Architecting the Internet of Things

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Editors

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With a foreword by Bernd Scholz-Reiter

Springer

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ISBN 978-3-642-19156-5 e-ISBN 978-3-642-19157-2
DOI 10.1007/978-3-642-19157-2
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011925652

Cover design: eStudio Calamar S.L.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

The Internet of Things – Threats and Opportunities of Improved Visibility

The Internet has changed our business and private lives in the past years and continues to do so. The Web 2.0, social networks and mobile Internet access are just some of the current developments in this context. Ubiquitous computing and ambient intelligence have been fields of research where changes of computing in everyday situations have been examined. Today, the Internet of Things is a foundation for connecting things, sensors, actuators, and other smart technologies, thus enabling person-to-object and object-to-object communications.

The development of the Internet of Things is aligned with ongoing changes in information technology, logistics and electronic (e-)business. The significant reduction of message exchange times from analogue to digital messaging has led to reduced message sizes while increasing the number of message transactions. Additionally, there is a shift from mass broadcast to mass customisation and user-specified subscription to content tailored to an individual's interests. We expect to retrieve personalised information, as needed to cope with the growing information overflow. These changes are not limited to the Internet. We see similar changes in logistics, for example the increasing number of smaller deliveries, which has been influenced by e-business and improved material handling in the past years. The Internet of Things will bridge the gap between information technology and objects. The automatic identification of things and improved data handling capabilities allow individual product identification where we have previously been limited to types of products or batch identification. Large product recalls, which have led to severe financial and brand reputation losses, may be replaced by individual selective product recalls in direct business-to-consumer communication. E-business has changed our shopping habits. We retrieve information from the Internet, buy products online and contribute with information through product ratings. The speed of change in doing business has increased, thus requiring a higher level of agility. Some catalogue-based retailers that were previously very successful have been among the first victims because they were not prepared for the digital age.

The Internet of Things may just prove to be the missing link between logistics and information. However, there is still no clear understanding of how the Internet of Things will change our lives. First visions of smart fridges being able to automatically send replenishment orders have not yet become a reality. We might argue that consumers as well as businesses are not prepared for this yet or that this scenario is too complex – but is it? Printer manufacturing companies have integrated automatic identification for print cartridges, sensors to measure the ink fill levels, user interfaces to inform the consumer about the current status, instant online ordering of replenishment cartridges through corresponding software utilities, e-business and e-fulfilment, e-servicing and, last but not least, e-billing and e-payment.

Nevertheless, this only represents one stand-alone solution dominated by a single large business company. We would not want isolated "business tunnels" for every Internet of Things application. One key to success is the freedom of choice! We want to choose between different manufacturers, suppliers, service providers, delivery options, and payment services without the need for proprietary technologies. For this, we need to cope with the heterogeneity of the involved technologies and architectures. Interoperability across businesses, service providers and consumers will only be achieved if standardised interfaces can be provided.

Additionally, we need to overcome the structural shortcomings of IT investments in businesses. So far, Small and Medium Enterprises (SME) have been burdened by large key-players through mandates to invest in new technologies that rarely provide substantial benefits for the SME themselves. Cost benefit sharing and other compensation approaches need to be researched to make the Internet of Things a solution that is not limited to large companies.

We will need different human interfaces as well as machine interfaces to release the full potential of the Internet of Things. While we see Barcode and 2D-reader software being installed on mobile phones to identify objects, only few users are using this functionality to link to Internet-based information. Near-Field Communication (NFC) seems to be the next technology to enable unique identification and linking automatically to Internet services. Billing and payment services operated through mobile providers will be in the forefront to exploit the business opportunities of NFC. Radio frequency (RF) SIM cards provide another option that may enable non-NFC mobile phones to participate in mobile business and product related information access. In addition to multi-purpose devices we may see dedicated personal identification gadgets that are simpler to operate. USB-sticks have been more successful than mobile phones for portable data-storage. A small and easy to use identification device may be just as beneficial to link objects to their virtual representations in the Internet.

Will the Internet of Things make our lives easier? Or will it just be another component in a world of information overflow? Currently, the Internet of Things is all about information visibility – it is not about autonomous decision-making. To relieve us from everyday decision tasks and to avoid delays between information availability and decisions, new methods and technologies need to be integrated. In logistics, autonomous cooperating logistic processes are being researched. The main idea of this concept is to use decentralised and hierarchical planning and control methods. The combination of autonomous control and the Internet of Things would provide a higher level of infrastructural robustness, scalability and agility.

However, the integration of autonomous concepts in the Internet of Things is not limited to logistics. Personalised software agents will cater for our needs in private life, including shopping, smart home and public environments. Bidding agents are already quite common in the Internet. Nonetheless, software agents need to go beyond simple if-then algorithms, integrate sensor data to perceive the nature of their environment, communicate with other agents, learn from experience, and allow human intervention. Nevertheless, they need to be easy to use and configure to reach a higher level of user acceptance among the general public. Current developments in the Internet, enabling end-user participation through mash-ups and other user-friendly do-it-yourself software tools, are leading in a similar direction of leaving the developer community and reaching out to the end-users.

However, technology can only provide us with new opportunities. It is up to us to use these for holistic innovation approaches. We need to rethink traditional business setups. Other research disciplines need to integrate the Internet of Things into their every-day thinking. Civil architecture needs to develop RF friendly factories to avoid reflections and interferences. Industry designers need to develop forklift trucks with information technology ergonomically integrated, instead of bulky attachments. Public infrastructures, such as toll systems, need to be extended to support additional services for and through the Internet of Things. Objects, such as cars, need to be able to communicate with each other and with their own environment to exploit a limited infrastructure and enable new sustainable sharing models. Wearable computing needs to be enhanced to "sleek fashion computing" – where stylishness, usability, intelligence, connectivity and mobility are integrated to produce superior end-user friendly devices. Smart phones, personal data terminals, and other mobile computing devices are still far away from what a future Internet of Things will require to connect people and things.

The advantages of the Internet of Things are obvious. Improved efficiency, effectiveness, and new business opportunities may be achieved. Nevertheless, there are also certain threats and issues of governance, security, and privacy that need to be considered. Open governance in an Internet of Things remains an important issue. However, it may be assumed that the ongoing discussions between different regions and countries will lead to a federated structure in the longer term, similar to the domain structures we know from the Internet today. Anyway, proprietary industrial approaches ignoring international standardisation approaches as well as political discussion will try to set their own de-facto-standards. A recent malware attack (Stuxnet), aiming to spy on and reprogram Supervisory Control And Data Acquisition (SCADA) systems, has revealed once more the need for security in a future Internet of Things. The Internet has been misused to manipulate the virtual world, such as stock markets; and the Internet of Things will have direct implications on the physical world. In relation to privacy, it is important that personal data should be treated as such. New legislation is being proposed to deal with the misuse of personal data by employers. According to current political discussions in Germany, secret video surveillance of employees shall be banned and social websites shall not be used for research in the employment process. The Internet of Things enables further surveillance possibilities concerning employees and consumers. Again, it is up to us to use the advantages of the Internet of Things while promoting a responsible usage of the newly achieved visibility. Improved laws and regulations will help, but self-regulating control mechanisms will be even more important. Responsible usage will be rewarded in a world that is more and more influenced by social and sustainable management. Businesses have already seen boycott requests in the Internet of Things that have forced them to rapidly change their strategy. It will be important for enterprises to understand that these self-regulating mechanisms are extremely powerful and can change their business for better or for worse. We should always remember the power of a webcam showing an oil stream from a broken oil pipeline.

The Internet of Things provides far more visibility than a webcam – yet, it also enables faster exception handling and agility, which may help to save money, the environment or even lives.

Prof. Dr.-Ing. Bernd Scholz-Reiter

Contents

Figures

Tables

Abbreviations

4PL – Fourth Party Logistics

6LoWPAN – IPv6 Low Power Wireless Personal Area Networks

ACA – Assisting Cargo Agent

ACEA – European Automobile Manufacturers Association

ACID – Atomicity, Consistency, Isolation, Durability

AJAX – Asynchronous JAvaScript and XML

ALE – Application Level Events

API – Application Programming Interface

AR – Augmented Reality

ASAM – Associsation for Standardisation of Automation and Measurement Systems

B2B – Business-to-Business

B2C – Business-to-Consumer

BIBA – Bremer Institut für Produktion und Logistik GmbH

BMS – Building Management Systems

BOL – Beginning of Life

BPEL – Business Process Execution Language

BPMN – Business Process Modelling Notation

CAN – Controller Area Network

CBS – Cost Benefit Sharing

CERP – Cluster of European Research Projects on the Internet of Things

CH – Cluster Head

COBRA – Common Object Request Broker Architecture

CO-LLABS – Community-Based Living Labs

COM – Component Object Model

CPG – Consumer Packaged Goods

CPU – Central Processing Unit

CRC – Collaborative Research Centre

CRM – Customer Relationship Management

DCOM – Distributed Component Object Model

DFG – German Research Foundation

DiY – Do-it-Yourself

DiYSE – DiY Smart Experiences

DLNA – Digital Living Network Alliance

DNS – Domain Name Service

DoD – Department of Defense

DOGMA – Developing Ontology Grounded Methods and Applications framework

DOGMA-MESS – DOGMA Meaning Evolution Support System

DPWS – Device Profile for Web Services

DSRC – Dedicated Short Range Communications

EAN – Electronic Article Number

EANCOM – EAN Communication

EASE – Ecological Approach to Smart Environments

ebXML – Electronic Business Extensible Markup Language

ECM – Enterprise Content Management

ECR – Efficient Consumer Response

EDI – Electronic Data Interchange

EDIFACT – Electronic Data Interchange For Administration, Commerce and Transport

EEML – Extended Environments Markup Language

EnoLL – European Network of Living Labs

EOL – End of Life

EPC – Electronic Product Code

EPCIS – Electronic Product Code Information Service

ERP – Enterprise Resource Planning

ESSI – European Semantic Systems Initiative

ETSI – European Telecommunications Standards Institute

EURIDICE – European Inter-Disciplinary Research on Intelligent Cargo for Efficient, safe and environment-friendly logistics

FIFO – First In, First Out

FIPA – Foundation for Intelligent Physical Agents

FOSSTRAK – Free and Open Source Software for Track and Trace

FSF – Free Software Foundation

GEF – Graphical Editing Framework

GNSS – Global Navigation Satellite System

GPRS – General Packet Radio Service

GPS – Global Positioning System

GRAI – Global Returnable Asset Identifier

GSM – Global System for Mobile Communications

GUI – Graphical User Interface

HAL – Hardware Abstraction Layer

HF – High Frequency

HTML – HyperText Markup Language

HTTP – HyperText Transfer Protocol

I/O – Input/Output

IC – Integrated Circuit

ICT – Information and Communication Technology

ID – Identifier

IDE – Integrated Development Environment

IERC – Internet of Things Research Cluster

IETF – Internet Engineering Task Force

IFC – Industry Foundation Classes

IFTF – Institute for the Future

IMSAS – Institute for Microsensors, -actuators and -systems

IOT – Internet of Things

IoT IS – Internet of Things Information Service

IP – Internet Protocol

IPv6 – Internet Protocol version 6

IRTF – Internet Research Task Force

ISO – International Organization for Standardization

IT – Information Technology

ITEA2 – Information Technology for European Advancement, period 2

ITS – Intelligent Transport Systems

ITU-T – International Telecommunication Union - Telecommunication Standardisation Sector

IWT – Agency for Innovation by Science and Technology (Belgium)

J2SE – Java 2 Platform, Standard Edition

JADE – JavaAgentDEvelopment framework

JSON – JavaScript Object Notation

KB – Knowledge Base

LCD – Liquid Cristal Display

LED – Light-Emitting Diode

LOD – Linked Open Data

LTE – Long Term Evolution

M2M – Machine-to-Machine

MAC – Medium Access Control

MANET – Mobile Ad-hoc NETworks

MAS – Multi-Agent Systems

MIDI – Musical Instrument Digital Interface

MIT – Massachusetts Institute of Technology

MOL – Middle of Life

NFC – Near Field Communication

NIP – Non-Internet Protocol

NJMF – Norwegian Iron and Metal Workers Union

OBU – On-Board Unit

OCA – Operational Cargo Agent

ONS – Object Name Service

OOS – Out of Stock

ORiN – Open Robot Resource Interface for the Network

OSGi – Open Services Gateway initiative

ORPHEUS – Object Recognition and Positioning Hosted European Service

OS – Open Source

OS – Operating System

OSGi – Open Service Gateway initiative

OWL – Web Ontology Language

OWL-S – Web Ontology Language for Web Services

P2P – Peer-to-Peer

PaaS – Product as a Service

PbH – Power by the Hour

PBL – Performance-based Logistics

PD – Participatory Design

PDT – Personal Data Terminals

PEID – Product Embedded Information Device

PLCS – Product Life Cycle Support

PLM – Product Lifecycle Management

PMI – PROMISE Messaging Interface

PuSH – PubSubHubbub

QoS – Quality of Service

R&D – Research and Development

RDF – Resource Description Framework

RDFa – Resource Description Framework in attributes

REST – Representational State Transfer

RFC – Remote Function Call

RFD – Reduced Functionality Devices

RFID – Radio Frequency Identification

ROI – Return on Investment

ROLL – Routing Over Low power and Lossy networks

RTI – Returnable Transport Items

RTP – Real Time Protocol

RTSP – Real Time Streaming Protocol

SAC – Social Access Controller

SCM – Supply Chain Management

SDO – Sensor Data Ontology

SGTIN – Serialised Global Trade Identification Number

SHO – Sensor Hierarchy Ontology

SHOE – Simple HTML Ontology Extension

SMD – Service Mapping Description

SME – Small and Medium-sized Enterprises

SOA – Service Oriented Architecture

SOAP – Simple Object Access Protocol

SOC – Service-Oriented Computing

SPARQL – SPARQL Protocol and RDF Query Language

SPI – Serial Peripheral Interface

SQL – Structured Query Language

SSCC – Serial Shipping Container Code

SUMO – Suggested Upper Merged Ontology

SWS – Semantic Web Services

SWSF – Semantic Web Services Framework

TCP – Transmission Control Protocol

TDS – Tag Data Standard

TDT – Tag Data Translation

UCD – User-centered Design

UCSD – University of California San Diego

UDDI – Universal Description, Discovery and Integration

UHF – Ultra High Frequency

UI – User Interface

UML – Unified Modelling Language

UMTS – Universal Mobile Telecommunications System

UPnP – Universal Plug-and-Play

URI – Uniform Resource Identifier

URL – Uniform Resource Locator

URN – Uniform Resource Name

USB – Universal Serial Bus

UWB – Ultra Wide Band

VSP – Virtual Service Point

W3C – World Wide Web Consortium

WIMP – Window, Icon, Menu, Pointing device

WMS – Warehouse Management System

WoT – Web of Things

WS – Web Services

WSAN – Wireless Sensor and Actuator Network

WSDL – Web Service Definition Language

WSMO – Web Service Modeling Ontology

WSMX – Web Service Execution Environment

WSN – Wireless Sensor Network

WWAI – World Wide Article Information

WWW – World Wide Web

XML – Extensible Markup Language

XMPP – Extensible Messaging and Presence Protocol

XOL – Ontology Exchange Language