

Helmut Krcmar · Ralf Reussner
Bernhard Rumpe
Editors

Trusted Cloud Computing



 Springer



[KRR14] H. Krcmar, R. Reussner, B. Rumpe (Hrsg):
Trusted Cloud Computing.
Springer International Publishing, Schweiz 2014.
ISBN 978-3-319-12718-7.
www.se-rwth.de/publications

Editors

Helmut Krcmar
Technische Universität München
Munich
Germany

Bernhard Rumpe
RWTH Aachen
Aachen
Germany

and

and

fortiss - An-Institut Technische Universität
München
Munich
Germany

RIT - Rumpe Information Technologies
Aachen
Germany

Ralf Reussner
Karlsruhe Institute of Technology
Karlsruhe
Germany

and

FZI - Forschungszentrum Informatik am
KIT
Karlsruhe
Germany

ISBN 978-3-319-12717-0 ISBN 978-3-319-12718-7 (eBook)
DOI 10.1007/978-3-319-12718-7

Library of Congress Control Number: 2014955316

Springer Cham Heidelberg New York Dordrecht London

© Springer International Publishing Switzerland 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

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



Bundesministerium
für Wirtschaft
und Energie



Message of Greeting

by Sigmar Gabriel,

Federal Minister for Economic Affairs and Energy

**for the *Trusted Cloud* Technology Programme run by the Federal Ministry for Economic
Affairs and Energy**

Cloud computing is emerging as a key tool of digitisation: it creates opportunities for companies - for example when it comes to finding tailored software, computing power and storage capacity via the internet. This saves companies the need to invest in large-scale IT infrastructure. It is a crucial advantage, not least for start-ups as it allows companies to access innovative technologies that so far have been reserved for the big players of the industry. In addition: employees can have mobile access to their data. This makes companies flexible and opens up space for new business models.

The Federal Ministry for Economic Affairs and Energy launched the *Trusted Cloud* Technology Programme in order to open up the big innovation and market potential of cloud computing, especially to SMEs. The programme demonstrates the opportunities and diversity of the new applications in different areas, ranging from industry and crafts to the health and public sector. Special emphasis has been placed on security by design: from the outset, IT security and data protection have been part of the technological development.

To successfully introduce cloud computing in Germany and help SMEs make use of it, we need reliable solutions for a number of different tasks. Germany has in-depth scientific and engineering skills and is therefore very well placed to set benchmarks by giving best practice examples and introducing cloud applications in different industries.

This book presents important scientific results from different areas of application of the *Trusted Cloud* Programme. The applicability and usability of research results always play an important role, be it for security aspects, software architecture or business models.

Germany has every chance to establish itself as a leading player on this promising market. The foundation for our success is a strong scientific base. I hope you will find this publication enjoyable and stimulating.

Sincerely yours,

A handwritten signature in blue ink, reading "Jürgen Freil". The signature is written in a cursive style with a large initial 'J' and 'F'.

Preface

The research projects of the Trusted Cloud Initiative of the Federal Ministry for Economic Affairs and Energy are developing novel cloud services and making them, as well as already existing services, usable for trustable IT applications. Cloud services have a number of advantages over in-house services, starting with cost efficiency and flexible payment models, where customers only pay for resources and services they actually use. Combined with the elasticity of service provision, that is the dynamic adaptation to seasonal or task-depending resource demands of a service's operation, it makes Cloud Computing an attractive model for service provisioning on many layers (as application platform, programming model, or for domain-specific services).

However, the user gives up some control over the operation of the IT services to the service provider. This particularly concerns non-functional aspects of service provision, including quality attributes that impact the trustworthiness of the service. However, since the platform provider, due to economy of scale, can address these aspects more professionally, the service is expected to operate at a higher level of quality and under more robust security standards. Service-level agreements specify the qualities promised by the service provider, yet this does not solve the general problem that the service provider has to be fundamentally trusted. If the user does not or cannot grant this trust, Cloud Computing is not an option and its benefits not available.

The projects of the Trusted Cloud Technology Programme address this issue. The research and development conducted in groups of research institutes and enterprises aim at making Cloud Computing practical for trustworthy IT applications. This book documents the progress and results of these programmes and their critical discussion during a workshop at the Forschungszentrum Informatik (FZI) on the 10th of July 2013 in Karlsruhe which was organized by researches from the Karlsruhe Institute for Technology (KIT), the RWTH Aachen University, and the Technische Universität München. This workshop and the book at hand are a platform for presenting the scientific results of these projects and focus less on the business-related aspects. Nevertheless, the discussions have shown that business models, legislative circumstances, technical possibilities, and realizable security are tightly entangled and thus

have to be addressed jointly. This way, legislative requirements may be reflected in the Cloud's physical properties, for instance by a "private cloud" distribution model, or by ensuring that the service provider is operating in an appropriate legal sphere.

A holistic consideration of technological, societal and legal aspects is necessary to ensure the security of cloud services and the data they process, and to gain the trust of society and science in these services, especially in the light of the recent public discussions concerning the security of online data. Nevertheless, it is clear that the issue of security cannot be the responsibility of private enterprises alone. Small and medium enterprises, which are prevalent and of central importance in Germany, cannot stand up to foreign powers and intelligence agencies alone. The security of the Internet and the service that are based on has to be a national concern, if not a European one, in order to compete, and in some areas to catch up, in the marketplaces of the Internet. The Internet, including the operating systems of its nodes, its communication middleware and the application software, no longer is an infrastructure that is just relevant to IT enterprises. Instead, it impacts all areas of economy in Germany. The Trusted Cloud Programme is a highly relevant building block for innovation in the German economy.

Additional building blocks are the programmes Big Data of the BMWi and the Smart Data of the BMBF, both of which deal with the gathering of data over the Internet. We refer in this context to the Smart Data Manifesto, that originated as a key result of the discussions during the Trusted Cloud workshop.

Cloud components are moreover key parts of the cyber-physical infrastructure that will arise in the manufacturing, transportation, and service industry, as well as in the automation of mechanical activities through intelligent, cooperating robots, machines, and transporters. This change in our manufacturing business called "Industry 4.0" will be based on a strong cloud-based IT-infrastructure. It will need to be trustworthy to prevent massive economic damage beyond the IT industry. Reluctance in embracing this change will not be an option, since otherwise new business models will emerge outside of Germany instead of inside.

The research topics discussed in this book are diverse. They are in part fitted to the specific application domain of their projects, nevertheless, as it is typical in computer science, their fundamental technological solutions and platforms are portable to other domains.

The contributions in this book are categorized into the following topics:

- Security and Privacy
- Software Engineering and Quality
- Platforms and Middleware
- Social Aspects
- Business Models
- Standards

We thank all the authors and reviewers for their help to bring this book into existence. Herbert Weber was of great help with his advice for the projects and the field and Jennifer Welp helped organizing the projects from their start up to their current status. The projects also profited from a science and technology visit

to the Silicon Valley with Nadine Schön, MdB and Jennifer Welp. We especially thank Matthias Huber, Antonio Navarro Perez, and Jan Wollersheim that helped to organize the workshop and put the book together.

We hope that the book will inspire you to further scientific research or to use the results for the implementation of trustworthy cloud services. This would achieve one goal of the workshop and this book, to distribute these results to a broader audience and to applications beyond the scope of the Trusted Cloud projects.

Karlsruhe, Aachen, and Munich, March 2014

Helmut Krcmar (Fortiss and TUM)

Ralf Reussner (FZI and KIT)

Bernhard Rumpe (RIT and RWTH)

Contents

Part I Security and Privacy

1	GeneCloud: Secure Cloud Computing for Biomedical Research	3
	Martin Beck, V. Joachim Haupt, Janine Roy, Jan Moennich, René Jäkel, Michael Schroeder, and Zerrin Isik	
2	Sealed Cloud – A Novel Approach to Safeguard against Insider Attacks	15
	Hubert A. Jäger, Arnold Monitzer, Ralf Rieken, Edmund Ernst, Khiem Dau Nguyen	
3	Side Channels in Secure Database Outsourcing on the Example of the MimoSecco Scheme	35
	Matthias Huber and Gunnar Hartung	
4	ReDS: A System for Revision-Secure Data Storage	49
	Tobias Pöppke and Dirk Achenbach	
5	Automatic Data Protection Certificates for Cloud-Services based on Secure Logging	59
	Thomas Kunz, Annika Selzer, Ulrich Waldmann	
6	A Trust Point-based Security Architecture for Sensor Data in the Cloud	77
	Martin Henze, René Hummen, Roman Matzutt, and Klaus Wehrle	

Part II Software Engineering and Software Quality

7	Quality Analysis Approaches for Cloud Services – Towards a Framework along the Customer’s Activity Cycle	109
	Jan Wollersheim and Helmut Krcmar	

8	A Model-based Software Development Kit for the SensorCloud Platform	125
	Lars Hermerschmidt, Antonio Navarro Perez, and Bernhard Rumpe	
9	TRESOR – Towards the Realization of a Trusted Cloud Ecosystem	141
	Sebastian Zickau, Mathias Slawik, Dirk Thatmann, Sebastian Uhlig, Iwailo Denisow, and Axel Küpper	
10	Towards Reliability Estimation of Large Systems-of-Systems with the Palladio Component Model	159
	Fouad ben Nasr Omri and Ralf Reussner	

Part III Platforms, Middleware and Integration

11	Data Protection in the Cloud – The MimoSecco Approach	177
	Jonas Lehner, Andreas Oberweis, and Gunther Schiefer	
12	Secure Database Outsourcing to the Cloud Using the MimoSecco Middleware	187
	Matthias Gabel and Gerald Hübsch	
13	SensorCloud: Towards the Interdisciplinary Development of a Trustworthy Platform for Globally Interconnected Sensors and Actuators	203
	Michael Eggert, Roger Häußling, Martin Henze, Lars Hermerschmidt, René Hummen, Daniel Kerpen, Antonio Navarro Pérez, Bernhard Rumpe, Dirk Thißen, Klaus Wehrle	
14	Testbed for the Sensor Cloud	219
	Gregor Büchel, Henning Budde, Maria Bunina, Sven Elbrandt, Martin Fehre, Georg Hartung, Tobias Krawutschke, Andreas Lockermann, Thomas Partsch, Daniel Scholz, Andre Schüer, and Lothar Thieling	
15	An Architecture for Trusted PaaS Cloud Computing for Personal Data	239
	Lorena González-Manzano, Gerd Brost, and Matthias Aumüller	
16	Privacy-Preserving Cloud Computing for Biomedical Research	259
	Martin Beck, V. Joachim Haupt, Janine Roy, Jan Moennich, René Jäkel, Michael Schroeder, and Zerrin Isik	

Part IV Social Aspects, Business Models and Standards

17	Designing a Business Model for a Cloud Marketplace for Healthcare	285
	Nicolai Hanner, Tatiana Ermakova, Jonas Repschlaeger, and Ruediger Zarnekow	

**18 SensorCloud: Sociological Contextualization of an Innovative
Cloud Platform 295**
Michael Eggert, Daniel Kerpen, Kirsten Rüssmann, and Roger Häußling

**19 Cutting Through the Jungle of Cloud Computing Whitepapers:
Development of an Evaluation Model 315**
Pascal Grochol, Stephan Schneider, and Ali Sunyaev