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PREFACE

Preface to the focus theme section: 'Internet of things'

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Introduction

"Ubiquitous Computing" (Weiser 1991, 1993), "Pervasive Computing" (Satyanarayanan 2001; Estrin et al. 2002), "Things that think" (Gershenfeld 1999), "Ambient Intelligence" (Aarts et al. 2002), "Silent Commerce" (Ferguson 2002)—a plethora of novel terms has evolved in recent years that propagate the coming of a new paradigm shift in information processing. Common to all these concepts is the shared vision of a future world of everyday physical objects equipped with digital logic, sensors, and networking capabilities, which together form a so-called "Internet of Things" (IoT). Whereas computing power was a scarce resource in the former times of mainframe computers and PC's, the IoT bears the promise of omnipresent real-time access to information and services centred around arbitrary objects and users with their individual tasks and objectives.

It is neither a single technology nor a specific functionality which is behind the IoT but rather a bundle of functions implemented by a diverse set of systems and technologies. IoT-related research is accordingly characterised by a multi-disciplinary approach that includes aspects of electrical engineering, computer science, management research, psychology and many more (Satyanarayanan 2001). For this reason, the following list of an object's technological capabilities in the IoT can be regarded as typical but does not claim completeness:

- *Identification.* The transformation of physical objects into network nodes of the IoT requires a technique for unique identification, e.g., by means of an unambiguous numbering scheme. This identification allows the object to be linked with services and data which are stored on a remote server in the network.
- *Memory.* The object has storage capacity so that it can carry information on its past or future, e.g., a product that records its manufacturing steps. Storage capacity on the physical object allows for the creation of highly decentralized systems with individual objects knowing the business processes they are involved in.
- *Sensor technology.* The object collects information about its environment (temperature, light conditions, other objects, etc.), records it and/or reacts to it (referred to as "context awareness"). Organizations can thus learn more about their products' usage processes and utilize this information for offering novel services or improve their products' design.
- *Positioning & tracking.* Objects in the IoT may know their location (Positioning) or can be located by others (Tracking), for example at the global level by GPS or

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inside buildings by ultrasound. Information systems may thus reach out into the physical world and provide location-dependent service to users whenever and wherever they are needed.

- *Processing logic.* Objects in the IoT may be able to make decisions automatically without a central planning instance, e.g., in the sense of an industrial container which determines its own route through the supply chain. The IoT thus becomes not only an infrastructure for data collection, but rather offers the opportunity for changing the architecture of today's information systems by delegating decision-making authorities down to the outer edge of the network.
- *Networking.* In contrast to the simple pocket calculator, objects in the IoT have the capability to connect with resources in a network or even amongst themselves (referred to as "ad-hoc networking") for the reciprocal use of data and services. Every object may thus become an interface to employees within the organization, consumers, and partners in the supply chain.
- *User interface.* With the merging of computer and physical object come new requirements to be met by the user interface. This calls for new approaches similar to the mouse & desktop metaphor of graphical user interfaces, e.g., in the form of haptic interfaces.

RFID perhaps represents the best-known example of an IoT-related technology which is poised for mass use (Sarma et al. 2001). The ability of an object to store a unique identification number and to report it to its environment constitutes the first step toward the integration of object and information, and provides the basis on which farther-reaching functionality can be built (Want 2004). RFID provides a variety of advantages compared to the classical barcode and contributes to the optimisation of several manual and error-prone processes in organizations. After the huge hype around RFID tagging in retail and beyond in recent years, we currently witness the rise of integrated networks of RFID devices and repositories, such as the EPCglobal Network (EPCglobal 2007), which can be regarded as the first building blocks of the forthcoming IoT infrastructure.

Managerial implications

Ongoing informatisation and interconnectedness of physical objects has become a research issue in various academic disciplines. Whereas the early protagonists of the IoT vision were often regarded as utopists, technological feasibility of many application scenarios has now become reality due to increased technological performance, standardisation efforts, miniaturisation and price decline. In parallel, the IoT has also attracted the interest of several companies and industries. On the long run, the IoT might become the enabling technology for new management principles, which makes use of fine-grained data on physical goods flows instead of statistics, extrapolations, and mere "guesstimates" (Fleisch and Dierkes 2003; Allmendinger and Lombreglia 2005). From this perspective, the emergence of the IoT can be interpreted as the logical next wave of IS integration after the introduction of ERP systems and the Internet as we know it today.

With the development of corporate information management over the last decades, the scope of integration has been constantly expanded (Fleisch and Österle 2000). Here, "integration scope" describes the number of tasks which an enterprise or enterprise network performs in an information system. The following phases can be distinguished in this evolutionary process:

- *Phase 1*. In the initial stages of electronic data processing, the aim of informatising single functions within the firm was to achieve efficiency gains through the automational impacts on functions such as billing or job scheduling. Here, manual operations are transferred to the computer but remain unchanged. This results in isolated solutions, i.e., separate information systems which efficiently support individual operations.
- *Phase 2*. By informatising some of the most important functional areas of the firm such as, e.g., production or financial accounting, integration was achieved and thus the efficiency of entire departments improved. IT enabled the application of new methods for the first time, such as financial planning, through which business processes could be redesigned.
- *Phase 3*. The development of Enterprise Resource Planning (ERP) systems offered enterprises the possibility of introducing integrated processes across departments and/or across functions. This meant that consistent processes could be set up from the customer (e.g., sales, order entry) and to the customer (e.g., distribution, billing, payment receipt).
- *Phase 4*. In parallel with the introduction of ERP systems, some enterprises began creating closer networks with their customers or suppliers. In a first step, they started employing systems for electronic data interchange (EDI) in order to process mass transactions efficiently.
- *Phase 5*. Today, novel information systems for supply chain management and e-commerce place the customer's processes at the forefront of process and IS design by enabling the integration of interorganisational processes and/or systems and thus a step toward the extended enterprise.

From this perspective on the evolution of integrated information systems, the IoT vision suggests a new quality of integration, which is no longer limited to the information flows of the digital world but also directly links processes in the physical world as well as the associated products (e.g., drugs, textiles) and means of production (e.g., pallets, machines). Thus, the scope of integration crosses the boundaries of information systems and pervades the world of physical goods and processes.

The consequences of this technological change on management might best be described by an analogy from medical imaging. For centuries, the knowledge of physicians on the structure and the functioning of the human body were based on macroscopic investigations of corpses. Accordingly, the ability to recognize and treat a disease in a patient was limited by the physician's experience and the capacity of his five senses. It was not until the development of modern imaging procedures that an "anatomy of the living" was first made possible, e.g., by magnetic resonance imaging (MRI) introduced in the 1970s. The high-resolution images provided by these new technologies eventually led to an unprecedented level of precision and information in diagnostics.

While in our times the clinical procedures of a mediaeval "medicus" seem to be part of a far-distant past, many of the practices of planning and decision making in today's organizations take place under distressingly similar conditions. The management of processes in manufacturing, logistics, sales, and services, for example, largely depends on accurate information on the availability of parts, the status of machines and tools, the correct execution of workflows, customer behaviour on the sales floor, and many other things happening in the physical world. In practice, however, coarse-grained and untimely information is the rule owing to the fact that beyond highly automated processes no powerful measurement instruments exist that allow for zooming into the details of real-world events. Over time, companies have got used to such deficiencies. Moreover, strangely, the extensive use of information systems for improving the situation of managers can even contribute to the problem by hiding the nature of the underlying data and creating an illusion of accuracy. As a consequence, the performance of a broad range of complex physical processes remains below the theoretical optimum, which is reflected in stock-outs, high defect rates, spoilage, low customer satisfaction, and other symptoms of undetected cause. Against this background, the IoT will have an impact on the way companies manage their physical processes and products that can hardly be overestimated.

However, it is understood that profound changes of this kind do not come over night. If the MRI metaphor holds true, the IoT will provide legions of academic and industrial researchers and developers with challenging and fascinating questions for many years. Fruitful questions include not only the technological mechanisms, standards, and business benefits, but also the potential risks to privacy and data security (Thiesse 2007). The question whether the benefits will outweigh the costs and risk perceptions will not least depend on the creativity and performance of researchers who accept the challenge. The future is wide open. The race is on.

Contributions

The objective of this focus theme section on the Internet of Things is to foster the discussion in academia and practice on the development of a future Internet of Things. Out of the submissions that we received, four papers were positively evaluated by the reviewers and were eventually accepted. The different research questions pursued by these studies and the employed methodologies can be regarded as typical for the heterogeneity of research in this area.

Goebel and Günther investigate the use of RFID to improve the responsiveness of distribution systems. For this purpose, they present a simulation study of a retailer who operates one depot and N different outlets, which allows them to analyze the combined effect of inventory error sources. Their results show that the performance gains achieved by different responsive supply chain practices (e.g., the use of RFID), depend on the reliability of inventory data and can also be highly interdependent. Moreover, they conclude that the value of RFID can be significantly lower in more responsive distribution systems.

Thoroe, Melski and Schumann study the application of RFID in container management. The authors make use of an analytical inventory management model in order to develop a better understanding of the changes due to RFID regarding the optimum control policy. Second, they consider the profitability of the RFID system and determine relevant relations of costs and benefits. Third, they consider different alternatives of implementing an RFID-based container tracking system. The results suggest that the size of the container inventory relative to the demand rate is an important determinant in choosing an implementation alternative.

Ilic, Ng, Bowman and Staake consider a similar issue. They explore the impact of increased asset visibility on the management of returnable transport items (RTI). Today's RTI management processes are rather inefficient and rely on estimates about when, where and how RTIs are utilised. Against the background of a real case, the authors present a simulation study of a solution based on RFID technology and quantify its financial impact different perspectives. Their findings suggest that RFID provides a powerful means to counter inefficiencies in the RTI management process and improves the overall effectiveness of the RTI supply chain network.

Xu and Gupta examine the adoption of Location-Based Services (LBS) using survey data from users of an LBS application in Singapore. Drawing on the privacy literature and theories of technology adoption, they develop and test a conceptual model to explore the effects of privacy concerns and personal innovativeness on customers' adoption of the service. In particular, they separately consider the group of potential users and experienced users, respectively. The results indicate that privacy concerns significantly influence continued adoption as compared to initial adoption.

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