integrated asset management approaches require interdisciplinary know-how and competence. In particular, there is a clear need to combine engineering and economic evaluation methods. The essential elements of global asset management are knowledge and understanding of value creation processes and the risks endangering the resilience of business. Risk-conscious decision making, system thinking, ICT together with modern sensor technology, and new business models are needed for successful implementation. Globalisation, complexity of technological innovations and demand for interoperable solutions also create the need for networking and draw traditional technology providers towards transformation into collaborative service companies.

Service providers must have the capability, technologies and skills to collaborate not only with the principal client – the asset owner – but also with other service companies within the network. This kind of operational model will also lead to situations where network members find themselves cooperating together even though, from a competition perspective, they may have conflicting goals. Figure 3.4 illustrates the circular layers of a maintenance network that aims to support

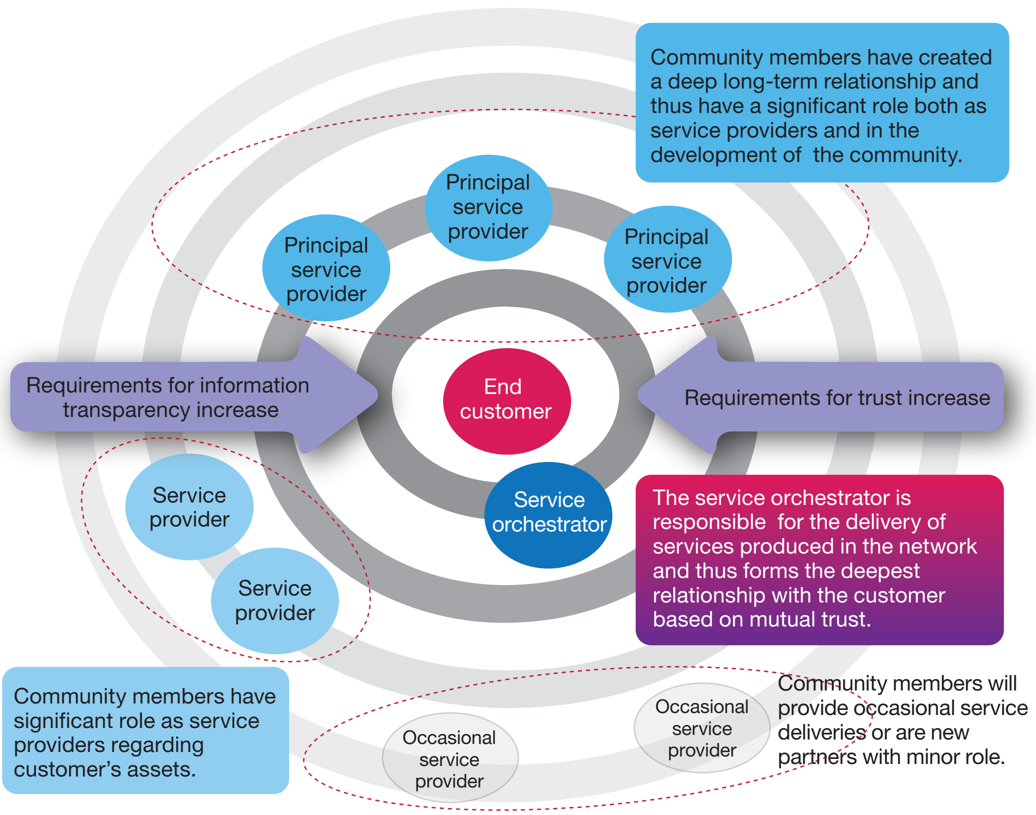

FIGURE 3.4. Illustration of the requirements for trust and information transparency and the roles of service ecosystem actors. The end customer is at the centre of the network, the service orchestrator being at the next level. Principal service providers and other service providers are located further away. The requirements for information transparency and trust increase towards the centre of the network. [2]

both the presence of long-term partners and the dynamics of the network with changing community members. In addition to trust, requirements for transparency of information exist.

The requirement level for each community member can vary depending on the nature of the member's role. The requirement levels are depicted as circular layers in Figure 3.4. The figure illustrates a situation in a service supply network where one company works as an orchestrator that provides total services with the help of a wide network. This company in these cases is in charge of the characteristics of the service and manages the relationship with the customer. The rest of the network members may vary in respect to their responsibilities, roles and backgrounds. Despite the differences, changes and dynamics of the network, there is a requirement for a good start-up and for maintaining efficiency with a certain level of trust and collaboration. A trusted orchestrator thus has a highly important role. Altogether, the objective is to generate a common value creation mind-set, earning principles, and rules of value sharing that can be accepted by all. Furthermore, technology should be introduced that meets the requirements of the new operational model. For instance, faulty or lacking information has been traditionally compensated by the benefits of the maintenance organisation having most resources on site and ways of getting real time information informally. The need for formal and reliable information on the service target increases when there are fewer on-site resources. This demand could be met by introducing new ICT. However, it is worth noting that the networked models should allow the members of the network to sufficiently consider their own individual business aspects while ICT systems are integrated and designed to support the collaborative environment.

3.8 Moving towards condition-based maintenance

There are many kinds of maintenance strategies. The simplest and still prevailing practice today is Corrective Maintenance, i.e. a component, device or system is run until it is broken, and then repaired or changed. An alternative to corrective maintenance is Preventive Maintenance. Preventive Maintenance can either be Predetermined Maintenance, i.e. scheduled maintenance, or Condition-Based Maintenance (CBM).

Scheduled Maintenance is typically based on the recommendations of the equipment manufacturer. Also, these recommendations are typically based on the running hours of the equipment and none of the other influencing factors, such as, load or dirt accumulation, are taken into account. In CBM, the idea is to allocate and plan maintenance tasks according to the anticipated, measured or calculated condition of a component, device or system, and considerable costs and downtime can be saved if CBM is used appropriately. However, effective CBM is generally extremely challenging to implement.

The introduction of new, more efficient and reliable, yet cheaper, sensors together with the development of ICT in connection with wireless communication and mobile devices have greatly influenced the development of CBM and made it economically more justified. Use of the Internet to support maintenance has also become widespread in the form of e-maintenance. E-maintenance can be seen as a network that integrates and synchronizes various maintenance and reliability related applications in order to gather and deliver asset information where it is needed. In this sense, e-maintenance can be considered a modern tool for supporting further development of CBM.

Implementing effective CBM is knowledge and experience intensive. Accurate CBM is possible, but, in general, comprehensive CBM (i.e. having everything monitored) is not practical or economically justified. CBM is improved by thorough engineering, deep expertise, detailed modelling and understanding, and accumulated field experience. When successful, a range of significant advantages are obtained.

Traditionally, maintenance has been the business of the plant or machine owner or operator. Today, machine vendors have knowledge or immaterial assets in CBM, on the basis of which they can offer industrial services. There are also some companies that specialize in providing such services. As ever more resources are needed at the end-users' side to obtain and keep needed knowledge, the more willing the end-users may become towards subcontracting or outsourcing maintenance.

REMOTE MONITORING OF A TRAIN WHEELSET

A wireless remote monitoring and analysis system has been developed to monitor the condition of train wheelsets. High impacts and continuous vibration cause wheelset fatigue and damage. With real-time monitoring, new component structures can be analysed during break-in periods. The current setup is capable of measuring and processing several high frequency vibration and strain gauge channels from different sensors in real time and sending the processed data to the remote service. Several wireless sensor nodes in the same car can be synchronized accurately via a wireless connection. The current system is based on VTT's own technology platform, VTT Node, and has been tested in several high-speed trains throughout Europe.

REMOTE MONITORING OF POWER LINES

Windy and snowy conditions pose a serious risk to power lines, causing unpredictable damage or total breakage of cables and poles. A cost-effective method and a suitable technology including sensors, data processing and communications has been developed to monitor the condition of power lines remotely. The information from the system is available not only to the power grid owner, but also to all partners of the ecosystem providing maintenance services.

ENERGY-AUTONOMOUS MONITORING FOR CRUSHING AND SCREENING IN MINERAL PROCESSING

An energy-autonomous condition monitoring system has been developed for the mining industry for use in rock crushing and screening machinery that vibrate at high amplitudes during operation. An embedded energy harvester converts enough power from the vibration to guarantee sufficient life time for sensor nodes to perform measurements, data processing and wireless transmission in cycles. The information is delivered from the sensor nodes to a remote system where it can be used for maintenance or control purposes. The current system is based on VTT Node technology.

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   17th International Working Seminar on Production Economics, Pre-Prints vol. 2. Innsbruck, AT, 20 - 24 February 2012. Linköping University of Technology and Universität Innsbruck. Innsbruck (2012), 257 – 264

4 Smart lighting – enter the comfort zone

"Beautiful day" she thought to herself, barely awake, feeling the light through her eyelids. She opened her eyes to a room ablaze with sunshine, reflections from the nearby lake, green grass, and blue sky. She sensed a small cloud momentarily hide the sun, but then pass, letting warmth and light fill the room again. The waves on the water and the movement of the leaves and grass in the wind kept the light alive. "What's up?" she asked. The sun seemed to morph back into a cloud and news headlines appeared on the wall. "More snow?" she thought. "Where will they put it all this winter?" "Enough", she said. "Who's up?" She gazed at some blobs of purple light on the floor towards the living room and, after listening for a while, heard her daughter moving downstairs. Purple was her daughter's favourite colour, now that pink was no longer "in". Turning her head she saw a warm blue glow on the desk. "Oh, Peter's still awake." She reached for her phone and asked it to place a call to her husband. Peter's face appeared on the wall. A beautiful Californian sunset filled the room. "Hello Darling. How was the conference?"

4.1 The next revolution in electric light

We have come a long way since the early days of electric light at the beginning of the 20th century, when light bulbs brought incandescent light to the masses. The evolution of electric light has continued with halogen, gas discharge, fluorescent lights and LED technologies, bringing enormous improvements in brightness and energy efficiency (see Figure 4.1).

Until now, the evolution of lighting has been much related to technical improvements – more light with less energy. Substantial improvements have been made in luminaire and lighting design as well as with lighting control system development.

4.2 "More than light" becomes a new driver for smart lighting market after energy efficiency

In 2005, lighting consumed about 19% of all electric power globally. Since electricity generation is one of the main factors contributing to greenhouse emissions, lighting must also be seen as a cause of emissions and the energy consumed by lighting should be decreased. From a technology perspective, this can be solved partly by using energy-efficient fluorescent lamps, metal halide lamps and LEDs. The next step beyond this comes with smart lighting: providing light only where needed and when needed. In fact, switching to LED illumination has been shown to achieve 50–70% energy savings. Up to 80% savings are achieved when LEDs are coupled with smart controls [1]. In next five years, the energy efficiency drives smart lighting market.

However, light can be more than just light. In buildings and shops light can be used to guide, entertain and attract. It can provide safety outdoors. It can enhance wellbeing by preventing depression, easing jet-lag and helping students concentrate in school. These and other more-than-light features present huge opportunities for new business and innovations. The possibilities are especially high for new spin-offs and SME's. Some large lighting companies are already entering this area and it is likely that other players will follow. Since large base of IoT devices can be smart luminaires, the semiconductor industry is also looking for possibility to integrate their communication and processing related integrated circuit products to a lighting domain.

The smart lighting market is expected to see aggressive growth over the next ten years, rising from $0.436 billion (2013) to $11.4 billion by 2020 [2].

Lighting system control components, which make up a key part of smart lighting systems, include hardware such as sensors, controllers, management systems, timers, dimmers and their respective software. Their market (see Figure 4.2) is predicted to grow substantially faster than general lighting, by almost 20% during the same time period [3]. Wireless lighting products, in particular, are expected to gain traction as they provide added flexibility and are easy to install [4].

OUR DEFINITION:

A SMART LIGHTING SYSTEM IS COMPOSED OF LAMPS, LUMINAIRES AND LIGHTING CONTROL SYSTEMS THAT UTILISE SENSOR INFORMATION AND EMBEDDED INTELLIGENCE TO PROVIDE BETTER ENERGY EFFICIENCY, COMFORT AND "MORE THAN LIGHT" FEATURES SUCH AS GUIDANCE AND WELLBEING WITH LIGHT.

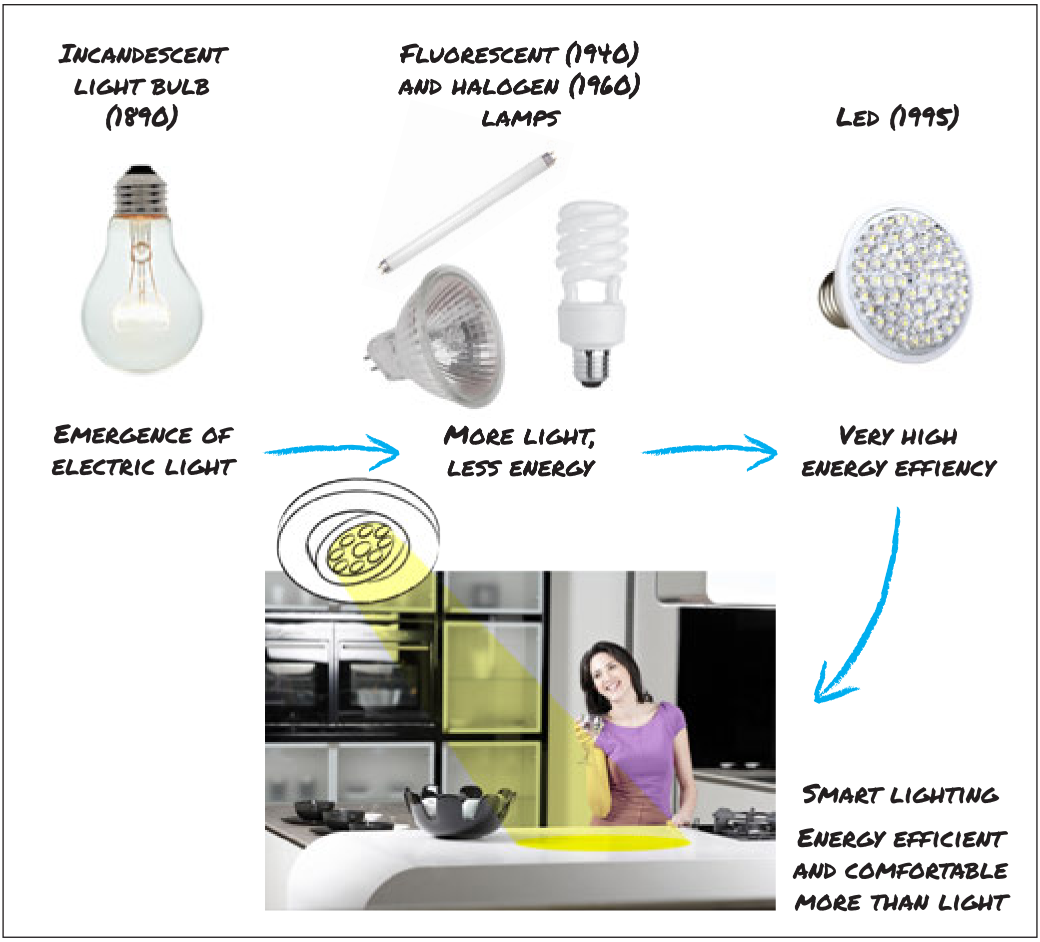


FIGURE 4.1. The evolution of electric light. The focus is now shifting from light source technologies towards smart lighting.

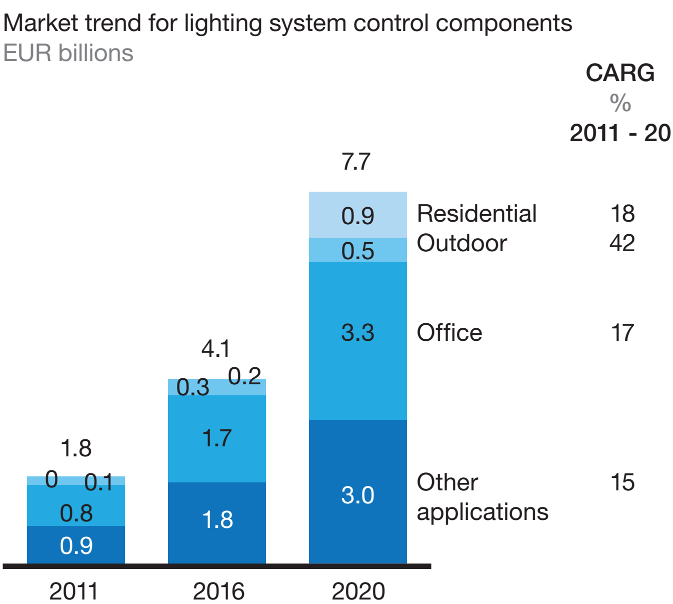
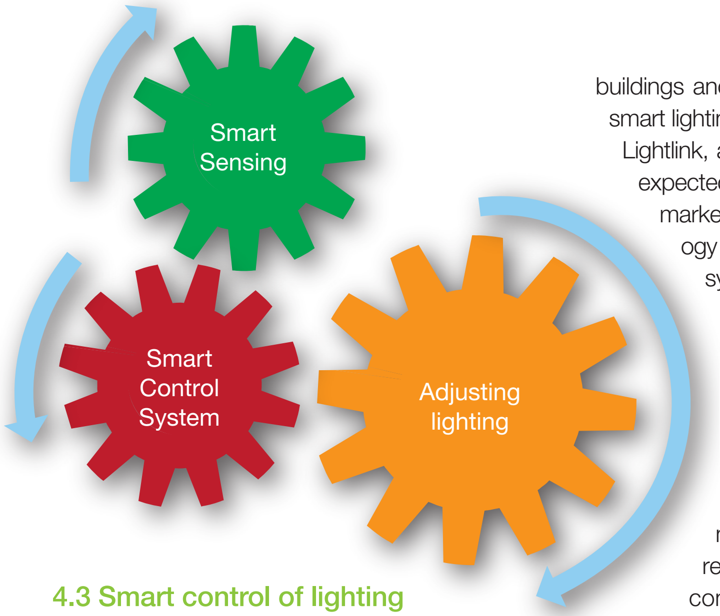


FIGURE 4.2. Market forecast for lighting system control components. Other application segments include architectural use of lighting for decorative and functional uses as well as the retail, industrial, hospitality, industrial and outdoor market segments. [3]



4.3 Smart control of lighting

A simple example of smart control is office lighting, where the lights switch off automatically when the last person leaves the room. Smart control can reduce electricity use considerably even when used with old and less energy-efficient light sources such as halogen lamps, but the highest energy savings are obtained when used with LEDs.

Professional lighting control systems based on DMX and DALI are currently most used in office buildings and large facilities. Consumer-targeted smart lighting network solutions, such as ZigBee Lightlink, are already being introduced and are expected to penetrate the residential lighting market in the coming years. New technology standards and products make control systems easier to install and affordable to most home owners.

The wide adoption of lighting control systems is fertile ground for new functions and new added value lighting products. Current control systems are evolving towards wirelessly controlled luminaires, higher levels of responsiveness via new sensors and context recognition, and adaptivity to new types of luminaires, see Figure 4.3.

Next-generation luminaires are equipped with radio control, enabling them to be controlled in multiple ways: by radio-equipped wall switches, central controller at the house, by mobile phone or even remotely via the Internet. Wireless capability and small size makes it possible to move luminaires fitted with battery operated switches and sensors freely around a room or building.

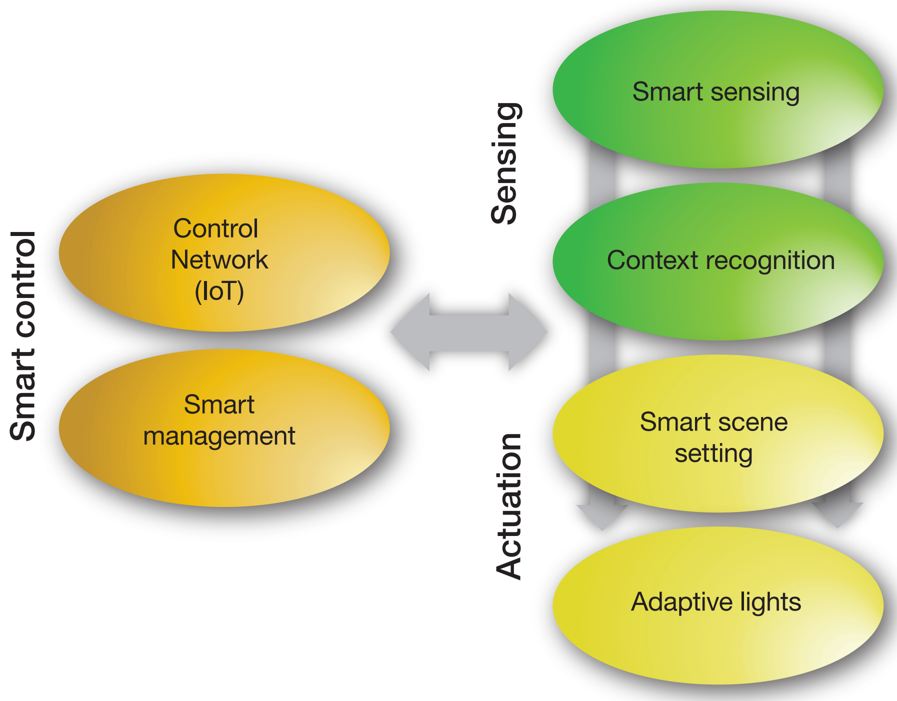


FIGURE 4.3. Smart sensing and actuation in smart lighting system.

VISION

Let's save energy – Too much light is a waste of resources.
Let's upgrade comfort – Inadequate light leads to a loss in performance.
Let's make it easy – Each second spent adjusting light is a loss of time.
Let's share good feeling – Light can do much more than illuminate.
Let's change the business model – Is it price of a lamp or price of the service?

Smart Lighting – Improvement in productivity

4.4 Vision of smart lighting

Too much light is a waste of resources

How much lighting are we wasting? In offices, half of all energy used for lighting a typical meeting room is lost on empty seats. You can easily find more examples just by looking around. We are wasting a significant amount of our limited energy resources on lighting spaces where light is not used or needed.

Energy efficiency requirements for buildings have made smart lighting control systems appealing to property owners. Equipped with present-day technologies such as LED lighting, timers, daylight compensation and motion (presence) detection, modern lighting control systems can significantly improve the energy class of buildings. Together with other smart building systems: smart air conditioning, smart heating, etc., the use of smart lighting is spreading from premium-class buildings to common practice (see Figure 4.4).

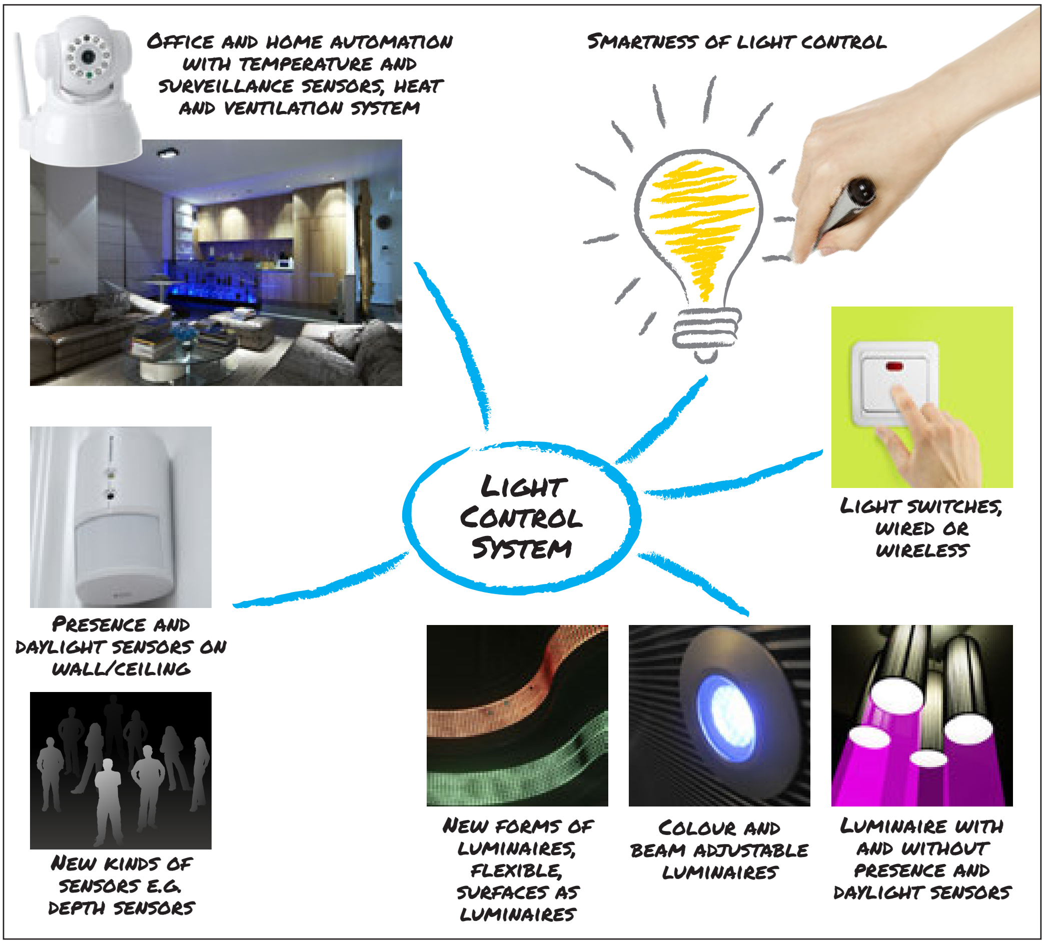


FIGURE 4.4. Building blocks of smart lighting.

Smart lighting systems also take into account the convertibility of buildings by adapting to changes in use and layout and maintaining a consistent quality of illuminance.

Inadequate light leads to a loss in performance

High quality light is the key to performance and productivity in visual tasks. People need lighting of adequate brightness and quality in order to work effectively. The colour, direction and distribution of light can be just as important as its illuminance (lux) value. The optimal lighting conditions are well known for a number of basic tasks, such as reading, computer work, and orientation indoors and outdoors. For these, there are recommendations and regulations in place. However, additional regulations may be needed if smart lighting is to be widely adopted in the built environment. On roads, for example, if new features are added to street lighting, we need to be certain that the systems are reliable and save lives and do not endanger people's safety.

Each second spent adjusting light is a loss of time

Switching lights on and off has been a daily routine for a hundred years in homes, farms, warehouses, workshops, and offices. With automation, we can save this time – literally billions of hours – for something more important.

"Am I too early?" Jack wondered as he headed towards reception at the small London hotel. Under the automatically brightening tasklight, he checked the agreed time to meet the client, scribbled on a newspaper front page. Yep, a few minutes to kill. He flipped open the paper. The light swelled to reading strength. After a moment or two, the guidance system initiated a guide beam, gently indicating the way to a better reading spot, over by the lifts. "I'm fine here", mumbled Jack. The guide beam dimmed instantly, and the wall lamp adjusted its shape and position to provide better reading light. "Nice!" said Jack, barely aware of the lights responding to his cues.

THE INSIDE LIGHT FADES OFF SMOOTHLY AS KALLE STEPS OUT AND CLOSES THE DOOR OF HIS CAR. AT THE SAME MOMENT, THE GARAGE LIGHTS BRIGHTEN SLIGHTLY, AND THE DOORWAY LEADING TO HIS APARTMENT LIGHTS UP INVITINGLY. KALLE WALKS TO HIS APARTMENT. AS HE APPROACHES HIS DOOR WITH THE KEY, THE DOOR HANDLE LIGHTS UP AND ILLUMINATES THE KEYHOLE. THE HALLWAY IS ALREADY LIT FOR HIM AS HE STEPS IN, AND THE LIGHTS BRIGHTEN SLIGHTLY AS HE ENTERS. COLOURFUL LIGHT PATTERNS GENTLY FLICKER ON THE LIVING ROOM WALL, MIMICKING THE WIND OUTSIDE.

With automation, we can make sure the lights are not carelessly left on, and that they are on when and where they are actually needed. This frees us to focus on the job in hand: getting the right things from the warehouse, or starting the meeting on time.

Light can do much more than illuminate

Lighting can provide added value beyond its basic function. In future, light will be used to guide people to lifts or exits in buildings, or drivers to empty parking spaces. In shops, products will be illuminated in attractive ways to draw in shoppers.

Light can be informative. Changes in colour or light patterns on a living room wall or on trees in the park will transmit information, for example on changes in the weather. In the road, street lights turn reddish to warn about traffic jam ahead.

Light can carry information as a part of your home wireless communication network, providing gigabits of data each second.

Lighting carries moods and emotions. Lighting systems interpret and present media content and project beautiful, natural-looking light schemes into rooms. Lighting can transform a daytime restaurant into a night-time theatre. In future, lighting will be considered as much a natural part of interior decoration as furniture is today. Fashion trends will emerge in lighting, with different luminaire designs and light colours 'in' today and gone tomorrow. One day we may be wearing clothes that reflect our personality or mood with different coloured lights or artistic multimedia.

Light also has direct a link with our biological processes. Smart lighting systems can be configured to help combat jet-lag by adjusting our daily rhythm before and after travelling, or shift-lag by helping shift workers adjust to nocturnal schedules. Certain types of light make us feel more energetic or help us recover faster from illness. For example, light therapy is used in treating Alzheimer disease and treatments related to ageing, weight management and stress. In the future, smart lighting will be an integral part of health and wellness management.

Light guides you. Light is informative. Light transfers data. Light carries moods and emotions. Light connects people. Light is part of decoration. Light heals us. Light is safety.

Price of a lamp or price of service?

Traditional manufacturers of luminaires are now moving into the service business. Lighting systems and luminaires will be accompanied with installation, maintenance and adaptive lighting design services.

Digital content will be a major part of lighting systems as same equipment can be used for multiple purposes. For example, school owner can download an application either to a mobile phone or to lighting control system directly, that changes class room basic lighting to support students learning during the day.

These new service providers not only offer lighting products, but also confidence that the buyer will get the lighting they want, i.e. energy efficiency, quality of light, adaptivity to changing building and user requirements and rapid-response luminaire servicing and replacement. Lighting service provision is based on high flexibility, adaptability and customisability. Lighting systems are designed and remotely managed to meet the customer's specific needs. Restaurant owners, for example, can use lighting scenes to create the right ambience for lunch, dinner or late evening diners. The scenes are made and transferred to restaurant lighting system by a service provider.

Lighting services can be priced based on a monthly fee, customer revenue levels, energy savings achieved, or added value created.

4.5 Technology roadmap

Today, lighting control systems are used more in offices, industrial sites, warehouses and other large facilities than in homes. Current systems employ simple sensors to detect motion and light levels, and lighting is adjusted based on this information. The systems are heavy, centrally controlled, and used by professionals. Luminaire types vary, ranging from incandescent light bulbs to LEDs producing primitive light with no colour adjustment, although some luminaires are dimmable.

By 2020, we can expect lightweight lighting systems to be commonplace (see Figure 4.5). DIYers and professionals will be able to install them in homes from components available in local hardware stores. An important functionality of the system will be wireless operation, enabling luminaires, switches and sensors to communicate with each other as a network of smart objects. They will also become part of the smart grid. Luminaires will be controlled wirelessly with smart phones, tab devices or computers in the home or from anywhere via the Internet. Sensoring will be taken to a new level through sensor fusion and use of new affordable 3D depth sensors that will enable simple context detection, such as whether someone is walking and in which direction. LEDs will be the most commonly used luminaire type, and will be available in a huge variety of forms and

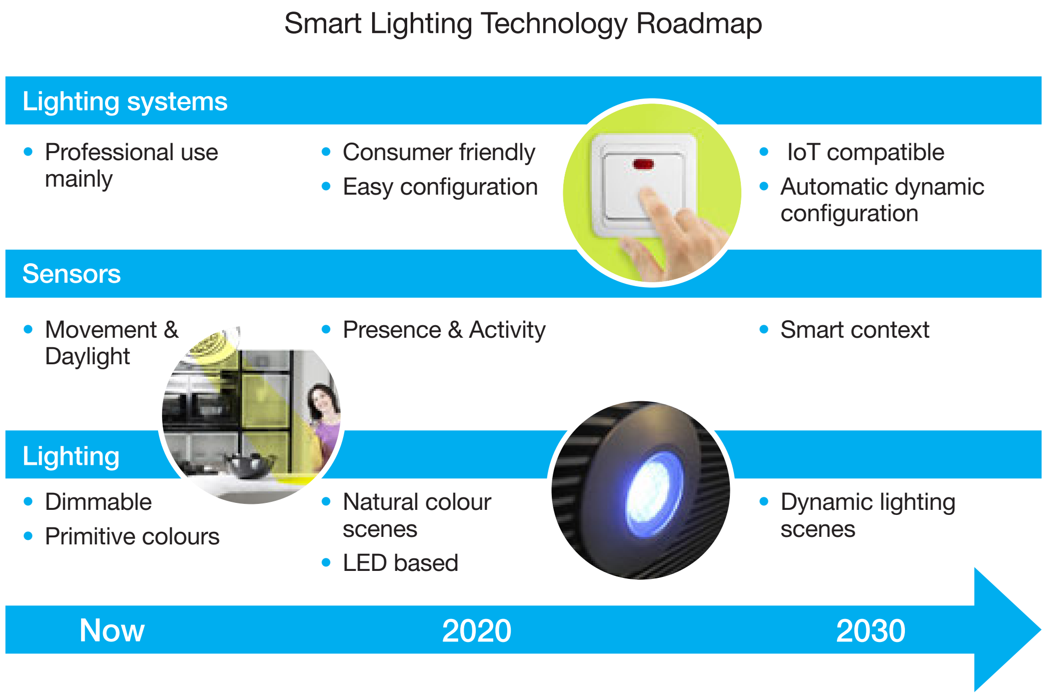


FIGURE 4.5. Technology roadmap of smart lighting.

sizes. LEDs will enable users to adjust the colour and beam direction of lights to create a more natural and comfortable lighting experience.

Ultimately, luminaires will become an integral part of the IoT infrastructure. They will not only produce light. They will form an essential part of the indoor environment, providing decoration and serving as context-detecting sensors delivering semantic information, such as ‘person is reading’, to other systems. Lighting scenes will not be fixed, but colour, intensity and direction will be dynamically adjusted as desired. Luminaires will be even used for communication, transferring data by means of visible light communication technologies or acting as wireless access points using Wi-Fi technology. Luminaires will be an integral part of interior decoration, as illuminating surfaces and vivid surfaces carrying multimedia projections.

4.6 Future challenges of smart lighting

Before we see smart lighting widely deployed in buildings, homes, industries and in society, there are several challenges still ahead that require research and development. The key challenge and opportunity of smart lighting lies in the multidisciplinary work needed to encourage and enable the use of smart lighting features, with the aim of reducing energy consumption and enhancing the quality and comfort of lighting compared to conventional technologies. It is known for a long time that light affects humans e.g. the daily rhytm and activity level. Understanding this is not only a technological challenge, it also requires understanding of human physiology and emotions. This is under scientific and clinical research.

As regards technology, there is still much to develop. One perhaps surprising example is occupancy detection, which remains a relevant development area despite decades of sensor development. Widely deployed low-cost passive infrared (PIR) sensors often fail to detect the presence of people when they are motionless, resulting in control systems mistakenly shutting off the lights. Other sensors capable of delivering reliable occupancy detection are available, but they are not cost efficient. The challenge for the smart lighting industry is to find a combination of sensors that can detect occupancy reliably and be manufactured cost efficiently.

GUIDING LIGHT

Henrika Pihlajaniemi, University of Oulu.

Much future effort will be invested in developing new kinds of algorithms for sensor fusion and smart control. With an ever-growing variety of sensors, luminaires and technologies on the market, the reliability and ease of use of lighting systems for the end user need to be ensured despite increasingly complexity. Thus, automation, self-learning and -adapting features are needed for the lighting system. For example, in the new building, the commissioning of lighting system should be automatic. The control system should find the location of the luminaires automatically even when the luminaires are controlled wirelessly over the mesh network. In addition, during the years, the operation statistics cumulate providing means to detect patterns and routines on how light is used and what affects to the energy consumption. When new luminaires and sensors are added to the system, or when some of the existing ones are taken of or broken, the system will readjust itself to continue it's operation as intended.

4.7 Solutions

Powering autonomous sensors

Printed intelligence technologies make it possible to create flexible solar cells that can be produced in a range of shapes and styles – a world away from conventional rigid, rectangular cells (see Figure 4.6). This opens the way for solar cells to enter the home as power sources and interior decoration products in their own right. They can be used to power sensors to provide more accurate sensing of light, presence and temperature.

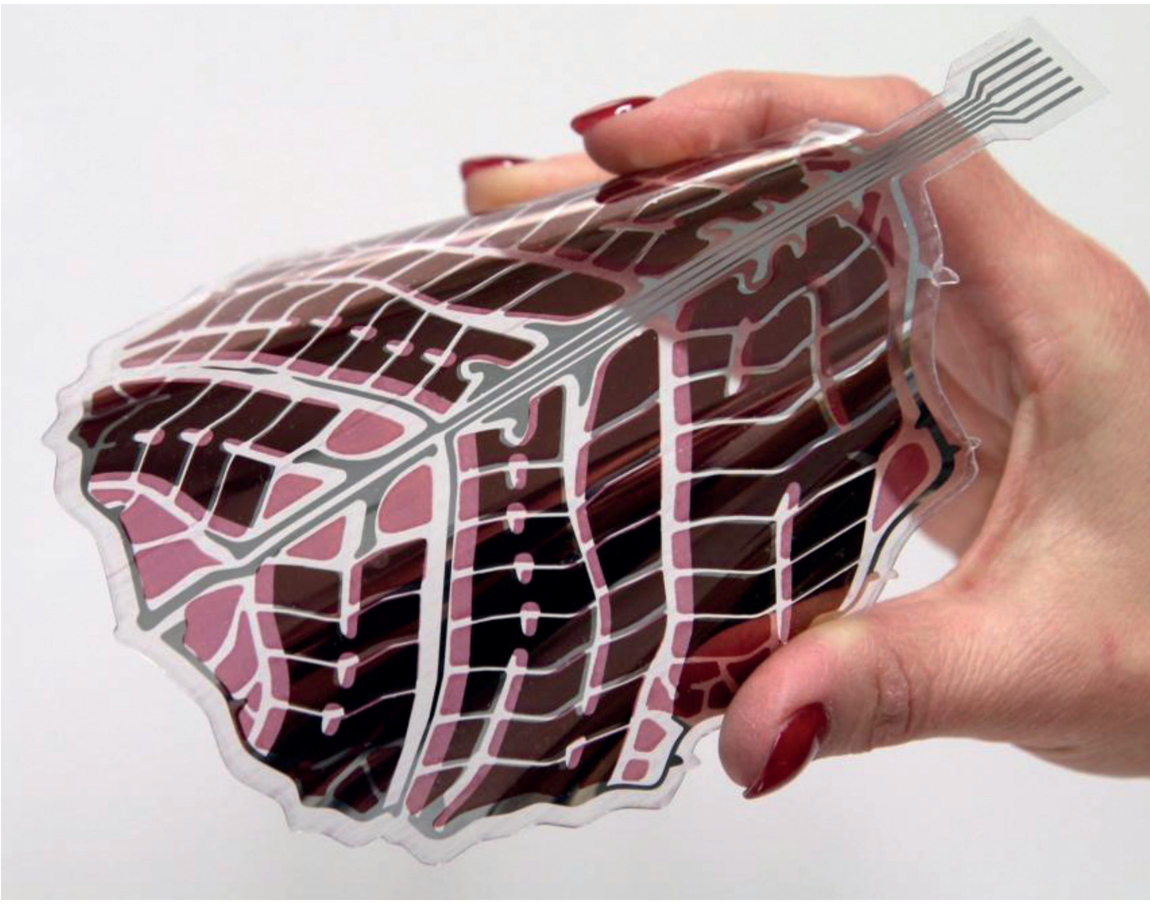


FIGURE 4.6. Decorative solar cell resembling a leaf. The cell can be used to power batteryless sensors for lighting control.

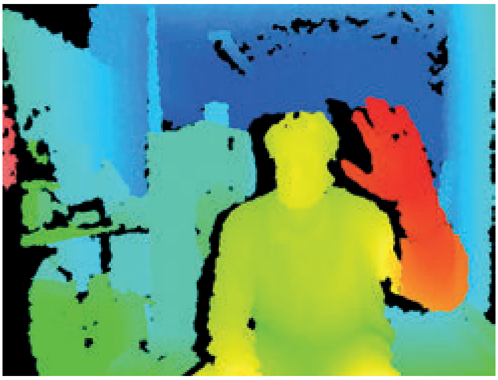


FIGURE 4.7. Depth cameras can be used to anonymously detect human presence and behaviour.

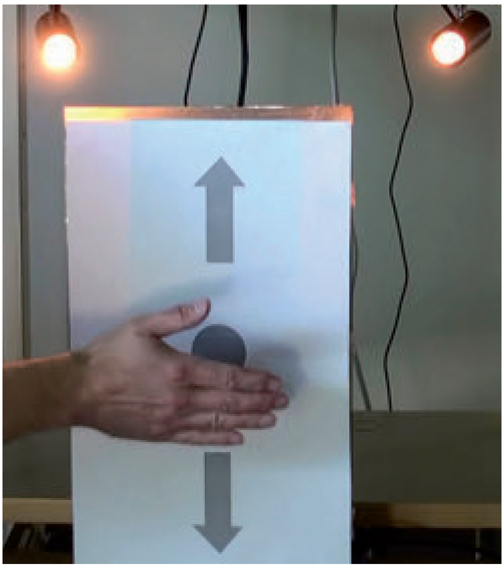


FIGURE 4.8. Capacitive printed intelligence sensor used for hand movement based lighting control.

Lighting systems start to see with depth cameras

In order for lighting to be smart and automatically controllable it has to be aware of the context of its environment: the presence, location, movement and behaviour of people, as well as information about groups and their properties. Various depth sensors can be used to collect this information (see Figure 4.7). Considerable savings can be achieved in areas where human presence varies highly depending on the time of day, such as shopping streets or industrial estates. Lighting control can proactively adjust the illumination as needed, for example by switching streetlights on ahead of an approaching pedestrian. Lighting can also be used for crowd management by directing people with controllable lights. Significant business potential can be achieved by combining information from different context sensors to create more effective and energy-saving advertising and surveillance systems.

Low-cost sensors from a printing machine

Printed intelligence enables sensors to be printed onto paper, fabrics, polymer, glass or steel film, and integrated into large surfaces – even as wall paper. Printed intelligence utilizes solution-based conductive, semiconducting and dielectric materials which can be directly deposited and patterned onto surfaces using printing processes. See Figure 4.8.

From pinpoint lighting to diffuse illumination

Printed intelligence techniques can be used to create large-area, thin luminaires that are flexible and can be mass produced at extremely low cost. This is made possible through hybrid integration of printed electronics functionalities and traditional microelectronic components. Multifunctional plastic foils with high compactness, a high degree of autonomy, overall integration of several functionalities and reduced installation costs can be developed. For example, a flexible plastic substrate can be used as a backplane for a lighting element and LED chips assembled and interconnected on this to produce a flexible LED matrix (Figure 4.9).

Mobile phones and smart TVs as context sensors

Combining information from multiple, low-cost sensors makes it possible to detect complex behavioural patterns and situations where people are that can be used effectively in controlling lighting (Figure 4.10). For example, smartphones can act as presence or absence sensors and provide rich information on the user's physical movements and location. Combining this information with other information sources such as PIR sensors and smart TV light sensors enables versatile and adaptive lighting solutions.

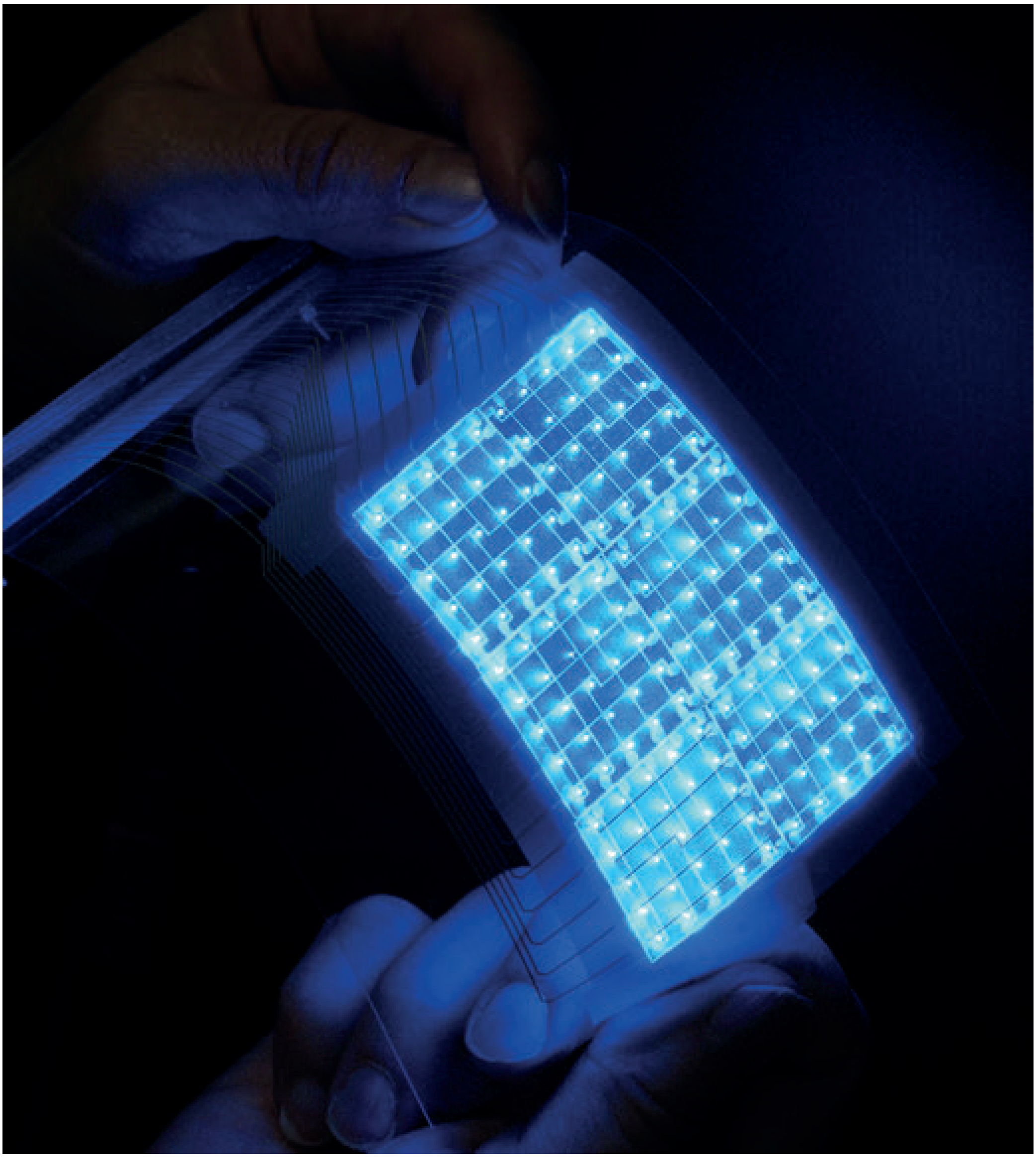


FIGURE 4.9. Bendable LED matrix luminaire. Manufactured on VTT's printed intelligence production line for low-cost mass production.

Luminaires that hear

Sound and voice can also be used to detect and localize people using microphone arrays and audio source localisation. For example, in meetings the lighting system could recognise who is speaking and automatically illuminate the speaker or that part of the room. Lighting systems could also be taught to understand voice commands. For example, Google provides voice recognition services in several languages on their Android platform that can be integrated to server-side applications. The Philips Hue smart lighting system has been also integrated with SiriProxy, which enables voice commands with iOS devices.

Colour of light matters

Colours affect us physiologically and emotionally. For example, blue light is calming, whereas red or orange light can stimulate activity. Since artificial and natural light can have quite different

FIGURE 4.10. Intelligent LED streetlights for energy saving. The lights are equipped with sensors to detect people and ambient light conditions. They also communicate with each other, adjusting light levels optimally for the street. (Picture: AthLEDics project.)

colour distributions, they affect people differently. Smart lighting systems therefore need to be able to monitor light colour especially, when there is several types of artificial light or daylight present. One low-cost solution for monitoring light colour, i.e. wavelength distribution, is the Fabry-Perot MEMS spectrometer. It can be used for detecting the colour of light, the wavelength distribution of LED luminaires, and the ratio of natural and artificial light.

The advance of solid-state lighting

Driven by increasing environmental concerns and cost of energy, LEDs are conquering the lighting world. Continuous improvements in energy efficiency, reliability and light properties, coupled with the decreasing cost of LED products have paved the way for the LED revolution. Due to the small size and long lifetime of LED components and the development of organic light-emitting diode (OLED) technology, opportunities for novel luminaire applications and integration of lighting into other elements, such as furniture or building structures, are emerging. In future, the current colour and intensity tuning properties of LEDs will be accompanied by more advanced controls, such as light beam steering (Figure 4.11).

Truly wireless LED luminaires

Imagine being able to effortlessly move lamps and lights about anywhere you like, with no plugs or cables to worry about. Sound like fiction? With wireless power this could be possible. In today's 'wireless' lighting systems, you still a need a cable for the electricity – only the communication is wireless. But wireless power is already a reality. Mobile phones are charged wirelessly over a distance of about a centimetre using dedicated 5W charging pads. As this technology advances, we will be able to transfer electricity over a distance of metres, with enough power to illuminate wireless LED luminaires. Tomorrow's LEDs could be installed without cables and operate with wireless power. They will either be directly wirelessly powered, or have batteries that are charged wirelessly during off-hours.

4.8 Where will we see smart lighting?

Highways adapt their illumination with the traffic – car lights are used as part of road lighting.

It is easier to navigate your way around **shopping centres** – routes, isles and escalators are illuminated in active manner, helping you find them more easily.

In parks, trees and bushes are illuminated with lights that are not just decorative but also give you information – you will be able to see the weather forecast from the changes in brightness and colour.

At home, the lights come on and off automatically – the lighting system learns how you live and gives you comfortable, energy-efficient lighting in return.

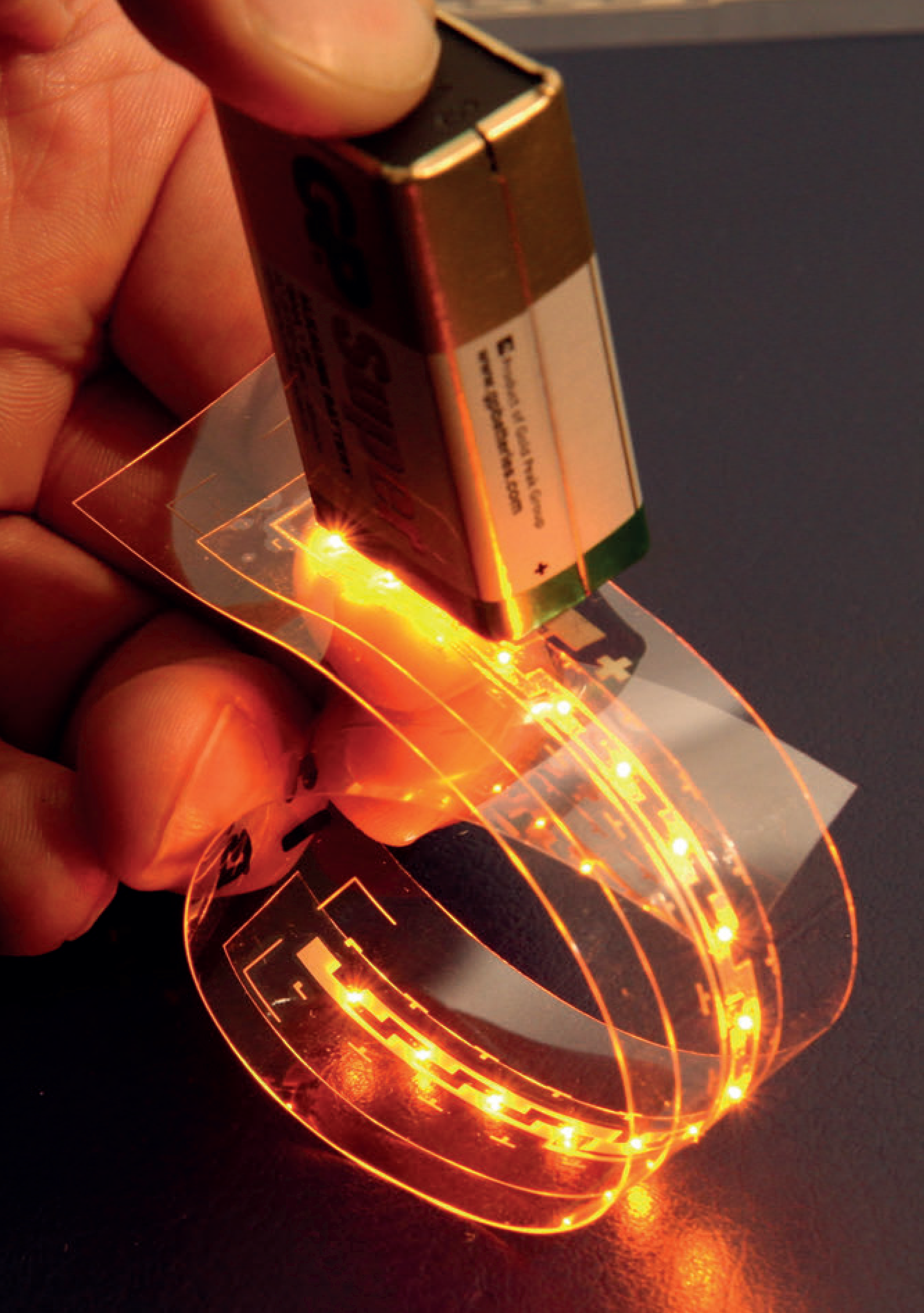
At the office, the lighting adapts to what you're doing – e.g. different light qualities for reading and working at your computer, taking into account the strength and direction of natural light from windows.

At the hotel you find your room effortlessly – lights lead you to your door.

At the factory, shift work is less tiring – the lighting at work and at home help your biological system to adapt to changes in wake and sleep hours.

And they can evolve further – luminaires will become Wi-Fi hotspots, fire alarm devices, surveillance systems, and will even tell the owner when they need replacing!

FIGURE 4.11. LED luminaire with adjustable beam size and brightness. The LEDs contain separate optical elements for steering light. (Picture: AthLEDics project.)



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5 Internet of things revolutionizes several areas of life

Preventive maintenance

Today, maintenance usually happens in two ways: firstly, when equipment breaks, and, secondly, according to a predefined maintenance schedule –irrespective of the actual need for maintenance. In both cases, productivity suffers from excessive downtime. In the future, IoT-enhanced condition-based maintenance will enable machines to monitor the temperature, duty hours, and wear and tear of individual parts and call for maintenance when needed. The information will be gathered by factory-installed sensors. This sensor information will be used not only by the manufacturer, but also by the wider service ecosystem, which provides maintenance and logistics services based on open sensor data. When something breaks, a new replacement part will be manufactured fast and locally using additive manufacturing. – Just print the part!

... TO BEARING REPORT: ESTIMATED LIFETIME 76.4 HOURS

Preventive maintenance

Internet of Things enhances production

- Internet of Things together with wireless sensoring systems enables sense—control—affect loops for increased control efficiency.
- Asset management services will operate as a cloud and be accessible everywhere, allowing centralised asset management.
- Machine fleets will be able to analyse and optimize their state and the whole process they are a part of based on information collected from other similar processes globally, leading to efficient real-time process tuning and learning.

Disruptive innovations

- Business models will transform towards performance-based contracts, access rights, leasing, sharing, or other forms of collaboration.
- Manufacturing companies will increasingly focus on their core business – developing and manufacturing their own products – with additional services provided by partner networks via an industrial ecosystem whose operation will be increasingly enabled by Internet of Things technologies.

Impacts and opportunities

- New forms of service companies will emerge.
- Expertise will change from reactive repair to predictive and preventive maintenance.
- Security issues in data transmission will pose huge risks as numbers of broadcasting sensors increase.

Properties

- IoT-enabled communication networks, sensors and actuators will bring reactive and control centre based intelligence close to machinery.

- Machines will know when they need maintenance as well as when and whom to notify.
- Service networks will be wireless and thus less infrastructure dependent.
- Security issues will gain importance as the numbers of connections to equipment increase.
- Systems with hundreds or thousands of sensors per machine will produce vast amounts of raw data. Local-level systems will have sufficient computational capacity to process this raw data into a sophisticated usable form.

Solutions

- Sensoring and wireless communication technologies are the key enablers. There is also need for development of privacy, interfaces, etc.
- The IoT enables flexible and adaptable systems and installation to existing infrastructure.

Based on VTT research competence and solutions:

- Measurement sensors and indicators.
- VTT Node wireless sensor technology can be used for modular sensor systems.
- Wireless data management protocols.
- Data management strategies and integration of data from many sources.
- Monitoring and control strategies.
- Experience in demand response and active customer appliances in the smart grid sector.
- Deep experience in condition monitoring and management.

Pirkka Tukeva
Key Account Manager
Tel. +358 40 542 9791
pirkka.tukeva@vtt.fi

Tommi Katainen
Manager, Business development
Tel. +358 50 499 9620
tommi.katainen@vtt.fi

Kaisa Belloni
Specialist, Managing editor
Tel. +358 40 545 6715
kaisa.belloni@vtt.fi

Smart Lighting, that do more than light

FROM WASTING RESOURCES...

Why are we wasting lighting on empty roads, streets and rooms? Why are we using too much light where we could manage just as well or better with less? Once lighting systems get smart, light will only be there where the people are. For example, dimmed street lights will brighten in advance as other street lights inform them of an approaching jogger. Lights will become much more than light sources. They will guide you to your destination, whether you are looking for a room in a hotel or a free parking place in a parking hall. Lighting will help energize us when we are tired and relax us when we need to unwind. It will help us adapt to changes in our daily rhythms. Lights will also serve as a visual identifiers, connecting people with places. By changing the lighting scheme, a neutral meeting room becomes a cosy corner for creative discussion during coffee.

Smart Lighting, that do more than light

Connection with the Internet of Things

- Lighting systems will become wirelessly controlled, enabling luminaires, switches and sensors to communicate wirelessly with each other as a network of smart objects.
- Ultimately, luminaires will become an integral part of the IoT infrastructure. They will not only produce light but also positively influence our activity, health and mood. Luminaires will respond to different lighting needs by detecting contexts, such as 'person is reading', and adjusting the lighting correspondingly.

Underlying disruptive innovation and drivers

- Until now, the focus of the lighting industry has been to produce more light with less energy. The next phase of evolution will be about serving people with the right kinds of light – intelligent, fit-for-purpose lighting to suit people's everyday lives. This is the era of smart lighting.
- Need to save energy. In 2005, lighting consumed about 19% of all electric power globally.
- Especially with LED technology, luminaires have been equipped with electronics enabling lighting control. Now the path is open to add new electronics to luminaires in order to provide communication and intelligence.
- Smart lighting components will become a commodity. Lighting control systems will no longer be just for professional use in offices and large buildings. Do-it-yourself users will have access to low-cost, easy-to-use lighting control and luminaire products in their homes.
- Printed intelligence technologies are also enabling the creation of flexible luminaires.

Effects on productivity

- Considerable energy savings are possible with energy efficient luminaires and smart control of lighting.
- High quality light is key to performance and productivity in visual tasks at work and home.
- Smart lighting systems take into account the convertibility of buildings by adapting to changes in use and layout throughout the building life cycle.

- Human activity, and therefore productivity, can be enhanced by lighting.

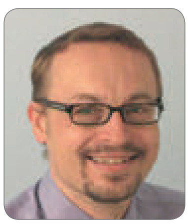
Business potential

- Switching to LED illumination has been shown to achieve 50–70% energy savings and up to 80% savings when coupled with smart controls (The Climate Group, June 2012).
- The smart lighting market is expected to see aggressive growth over the next ten years, rising from $0.436 billion (2013) to $11.4 billion by 2020 (Smart Lighting Markets and Opportunities 2013, NanoMarkets, May 2013).
- Light can be used for more than just lighting. In buildings and shops it can be used to guide, entertain and attract. It can provide safety outdoors and enhance wellbeing by preventing depression, easing jet-lag and helping students concentrate in school. These and other more-than-light features present huge opportunities for new business and innovations.
- New business models based on lighting services will emerge, with installation, maintenance and adaptive lighting design sold as additional services.

Sound like fiction?

- Lights will switch themselves on before you enter a room. You will also control them with your mobile phone or pad.
- In meetings, the lighting system will recognise who is speaking and automatically illuminate the speaker or that part of the room.
- Your wall paper gives light at your living room, these printed electronics large-area thin luminaires are flexible and can be mass produced at extremely low cost.
- Luminaires will become Wi-Fi hotspots, fire alarm devices, part surveillance systems, and will even tell the owner when they need replacing!

Janne Aikio
Principal Scientist, Team Leader
Tel. +358 40 703 4633
janne.aikio@vtt.fi



Marko Jurvansuu
Principal Scientist, KAM
Tel. +358 40 547 9441
marko.jurvansuu@vtt.fi

Sensors, knowing the world in real time

In the future, most measurable phenomena in the physical world will be measured or observed by wireless sensors. These sensors will be all around us and, with the exception of secure private information, the majority of the information they provide will be open and free to use. This open real-time sensor data will enable new innovative services and improve productivity through better optimization of processes. The sensor information will not be for human eyes only, but shared between machines and gadgets. For example, cars will be informed of empty parking places, and waste bins will tell the waste collector when they are full. Even your lawn and plants will tell you and the sprinkler when they need watering!

Sensors, knowing the world in real time

Drivers for change

- Wireless sensors are cheap to install and existing environments can be retrofitted without disturbing their operation.
- New printed electronics solutions are driving sensor manufacturing costs down.
- Low power consumption, energy harvesting, and wireless power make it feasible to install millions of wireless sensors, as their maintenance is much simplified. Structurally embedded sensors are also becoming a reality due to, e.g., additive manufacturing.

Effects on productivity

- Automation systems will be capable of fast and flexible reaction to changing conditions, e.g. compensating for excess heat in a kitchen caused by an oven, thus saving energy.
- Businesses will also be able to optimize their operations; e.g. on a construction site, the real-time data on concrete drying will help optimize drying schedules to enable better quality management. At suburbs, waste receptacles will give timely notification of the need for emptying as they become full.
- Early warnings and alerts in many domains (environment, health, infrastructure and building management, etc.) will help to avoid future costs.
- People will be able to make better-informed decisions; e.g., car drivers guided to free parking spaces, saving time and effort.

Business

- The global wireless sensor market totalled $790 million in 2011, but is rapidly growing. At an annual growth rate of 43%, it is forecasted to reach $4.7 billion by 2016, and, if the same rate continues, around $20 billion by 2020.
- The market for third-party applications utilizing wireless sensor data is practically nonexistent at present (software is bundled with sensors or gateways), but will emerge and generate significant revenues.

What needs to happen?

A wide range of radio technologies are currently being trialled with respect to wireless sensing (ZigBee, Z-Wave, cellular, Bluetooth, NFC, WiFi low power, etc.), and some consensus on their selection or interoperability needs to emerge in order for wide-scale deployment of sensors to appear attractive. Achieving energy autonomous sensors, lowering their manufacturing costs, as well as assuring the security of critical data are other critical issues to be resolved to make wide-scale deployments feasible. We also expect a significant acceleration in the domain to occur upon eventual decoupling of hardware and software, with some market players focusing solely on installation and operation of sensors and networks, while other players develop and provide (e.g. via an "app store") applications utilizing the data from those sensors.

Impact and opportunities

- Less time wasted, both by individuals and in business operations.
- Less resources spent, including energy, fuel.
- Less traffic and carbon emissions.
- Increased well-being and quality of life.

Artem Katasonov
Senior Scientist, Team Leader
Tel. +358 40 197 6669
artem.katasonov@vtt.fi

Jouni Hiltunen
Research Scientist, Team Leader
Tel. +358 40 564 2820
jouni.hiltunen@vtt.fi

Autonomous sensors at a penny

FROM BATTERY POWER...

The potential of the IoT can be realized only with a new breed of maintenance-free, self-powered sensors located ubiquitously and in vast numbers. This requires sensors that are extremely cheap and capable of harvesting their own energy. In addition, they must also be eco-friendly and safe. These energy-autonomous sensors will capture free energy from the surrounding environment: from sunlight, movement, even from temperature differences. The phone in your back pocket will draw energy from the sun-baked step you are sitting on, while sensors on the passing city tram will draw energy from vehicle vibrations to detect rail conditions. Toxic batteries – currently sold in their billions each year –will be a thing of the past.

...TO HARVESTING AMBIENT ENERGY

Autonomous sensors at a penny

IoT business opportunities will expand vastly in the future with the provision of affordable, reliable power to inaccessible IoT objects having more than 10 years maintenance-free operation. Energy harvesting is likely to replace many of the 30 billion button batteries currently sold each year, many of which contain toxic chemicals.

Energy harvesting – powering the Internet of Things

Without energy harvesting, 90% of envisioned uses of wireless sensors for IoT applications are unviable, as dependence on traditional batteries would limit use to short-term applications dependent on manual battery replacement.

Productivity example

- German energy harvesting technology company EnOcean installed 4,200 wireless and battery-free light switches, occupancy sensors and daylight sensors in a new building in Madrid. The wireless installations have achieved savings of 40% in lighting energy costs through autonomic lighting control, 20 miles of cable through the use of wireless sensors, 42.000 batteries (over 25 years) through the use of sensors that harvest their energy from the ambient environment, and eliminated retrofitting costs.

Market view

- The global market for energy harvesting is expected to grow from $0.7 billion (2012) to $3.6 billion (2020).

Key energy harvesting enablers: printed electronics, smart substrates and microelectromechanical systems (MEMS)

- Printed or thin-film batteries enable more manageable, safer and potentially cheaper energy storage.

- Photovoltaics (PV) are being increasingly printed to reduce costs and provide flexibility and thinness.
- Electroactive polymers that generate electricity when distorted offer an interesting smart substrate opportunity.
- MEMS-based piezo vibration harvesters will play an important role in future energy harvesting technologies.
- VTT's foreseen key technology developments in energy harvesting: roll-to-roll (R2R) manufactured thin-film photovoltaics development; MEMS-based energy harvesters; materials research and roll-to-roll processing development of supercapacitors, thermoelectric generators and dielectric elastomers; hybrid integration of energy harvesters and storage for flexible autonomous systems.

Did you know that...

- Until now, the main commercial successes in care-free sensors have been seen in photovoltaics in space vehicles, in road furniture, in consumer goods such as bicycle dynamos and wristwatches and in piezoelectrics in light switches.
- In terms of power conversion efficiency, energy harvesting technology is improving faster than battery technologies.
- Energy harvesting currently provides about 10% of the power required for the more than one billion electronic wristwatches, electronic car keys and other active radio identification (RFID) tags, miniature FM radios, and Bluetooth transceivers in current circulation. Replaceable button batteries are still the most used power source.

Kari Rönkä
Principal Scientist
Tel. +358 40 774 9846
kari.ronka@vtt.fi

Healthcare up, close, and personal

The year is 2020, and Leila is a typical 70-year-old. She has lived with type 2 diabetes and high blood pressure for the last ten years. With lifestyle changes and medication she has attained a good balance of treatment with her chronic diseases and lost 15 kilos in weight. She feels empowered by the new municipal health care system, which provides patients with tools to monitor their weight, physical activity, sleep, nutritional level, medication, blood pressure and glucose levels. Various embedded sensors enable the collection of data, which is stored in an interoperable database. The service, My Health Timeline, collects information and gives motivating on-line feedback and tips for patients' health management. Leila can keep in secure contact with her nurses, doctors and support peer group via the service. She contributes 10 euros per month towards the service and the remaining costs are covered by her home town.

I am responsible for my health!

Connection with the Internet of Things

- IoT technologies and various health applications enable cost-efficient, patient-centric healthcare.
- Nutritional guidance and support based on user's shopping behaviour information.
- Over-the-web communication with professionals via mobile phones, tablets and PCs, as well as monitoring of personal data.
- Interfaces to electronic personal health records (PHR) and electronic health records (EHR).
- Health-related measurement devices that transmit information over the Internet on, e.g., weight, physical activity, sleep quality, blood pressure, blood glucose and heart rate.

Business drivers and societal aspects

- In 2010 in Finland basic health care costs totalled EUR 2.8 billion and special health care EUR 5.5 billion.
- In 2011 in Finland 1.79 million citizens had a metabolic syndrome, 0.31 million citizens had type 2 diabetes, and 0.25 million citizens had myocardial infarct or coronary artery disease.
- Lack of health resources in society (money, infrastructure, professionals) drives the development of personalized health care systems.

Productivity and impact

- Healthier, happier, more productive citizens.
- More productive ICT-aided health care system (smaller costs and resources).
- Less travelling costs due to ICT-aided remote tools.
- New possibilities for health service business.
- In the long run, possibility for lower taxes and pension costs.

Future

- All personal health information will be available time and place independently via secure connections. Systems will be modular and interoperable and based on standardized information formats by 2020.
- The automation level of technical solutions will increase dramatically. The wealth of health information produced will be analyzed and converted into useful forms for the benefit of users.

Solutions

- Current health monitoring devices have communication capabilities based on USB, NFC, Bluetooth or WiFi. The Continua Health Alliance is dedicated to establishing a system of interoperable personal connected health solutions.
- In Finland, the integration of health record systems has started. In the future, information produced by medical professionals will be collected from local EHR systems to the national Kanta system. Health information produced by citizens will be collected in a common database using, e.g., the Taltioni system.

Considerations for industry and society

- Device and system manufacturers: solving interoperability and information management issues using standards and alliances (Continua, Taltioni, Kanta).
- Health service providers: renewing health care services to provide proactive care (e.g. Finnish chronic care model).
- Health care legislation and guideline reform and support for new kinds of health service business are needed.
- Research: cross-disciplinary R&D in the health care sector, new service and business models, human behaviour change, health data processing and interoperability.

Jouni Kaartinen
Senior Scientist
Tel. +358 40 753 2893
jouni.kaartinen@vtt.fi

From eco-aware to eco-savvy

A smart environment enables energy-efficient, carbon neutral living without compromising your well-being or quality of life. Imagine a system that manages your indoor living conditions and optimizes your energy use. It charges your electric car from solar panels on the roof of your home, it welcomes you home from work with a pleasantly warm or cooled and illuminated home, it keeps an eye on security for you. It provides you with feedback on your environmental impacts and promotes your eco-achievements on social media. It also allows you to compare yourself, and even compete, with your friends' eco-performance. Over time, it learns your behaviour and becomes your virtual housekeeper. It is also simple to use – a cloud-based service takes care of the system. With this knowledge at your fingertips, you will soon shift from being eco-aware to fully informed and eco-savvy.

...TO ENVIRONMENTALLY AWARE

From eco-aware to eco-savvy

Smart environment enables energy efficient and carbon neutral living and working without compromising the wellbeing and good quality of life.

Internet of Things enables environmental awareness

- Wireless sensoring systems are modular and easy to install in existing buildings. They can start small and expand with added functions.
- The IoT system enables a sense—control—affect loop.
- Service operates as a cloud and is accessible everywhere.

Disruptive innovations: combination of different areas to benefit the end-user

- Combination of Energy – Home automation – Wireless sensing – User behaviour at the system level and their interaction.
- Energy grid and smart city as technical basis.
- Increasing awareness and making sensor and energy information easily available.
- Cross-system optimization for operational efficiency.

Productivity improves with monitoring and control

- In home applications, the concept offers easy access to information. Together with optimisation, this results in improved living conditions as well as economic benefits through efficient use of energy.
- In larger building applications (hotel/shopping centres, etc.) additional surveillance, security, door locking, etc. functions can be added.

Impacts and opportunities

- Sustainable development in urban areas.
- Resource efficiency increases, greenhouse gas (GHG) emissions decrease.
- Wellbeing and quality of life are increased.
- Increased awareness of individual energy use and living conditions.

Roadmap and trends

By 2020, we will be able to monitor and control environmental variables through IoT technology, and we will also be increasingly able to understand and predict human and system behaviour and their interactions. These aspects will be integrated in cloud services for improved management of living conditions. The services will be easy to install, modular and ubiquitously accessible. They will be based on open data structures and tailorable for different applications. Use of open interfaces will enable easy application development, as seen with smartphones.

By 2020, living conditions monitoring services will be offered by dedicated service providers. As regards energy, the focus will be on energy efficiency, but also on using own power generation or providing demand response. As regards indoor conditions, there will be rapidly growing interest in living environment quality. General awareness of environmental aspects will rise as individuals see the impacts of their living behaviour and choices.

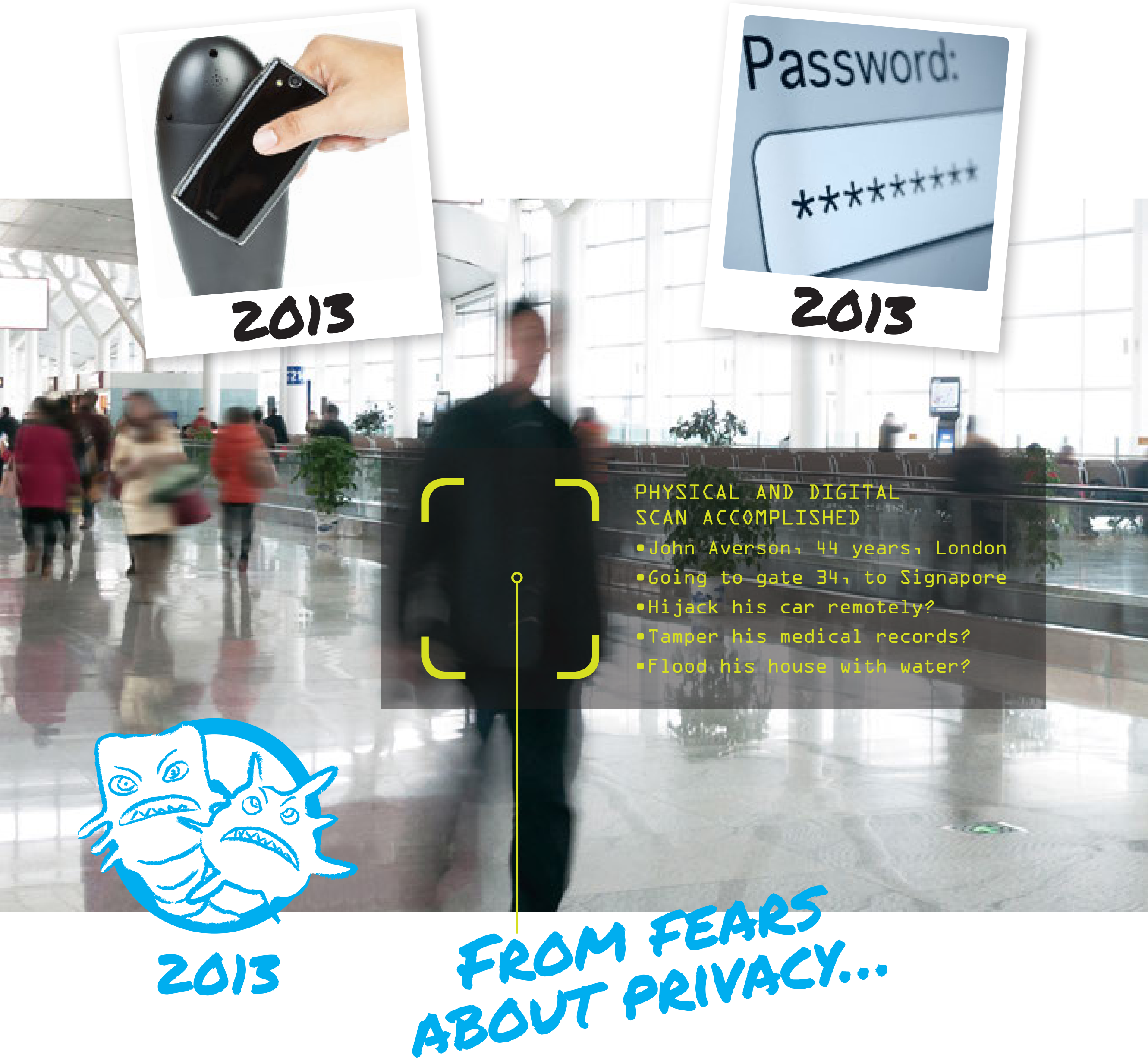
Solutions

- Sensoring and wireless communication technologies are the key enablers. There is also a need for development of privacy, interfaces, etc.
- IoT enables flexible and adaptable systems and installation to existing build environment / buildings is easier and cheaper.

Miimu Airaksinen
Research Professor
Tel. +358 40 770 4832
miimu.airaksinen@vtt.fi

Kari Mäki
Senior Scientist
Tel. +358 40 142 9785
kari.maki@vtt.fi

Security, integral part of IoT data based economy



Viruses, worms, spam and malicious attackers threat our privacy, identity and money on the Internet today. So what about the future – will the IoT make us more vulnerable? What if your car stops recognizing your key, or is remotely hijacked? Could your home be robbed while you are away by criminals hacking your home sensors? The reality is that, yes, we will be more open to attack, since we will be doing things in new ways. We will control our homes remotely, we will be surrounded by sensors, some that are ours, some that are not. We will monitor our health with sensors and shop with our phones. Much of our lives will be based on data flow and sensors, whether we welcome it or not. In the future, security will therefore need to be embedded as an integral part of the IoT to ensure safety and peace of mind in this highly complex environment.

Security, integral part of IoT data based economy

Alice – a housewife and mother – notices it's time to change the car seat of her fast-growing 2-year-old for a bigger model. The seat looks almost as good as new, so maybe she can sell it on. Alice launches the second-hand market widget on her phone, takes a couple of snapshots of the seat in the car, and decides on a price – 50 euros. Two days later, Bertha, a mother of a newborn baby girl, views the car seat on her phone while out on her daily afternoon walk with the pram, and drops round to fetch the seat couple of hours later.

Security integral to the Internet of Things

- The mobile phone widget makes the sale anonymous, hiding the context details until it can negotiate an adequate trust level of potential buyers with the market back-office system. Details such as the car registration plate and the baby's face are hidden in the image, as well as the exact geographic position until Alice responds positively to Bertha's meeting request. Bertha's interest was raised partially due to knowing that the offer was only 1.5 km away and on her daily walking route.
- The payment is carried out automatically and confirmed with Alice and Bertha once the terms have been agreed.

Underlying disruptive innovation

- Privacy and security are built into the service.
- Standardization defines the interface for digital service design, e.g. for selecting personal profiles and (re-)negotiating trust levels in the information interchange.

Impact on productivity

- Buying and selling online and in-situ is easy and reliable.
- Everyday life IoT world become smoother as ownership, right of use, and right of passage can be confirmed automatically and confidentially – based on a digital identity.

Impact and opportunities

- Socio-economic prosperity through increased efficiency of economic data interchange.
- Appropriate security and privacy levels in interactions: no resources wasted in system development and use, no risks imposed on the actors, i.e. end-users, of the forthcoming system.

Solutions needed

- Identification mechanisms of people based on individual characteristics, from distance and in crowds, and power-efficient machine-to-machine trust applications.
- While society benefits from increased information security and promotes technologies for tracing people at transit nodes, such as airports, terminals and city centres, privacy enhancement is demanded to protect the civil rights of individuals.
- New digital trust and reputation management mechanisms.
- Standardization at the European level.

Reijo Savola
Principal Scientist
Tel. +358 40 569 6380
reijo.savola@vtt.fi

Pekka Savolainen
Principal Scientist, Team Leader
Tel. +358 40 730 0237
pekka.savolainen@vtt.fi

Flooding the Web with Internet-of-Things data

FROM 10^{24} BYTES OF DIGITAL UNIVERSE TODAY...

The Internet of Things (IoT) is based on a common infrastructure that connects the real and digital worlds. It will bridge wireless sensors, actuators, and embedded systems and connects them with the Internet. The amount of data will grow dramatically as information related to everyday real world items and goods is transferred to the digital world. For example, before fresh fish reaches the cold counter at the supermarket, a huge amount of data on its origin, breed, farming conditions, cold chain, and supermarket is created and transferred within IoT. And after the fish is being bought, information on the individual consumer will be linked to this data. Ultimately, we will have detailed information on individual apples, shoes, bicycles, cars and practically everything. But it won't end there, 50 billion connected devices in 2020 will flood our world with data. Everything from the washing machine to your 'smart' clothes will be connected!

Flooding the Web with Internet-of-Things data

What is IoT infrastructure?

- The predicted scale and potential of the IoT calls us to rethink how systems will be constructed, how the required networking and interoperability of devices can be achieved, and what infrastructures and platforms can provide the performance, scalability, security, and other key characteristics needed.
- IoT infrastructure revolutionises our view of electronic devices by making their information and capabilities usable beyond their original purpose.
- The key topics of IoT disruption are identification approaches and related technologies, semantic interoperability, advanced networking, and security and privacy issues.

Drivers of infrastructure development

- The large amounts of data and traffic generated by billions of connected devices will create new demands for underlying network technologies. This will especially impact the technology solutions used by Internet service providers and operators.
- The IoT infrastructure is the key enabler of interoperability between heterogeneous devices, services and their users and the backbone that enables information sharing.
- The IoT infrastructure is an enabler of large-scale combinations or mash-up of information and services related to objects.
- Manufacturers move from proprietary solutions towards exploitation of shared information and services. This will create new business models based on information creation, processing, ownership and governance, and supporting infrastructure is therefore needed.

Roadmap stages and trends

- The IoT will evolve from today's proprietary and dedicated solutions to an open, common infrastructure that brings the benefits of the Internet to the ubiquitous cyber-physical systems domain. It will create an open digital data structure of the world that is based on open and linked data from objects, devices and systems around us. It will be the basis of digital systems interacting with the real world and creating smartness for improved living conditions.
- Current IoT solutions are dedicated proprietary systems or targeted at advanced enthusiasts. They are mostly address-based and lack interoperability features. Current research aims predominantly at bridging these isolated islands by developing reference architectures, models and communication protocols in an M2M (machine-to-machine) fashion.
- The next phases will introduce more general purpose cloud and unique ID based solutions that aim to cover wider application areas and adoption of interoperability solutions in bridging the different business domains and information sources.
- The longer term vision is for a very large scale Internet-like IoT ecosystem to form the basis for a smart world. This will involve IoT data repositories and advanced discovery and access support covering address, identifier and information based solutions, and support for the mash-up of data and services.

Juha-Pekka Soininen
Research Professor
Tel. +358 40 730 5921
juha-pekka.soininen@vtt.fi

Jussi Kiljander
Research Scientist
Tel. +358 40 197 0467
jussi.kiljander@vtt.fi

Jyrki Huusko
Senior Scientist, Team Leader
Tel. +358 40 525 4698
jyrki.huusko@vtt.fi

Wireless electricity, no cables needed

In the future, a large proportion of our everyday devices, appliances, sensors and vehicles will be charged or partly powered by wireless means. This old technology, invented in the late 19th century by Nikolae Tesla, is undergoing a renaissance. Imagine a wireless TV that you can move around the room wherever you like without worrying about power or antenna cords. Your mobile phone will always be fully charged when you are at home. You can put those new LED lights you bought anywhere you want, without a thought about wires or sockets. Your hybrid car draws electrical power from inductive power sources embedded under the road. Even your window frames will be used to convey wireless electricity from roof-top solar panels to your living room. And as for the vacuum cleaner, well, naturally, that’s wireless too.

Wireless electricity, no cables needed

Why is wireless power important to the Internet of Things?

- One of the major obstacles to wide-scale deployment of the IoT is the difficulty in providing electricity to wireless sensors, devices and actuators. The use of battery power for literally trillions of devices worldwide is not viable due to extreme impracticality and cost.
- Wireless power creates the possibility to incorporate IoT devices and electronics almost everywhere without the need for cables.

Situation today

- Standards are in place for wireless power in the consumer and automotive sectors.
- Wireless mobile phone chargers are on the market. As the technology develops, the distance between charger and device will ultimately increase from millimetres to metres.

Business and application fields

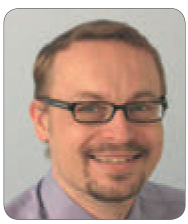
- The market for wireless power will grow from $4.9 billion (2012) to $15.1 billion (2020), including both consumer electronics and electric vehicles (Pike Research). In comparison: the global mobile phone market stood at ~$250 billion in 2012.
- The automotive industry is heavily developing wireless charging technologies both for charging electric vehicles (EVs) and for charging gadgets inside vehicles.
- In manufacturing, wireless connectors are enabling new kinds of equipment packaging, electronics, and hermetic sealing. Manufacturing can also benefit from wireless power in production lines. In logistics warehouses, automated trucks can receive power while on the move.
- In the health sector wirelessly powered instruments are more hygienic and enable examination of patients with instruments placed inside the body.

- The defence industry can benefit from more reliable operation of digital devices.
- As everyday gadgets become battery-free, use of natural resources and production of hazardous waste are both decreased.

Did you know?

- Wireless power was invented over 100 years ago by Serbian-American Nikola Tesla.
- Inductively charged toothbrushes (wireless power!) are used in households worldwide.
- In Turin, Italy, buses have been wirelessly charged at bus stops since 2002.
- The 2013 Toyota Avalon has in-car wireless power for charging mobile phones.
- Wireless power for mobile phone charging is is publicly available at several airports and even in some Starbucks cafe outlets.
- Completely wireless TV has been introduced by several TV manufacturers, e.g. Sony 2009 and Haier 2012.
- You will soon be able to charge your electric car in its parking place overnight. An under-asphalt transmitter can use 3.3kW as stated in the IEC 62196 standard.
- Several pilot systems around the world are powering electric cars in motion via coils located under the asphalt.

Esko Strömmer
Senior Scientist
Tel. +358 40 546 0121
esko.strommer@vtt.fi



Marko Jurvansuu
Key Account Manager
Tel. +358 40 547 9441
marko.jurvansuu@vtt.fi

6 Summary

The industrial and economic base of European society is being challenged by three trends: flight of manufacturing, ageing population and depleting natural resources. These challenges must be countered with social and political measures and by developing new technological and business approaches. According to our vision, all of these three challenges can be met through improved productivity.

During the current decade, the Internet of Things will drive productivity. Successful deployment of the IoT is therefore crucial for the survival and thriving of companies and societies. Our goal is to help industry and the public sector to improve productivity by leveraging Internet of Things technologies in areas that are vital to the competitiveness.

VTT has launched a four-year spearhead programme 'Productivity leap with the Internet of Things (Pro-IoT)', which aims at leveraging IoT technologies to achieve increased productivity. Two areas of high expected impact, Global Asset Management and Smart Lighting, were chosen as focus areas.

In the global asset management business area it is anticipated that IoT technologies will enable the transformation from equipment sales to service-based business. In the lighting industry, smartness enabled by the IoT will provide enhanced user experience with less energy resources. Smart lighting infrastructure will also be the backbone for other IoT-enabled solutions.

IN OUR VISION FOR THE FUTURE, EVERY OBJECT WILL HAVE A UNIQUE DIGITAL IDENTITY AND EVERY DEVICE AND MACHINE WILL HAVE CONNECTIVITY. THE VALUE OF NEW IOT-ENABLED BUSINESS WILL BE IMMENSE,* AND EUROPE WILL BE AT THE FOREFRONT OF THIS CHANGE.

*) General Electric estimates connecting machines to the Internet will generate an additional $15 trillion in global GDP by 2030 by helping cut costs and wastage, while John Chambers, CEO of Cisco, envisions "connecting every device in the world, this would create a $14 trillion business".

Productivity Leap with Internet

Challenges of a society
- Flight of manufacturing
- Ageining population
- Depleting natural resources, increasing pollution

→ In order to maintain the wellfare and growth we need a productivity leap!

→ IoT, which is the next step in ICT evolution can have a huge effect to productivity

1. Why do we need a productivity leap?

Heikki Ailisto
Research Professor
Tel. +358 40 555 0726
heikki.ailisto@vtt.fi

2. Elements of productivity disruption

Seija Sihvonen
Vice President, ICT
Tel. +358 40 532 1637
seija.sihvonen@vtt.fi

Riikka Virkkunen
Helena Kortelainen
Juhani Heilala
Heikki Ailisto
Tapio Rauma
Kari Mäki
Matti Roine
Mark van Gils

Contribution, support:
Kari Kohtamäki
Tommi Katainen
Eetu Pilli-Sihvola

3. The future of maintainance business

Pirkka Tukeva
Key Account Manager
Tel. +358 40 542 9791
pirkka.tukeva@vtt.fi

Helena Kortelainen
Tuomo Niskanen
Olli Ventä
Kaisa Belloni
Erkki Jantunen
Tommi Katainen
Mikko Lehtonen
Rauno Heinonen

# of Things

ACTION: VTT ESTABLISHED A SPEARHEAD RESEARCH PROGRAMME "PRODUCITIVITY LEAP WITH INTERNET-OF-THINGS" WITH TWO BUSINESS AREAS

GLOBAL ASSET MANAGEMENT

SMART LIGHTING

4. Smart lighting – enter the comfort zone

Janne Aikio
Principal Scientist
Tel. +358 40 703 4633
janne.aikio@vtt.fi

Marko Jurvansuu
Juho Merilahti
Jaakko Ketomäki
Jukka Hast
Johannes Peltola
Satu-Marja Mäkelä
Ville Könönen
Jukka Ahola
Eveliina Juntunen

Contribution, support:
Vesa Pentikäinen
Klaus Känsälä
Henrika Pihlajaniemi

5. Internet of Things revolutionizes several areas of life

Marko Jurvansuu
Key Account Manager,
Editor in chief
Tel. +358 40 547 9441
marko.jurvansuu@vtt.fi

Kaisa Belloni
Tommi Katainen
Janne Aikio
Artem Katasonov
Jouni Hiltunen
Kari Rönkä
Jouni Kaartinen
Miimu Airaksinen
Kari Mäki
Reijo Savola
Pekka Savolainen
Juha-Pekka Soininen
Jussi Kiljander
Jyrki Huusko
Esko Strömmer

6. Summary

Kaisa Belloni
Specialist, Managing editor
Tel. +358 40 545 6715
kaisa.belloni@vtt.fi

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Title	**Productivity Leap with IoT** Visions of the Internet of Things with a special focus on Global Asset Management and Smart Lighting
Author(s)	Marko Jurvansuu, Heikki Ailisto, Seija Sihvonen, Pirkka Tukeva, Janne Aikio, Kaisa Belloni, Riikka Virkkunen, Helena Kortelainen, Juhani Heilala, Tapio Rauma, Matti Roine, Mark van Gils, Olli Ventä, Erkki Jantunen, Tommi Katainen, Mikko Lehtonen, Rauno Heinonen, Juho Merilahti, Jaakko Ketomäki, Jukka Hast, Johannes Peltola, Satu-Marja Mäkelä, Ville Könönen, Jukka Ahola, Eveliina Juntunen, Artem Katasonov, Jouni Hiltunen, Jouni Kaartinen, Reijo Savola, Pekka Savolainen, Juha-Pekka Soininen, Jussi Kiljander, Jyrki Huusko, Miimu Airaksinen, Kari Mäki, Esko Strömmer, Kari Rönkä
Abstract	This publication presents visions and roadmaps for the Internet of Things, focusing on global asset management and smart lighting, with a strong productivity perspective.To maintain welfare and growth in Europe, a substantial productivity leap is needed. The Internet of Things (IoT) – the next step in ICT evolution – will boost productivity and create new business opportunities. In global asset management, productivity improves when downtime of production assets decrease and unnecessary service calls are eliminated. In smart lighting, productivity improves when there is right kind and right amount of light for the task in question. In the future, smart lighting will increase energy efficiency, comfort and introduce “more than light” features such as guidance and wellbeing with the light. In future asset management, equipment in the field will constantly monitor, adapt and report their state to service ecosystem and in the case of mechanical failure, outworn parts are made locally utilising additive manufacturing methods. There will be 50 billion connected devices by 2020, generating vast amounts of information. The real-time and openly available sensor information will offer immense benefits for business by enabling faster decision making, real-time control, enhanced operational efficiency and new business models.
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