Lecture Notes in Computer Science 4952

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Christian Floerkemeier Marc Langheinrich
Elgar Fleisch Friedemann Mattern
Sanjay E. Sarma (Eds.)

The Internet of Things

First International Conference, IOT 2008
Zurich, Switzerland, March 26-28, 2008
Proceedings

Springer

Volume Editors

Christian Floerkemeier
Sanjay E. Sarma
Massachusetts Institute of Technology
Auto-ID Labs
77 Massachusetts Avenue, Cambridge, MA 02139, USA
E-mail: {floerkem,sesarma}@mit.edu

Marc Langheinrich
Friedemann Mattern
ETH Zurich
Inst. for Pervasive Computing
Clausiusstr. 59, 8092 Zurich, Switzerland
E-mail: {langhein,mattern}@inf.ethz.ch

Elgar Fleisch
ETH Zurich and
University of St. Gallen
Dufourstrasse 40a, 9000 St. Gallen, Switzerland
E-mail: elgar.fleisch@ethz.ch

Library of Congress Control Number: 2008922619

CR Subject Classification (1998): C.2, C.3, B.7, E.3, D.4.6, K.6.5, J.1

LNCS Sublibrary: SL 3 – Information Systems and Application, incl. Internet/Web and HCI

ISSN 0302-9743
ISBN-10 3-540-78730-5 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-78730-3 Springer Berlin Heidelberg New York

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 12244263 06/3180 5 4 3 2 1 0

Preface

This volume contains the proceedings of the Internet of Things (IOT) Conference 2008, the first international conference of its kind. The conference took place in Zurich, Switzerland, March 26–28, 2008. The term 'Internet of Things' has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects. Technologies such as RFID, short-range wireless communications, real-time localization, and sensor networks are becoming increasingly common, bringing the 'Internet of Things' into industrial, commercial, and domestic use. IOT 2008 brought together leading researchers and practitioners, from both academia and industry, to facilitate the sharing of ideas, applications, and research results.

IOT 2008 attracted 92 high-quality submissions, from which the technical program committee accepted 23 papers, resulting in a competitive 25% acceptance rate. In total, there were over 250 individual authors from 23 countries, representing both academic and industrial organizations. Papers were selected solely on the quality of their blind peer reviews. We were fortunate to draw on the combined experience of our 59 program committee members, coming from the most prestigious universities and research labs in Europe, North America, Asia, and Australia. Program committee members were aided by no less than 63 external reviewers in this rigorous process, in which each committee member wrote about 6 reviews. The total of 336 entered reviews resulted in an average of 3.7 reviews per paper, or slightly more than 1000 words of feedback for each paper submitted. To ensure that we had quality reviews as well as substantive deliberation on each paper, a subsequent discussion phase generated 270 discussion items. As a result, some 40 submissions were selected for discussion at the meeting of the program chairs.

The term 'Internet of Things' describes an area with tremendous potential; where new sensing and communication technologies, along with their associated usage scenarios and applications, are driving many new research projects and business models. Three major themes pervade the technical discussions collected in this volume: novel sensing technologies to capture real-world phenomena; the evaluation of novel applications using both new and existing technologies; and the appropriate infrastructure to facilitate communication with (and the localization of) billions of networked real-world objects. While all these technological developments are exciting, they also bear profound challenges from a social, legal, and economic perspective. The research areas covered at IOT 2008 were thus not only technical in nature, but reflected the diverse angles from which to approach this emerging research field.

The scientific papers presented at IOT 2008 were not its only highlight. In addition to the technical sessions, the conference featured keynote speeches by leading figures from industry and academia, such as Bob Iannucci (Nokia), Gerd

Wolfram (Metro Group), Peter Zencke (SAP), and Haruhisa Ichikawa (UEC Tokyo). IOT 2008 also included an industrial track where industry experts presented challenges and lessons learned from current technology deployments. The conference offered a demo reception, as well as a full day of workshops and tutorials.

Several organizations provided financial and logistical assistance in putting IOT 2008 together, and we would like to acknowledge their support. We thank ETH Zurich for the conference organization and for managing the local arrangements. We very much appreciate the support of our Platinum Sponsor SAP, along with the generous donations from Siemens, Metro Group, Google, ERCIM, and IBM. We would also like to thank the keynote speakers and industrial experts who provided a fascinating commercial perspective on current developments towards an 'Internet of Things'. Lastly, we would like to thank both the authors who submitted their work to IOT 2008 and the program committee members and our external reviewers, who spent many hours reviewing submissions, shepherding papers, and providing the feedback that resulted in the selection of the papers featured in these proceedings.

March 2008

Christian Floerkemeier
Marc Langheinrich
Elgar Fleisch
Friedemann Mattern
Sanjay Sarma

Organization

Conference Committee

Conference Chairs	Elgar Fleisch (ETH Zurich & University of St. Gallen, Switzerland) Friedemann Mattern (ETH Zurich, Switzerland) Sanjay Sarma (MIT, USA)
Program Chairs	Christian Floerkemeier (MIT, USA) Marc Langheinrich (ETH Zurich, Switzerland)
Industrial Program	Ulrich Eisert (SAP Research, Germany)
Workshops & Demos	Florian Michahelles (ETH Zurich, Switzerland)

Conference Management

Financial	Marc Langheinrich (ETH Zurich, Switzerland)
Local Arrangements	Steve Hinske (ETH Zurich, Switzerland)
Press	Steve Hinske (ETH Zurich, Switzerland)
Proceedings	Philipp Bolliger (ETH Zurich, Switzerland)
Publicity	Benedikt Ostermaier (ETH Zurich, Switzerland)
Registration	Marc Langheinrich (ETH Zurich, Switzerland) Steve Hinske (ETH Zurich, Switzerland)
Sponsoring	Steve Hinske (ETH Zurich, Switzerland)
Student Volunteers	Steve Hinske (ETH Zurich, Switzerland)
Web	Marc Langheinrich (ETH Zurich, Switzerland)

Program Committee

Karl Aberer (EPFL, Switzerland)
Manfred Aigner (TU Graz, Austria)
Michael Beigl (TU Braunschweig, Germany)
Alastair Beresford (University of Cambridge, UK)
Peter Cole (The University of Adelaide, Australia)
Nigel Davies (Lancaster University, UK)
Jean-Pierre Émond (University of Florida, USA)
Alois Ferscha (University of Linz, Austria)
Elgar Fleisch (ETH Zurich & University of St. Gallen, Switzerland)
Anatole Gershman (Carnegie Mellon University, USA)
Bill Hardgrave (University of Arkansas, USA)

Mark Harrison (Cambridge University, UK)
Ralf Guido Herrtwich (Daimler, Germany)
Lutz Heuser (SAP Research, Germany)
Lorenz Hilty (EMPA, Switzerland)
Thomas Hofmann (Google, Switzerland)
Ryo Imura (Hitachi & University of Tokyo, Japan)
Sozo Inoue (Kyushu University, Japan)
Yuri Ivanov (Mistubishi Electric Research Laboratories, USA)
Behnam Jamali (The University of Adelaide, Australia)
Guenter Karjoth (IBM Zurich Research Lab, Switzerland)
Wolfgang Kellerer (DoCoMo Euro-Labs, Germany)
Daeyoung Kim (Information and Communications University, Korea)
Kwangjo Kim (Information and Communication University, Korea)
Tim Kindberg (Hewlett-Packard Laboratories, UK)
Gerd Kortuem (Lancaster University, UK)
Anthony LaMarca (Intel Research Seattle, USA)
Friedemann Mattern (ETH Zurich, Switzerland)
Hao Min (State Key Lab of ASIC and System, Fudan University, China)
Jin Mitsugi (Keio University, Japan)
Paul Moskowitz (IBM T. J. Watson Research Center, USA)
Jun Murai (Keio University, Japan)
Osamu Nakamura (Keio University, Japan)
Paddy Nixon (University College Dublin, Ireland)
Thomas Odenwald (SAP Research, USA)
Ravi Pappu (Thingmagic, USA)
Joseph Paradiso (MIT, USA)
Aaron Quigley (University College Dublin, Ireland)
Hartmut Raffler (Siemens, Germany)
Matt Reynolds (Georgia Institute of Technology, USA)
Antonio Rizzi (University of Parma, Italy)
Sanjay Sarma (MIT Auto-ID Center, USA)
Albrecht Schmidt (University of Duisburg-Essen, Germany)
James Scott (Microsoft Research, UK)
Ted Selker (MIT Media Lab, USA)
Andrea Soppera (BT Research, UK)
Sarah Spiekermann (Humboldt-University Berlin, Germany)
Michael ten Hompel (Fraunhofer Logistik, Germany)
Frédéric Thiesse (University of St. Gallen, Switzerland)
Khai Truong (University of Toronto, Canada)
Kristof Van Laerhoven (TU Darmstadt, Germany)
Harald Vogt (SAP Research, Germany)
Wolfgang Wahlster (DFKI, Germany)
Kamin Whitehouse (University of Virginia, USA)
John Williams (MIT, USA)

Reviewers

Gildas Avoine (Université catholique de Louvain, Belgium)
John Barton (IBM Research, USA)
Paul Beardsley (MERL, USA)
Richard Beckwith (Intel Research, USA)
Mike Bennett (University College Dublin, Ireland)
Martin Berchtold (University of Karlsruhe, Germany)
Jan Beutel (ETH Zurich, Switzerland)
Urs Bischoff (Lancaster University, UK)
Philipp Bolliger (ETH Zurich, Switzerland)
Gregor Broll (Ludwig-Maximilians-University Munich, Germany)
Michael Buettner (University of Washington, USA)
Tanzeem Choudhury (Intel Research Seattle, USA)
Lorcan Coyle (University College Dublin, Ireland)
Jonathan Davies (University of Cambridge, UK)
Benessa Defend (University of Massachusetts, USA)
Christos Efstratiou (Lancaster University, UK)
Michael Fahrmair (DoCoMo Euro-Labs, Germany)
Martin Feldhofer (Graz University of Technology, Austria)
Guido Follert (Dortmund University, Germany)
Adrian Friday (Lancaster University, UK)
Benoit Gaudin (University College Dublin, Ireland)
Stephan Haller (SAP Research, Switzerland)
Timothy Hnat (University of Virginia, USA)
Paul Holleis (University of Duisburg-Essen, Germany)
Elaine Huang (RWTH Aachen, Germany)
Xavier Huysmans (Isabel, Belgium)
Tatsuya Inaba (Keio University, Japan)
Lenka Ivantysynova (Humboldt-University Berlin, Germany)
Michael Jones (MERL, USA)
Oliver Kasten (SAP Research, Switzerland)
Hans Kastenholz (EMPA, Switzerland)
Dagmar Kern (University of Duisburg-Essen, Germany)
Matthias Lampe (ETH Zurich, Switzerland)
Carsten Magerkurth (SAP Research, Switzerland)
Bill Manning (USC/ISI, USA)
David Merrill (MIT Media Laboratory, USA)
Maximilian Michel (DoCoMo Euro-Labs, Germany)
Masateru Minami (Shibaura Institute of Technology, Japan)
Maxime Monod (EPFL, Switzerland)
Luciana Moreira Sà de Souza (SAP Research, Germany)
Steve Neely (University College Dublin, Ireland)
Britta Oertel (IZT, Germany)
Matthias Ringwald (ETH Zurich, Switzerland)
Christof Roduner (ETH Zurich, Switzerland)

Kay Roemer (ETH Zurich, Switzerland)
Enrico Rukzio (Lancaster University, UK)
Sajid Sadi (MIT Media Laboratory, USA)
Ross Shannon (University College Dublin, Ireland)
Paolo Simonazzi (University of Parma, Italy)
Timothy Sohn (University of California, San Diego, USA)
Tamim Sookoor (University of Virginia, USA)
Joao Pedro Sousa (George Mason University, USA)
Graeme Stevenson (University College Dublin, Ireland)
Martin Strohbach (NEC Europe Ltd., Germany)
Shigeya Suzuki (Keio University, Japan)
Thorsten Teichert (University Hamburg, Germany)
Toshimitsu Tsubaki (NTT Network Innovation Laboratories, Japan)
Keisuke Uehara (Keio University, Japan)
Rossano Vitulli (University of Parma, Italy)
Leonardo Weiss F. Chaves (SAP Research, Germany)
Raphael Wimmer (University of Munich, Germany)
Koji Yatani (University of Toronto, Canada)

Platinum Sponsor

SAP

Gold Sponsors

Metro Group
Siemens

Silver Sponsor

Google
Ambient Systems B.V.

Bronze Sponsors

European Research Consortium for Informatics and Mathematics (ERCIM)
IBM

Table of Contents

EPC Network

Middleware

Business Aspects

RFID Technology and Regulatory Issues

Applications

Sensing Systems