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Ivan Ganchev · R. D. van der Mei
Hans van den Berg (Eds.)


Autonomous Control for a Reliable Internet of Services

Methods, Models, Approaches, Techniques,
Algorithms, and Tools

 Springer Open

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IN SCIENCE & TECHNOLOGY

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ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-90414-6 ISBN 978-3-319-90415-3 (eBook)
<https://doi.org/10.1007/978-3-319-90415-3>

Library of Congress Control Number: 2018941550

LNCS Sublibrary: SL5 – Computer Communication Networks and Telecommunications

Acknowledgement and Disclaimer

The work published in this book is supported by the European Union under the EU Horizon 2020 Framework Program and especially the COST Action IC1304 “Autonomous Control for a Reliable Internet of Services (ACROSS).” The book reflects only the authors’ views. Neither the COST Association nor any person acting on its behalf is responsible for the use, which might be made of the information contained in this publication. The COST Association is not responsible for external Web sites referred to in this publication.

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Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

COST

This publication is based upon work from COST Action IC1304 “Autonomous Control for a Reliable Internet of Services (ACROSS)” supported by COST (European Cooperation in Science and Technology).

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Funded by the Horizon 2020 Framework Programme
of the European Union

Foreword



This book was prepared to play the role of a publication and dissemination platform of the technical aspects of the Final Report of the COST Action IC1304 “Autonomous Control for a Reliable Internet of Services (ACROSS)” that has run for four years, from Fall 2013 until Fall 2017. COST (European Cooperation in Science and Technology) is an EU funding agency for research and innovation networks that enables researchers to set up their interdisciplinary networks in Europe and beyond. In particular, the main goal of the COST Action ACROSS was to create a European network of experts, aiming at the development of monitoring and autonomous control methods for a reliable and quality-aware future Internet of Services (IoS). As usual for COST Actions, the collaboration within ACROSS proceeded on the basis of a Memorandum of Understanding (MoU) setting out its main objectives and technical scope.

The relevance of the IoS paradigm has been emphasized by the rapid developments regarding network softwarization (SDN, NFV, dew-, fog-, edge-, and cloud computing, etc.) in the course of the Action. This has raised many new research challenges and the need for the development of new methods to ensure the reliability of services offered via the IoS.

ACROSS has attracted many researchers. It has consistently grown over the years and has evolved into a powerful eco-system that consists of over 100 international experts from 31 European countries, where both academia and industry are well represented.

To support the realization of the Action’s main goals, we have organized semi-annual Management Committee (MC) meetings and co-located technical meetings, open international workshops on dedicated research topics within the Action’s scope, and international Summer Schools for training of PhD students and other early-stage researchers (ESR) in the field. In addition, ACROSS has also funded many so-called short-term scientific missions (STSM) to enable short international research visits.

This book contains chapters written by various groups of co-authors that cover a broad range of research challenges and topics addressed by them during the course

of the Action. We emphasize that the range of topics is based on the preferences and research interests of the members of these different groups.

The Action has been successful in establishing many new Pan-European research collaborations, and has boosted the career of a large number of participants. This book is the product of a fruitful informal collaboration, and we hope that it will be received in the same spirit that motivated its co-authors.

March 2018

Ivan Ganchev
R. D. van der Mei
Hans van den Berg

Preface

The explosive growth of the Internet has fundamentally changed global society. The emergence of concepts like service-oriented architecture (SOA), software as a service (SaaS), platform as a service (PaaS), infrastructure as a service (IaaS), network as a service (NaaS), and cloud computing in general has catalyzed the migration from the information-oriented Internet to an Internet of Services (IoS). This has opened up virtually unbounded possibilities for the creation of new and innovative services that facilitate business processes and improve the quality of life. However, this also calls for new approaches to ensure quality and reliability of these services. To overcome current shortcomings, a huge number of research challenges have to be addressed in this area, ranging from the initial conceptualization and modelling, to the elaboration of suitable approaches, techniques, and algorithms, and to the development of suitable tools and the elaboration of realistic use-case scenarios by also taking into account corresponding societal and economical aspects.

The objective of this book is, by applying a systematic approach, to assess the state of the art and consolidate the main research results achieved in this area. It was prepared as a final publication of the COST Action IC1304 “Autonomous Control for a Reliable Internet of Services (ACROSS).” The book contains 14 chapters and is a showcase of the main outcomes of the Action in line with its scientific goals. The book can serve as a valuable reference for undergraduate students, postgraduate students, educators, faculty members, researchers, engineers, and research strategists working in this field.

The book chapters were collected through an open, but selective, three-stage submission/review process. An open call for contributions was distributed among the COST ACROSS community in October 2016. In order to ensure a good book quality, reduce the overlap, and increase the level of synergy between different research groups working on similar problems, the leaders of the Task Forces, established within ACROSS, were asked to coordinate and consolidate the initial chapter proposals. As a result, a total of 17 extended abstracts were received in response to the call. These were reviewed by the book editors and their authors were invited to the next stage of full-chapter submission. At the end of this stage, 15 full-chapter proposals were received by the set deadline. All submitted chapters were peer-reviewed by independent reviewers (including reviewers outside the COST Action ACROSS), appointed by the book editors, and after the first round of reviews 14 chapters remained. These were duly revised according to the reviewers’ comments, suggestions, notes, etc. and finally were accepted for publication in this book.

The first chapter entitled “State of the Art and Research Challenges in the Area of Autonomous Control for a Reliable Internet of Services” serves as an introduction to this book. For this, it first analyzes the state of the art in the area of autonomous control for a reliable IoS and then identifies the main research challenges within it. A general background and high-level description of the current state of knowledge are presented.

Then, for each of the three subareas – autonomous management and real-time control, methods and tools for monitoring and service prediction, and smart pricing and competition in multi-domain systems – a brief general introduction and background are presented, and a list of key research challenges is formulated.

The second chapter, “Context Monitoring for Improved System Performance and QoE,” is focused on the potential of enhancing the quality of experience (QoE) management mechanisms by exploiting valuable context information. First, a general framework for context monitoring is discussed along with the context information, including technical, usage, social, economic, temporal, and physical factors. Then opportunities, challenges, and benefits of including context in the QoE monitoring and management are considered. The benefits are demonstrated through use cases involving video flash crowds, and online and cloud gaming. Finally, potential technical realizations of context-aware QoE monitoring and management, based on the software defined networking (SDN) paradigm, are discussed.

The concept of QoE management is also treated in the next chapter “QoE Management for Future Networks,” which provides an introduction to this concept by discussing its origins and key terms, and gives an overview of the most relevant existing theoretical frameworks. Promising technical approaches to QoE-driven management, provided across different layers of the networking stack, are also discussed along with an outlook on the future of the QoE management with a focus on the key enablers that are essential for ultimate transfiguration of the QoE-aware network and application management into reality.

Staying on the same note, the chapter “Scalable Traffic Quality and System Efficiency Indicators Towards Overall Telecommunication System’s QoE Management” delves into the conceptual and analytical models of overall telecommunication systems, and the definition of scalable indicators on each system level for QoS monitoring and prediction, and toward QoE management. Two network cost/quality integral criteria are proposed – mean and instantaneous – along with illustrative numerical predictions of the latter, which could be used for dynamic execution of pricing policies, depending on the network load.

The next chapter “Lag Compensation for First-Person Shooter Games in Cloud Gaming” continues by exploring the impact of latency, known as lag, on QoE for so-called first-person shooter cloud games. The authors, firstly, describe their approach for lag compensation, based on real-time equalization (within reason) of the uplink and downlink delays for all game players. Secondly, they describe the testbed (the open-source Gaming Anywhere platform), the use of the network time protocol (NTP) to synchronize time, the network emulator, and the role of the centralized log server. At the end the authors present results, validating their approach, along with small-scale and preliminary subjective tests for assessing its performance, and conclude the chapter by outlining ongoing and future work.

This is followed by the chapter entitled “The Value of Context-Awareness in Bandwidth-Challenging HTTP Adaptive Streaming Scenarios,” which analyzes an adaptive streaming technology, based on the hypertext transfer protocol (HTTP), which adapts the video reproduction to the current prevailing network conditions. Particularly, the authors study how context awareness can be combined with the adaptive streaming logic to design a proactive context-aware client-based video streaming strategy, showing promising results for successful mitigation of video stalling due to network

connectivity problems. The authors analyze the performance of this strategy by comparing it with the optimal case, as well as by considering situations where context awareness lacks reliability.

The next chapter, entitled “Conceptual and Analytical Models for Predicting the Quality of Service of Overall Telecommunication Systems,” presents scalable conceptual and analytical performance models of overall telecommunication systems, allowing the prediction of multiple quality of service (QoS) indicators as functions of the user and network behavior. The authors consider two conceptual model presentation structures along with an analytical method for conversion between them, and propose corresponding additive and multiplicative metrics for practical use. An analytical model, allowing the prediction of flow, time, and traffic characteristics of the overall network performance, is elaborated. Differentiated QoS indicators, as well as analytical expressions for their prediction, are proposed. The results demonstrate the ability of the proposed model to facilitate a more precise dynamic QoS management as well as to predict some QoE indicators.

The chapter “QoS-Based Elasticity for Service Chains in Distributed Edge Cloud Environments” is focused on elasticity as a dominant system engineering attribute for providing QoS-aware services to users by the emerging Internet of Things (IoT) and cloud-based networked systems relying heavily on virtualization technologies. Even though the concept of elasticity can introduce significant QoS and cost benefits, in distributed systems with several layers of abstraction, controlling the elasticity in a centralized manner could strongly penalize scalability. To address this problem, the authors propose an approach of splitting the system in autonomous subsystems, which implement elasticity mechanisms and run control policies in a decentralized manner, and coordinate elasticity decisions that collectively improve the overall system performance. The authors’ focus is on design choices that may affect the elasticity properties. For this, an overview of some decentralized design patterns, related to the coordination of elasticity decisions, is provided as well.

The next chapter “Integrating SDN and NFV with QoS-aware Service Composition” provides an overview of QoS-aware strategies that can be used at the network abstraction levels aiming to fully exploit the new network opportunities of full integration of heterogeneous hardware and software functions, configured at runtime, with a minimal time-to-market cycle, provided to end-users on a “as a service” basis. More specifically, the authors present three use cases of integrating SDN and network function virtualization (NFV) technologies with QoS-aware service composition, ranging from the energy-efficient placement of virtual network functions inside modern data centers, to the deployment of data stream processing applications using SDN to control the network paths, and to exploiting SDN for context-aware service compositions.

By stating that energy awareness and capability to deliver multimedia content with different possible combinations of quality and cost require complex optimization frameworks, the chapter “Energy vs. QoX Network- and Cloud Services Management” emphasizes that it is necessary to define more flexible paradigms by taking into account other design parameters, such as energy, and by considering these as tuneable variables playing a vital role in the adaptation mechanisms. The authors briefly introduce most commonly used frameworks for multi-criteria optimization and evaluate these under different “energy vs. quality of anything (QoX)” sample scenarios. Finally, the current

status of related network management tools is described in order to identify possible application areas.

The next chapter “Traffic Management for Cloud Federation” provides a survey on architectures for cloud federation and describes corresponding standardization activities, before proposing a comprehensive five-level model for traffic management for cloud federations, providing specific methods and algorithms at each level. The effectiveness of the proposed solutions is verified by using simulation and analytical methods. A specialized simulator for testing cloud-federation solutions within an IoT environment is described at the end of the chapter.

By arguing that most of the distributed systems simulators are either too detailed or not extensible enough to support the modelled IoT devices, and hence problematic to apply in the newly emerging IoT domain, the chapter “Efficient Simulation of IoT Cloud Use Cases” shows how generic IoT sensors could be modelled in a state-of-the-art simulator using a derived generalized IoT use case. A validation of the applicability of the introduced IoT extension with fitness and meteorological use cases completes the chapter.

Considering the IoT as one of the main building blocks of the future IoS, the next chapter “Security of Internet of Things for a Reliable Internet of Services” shifts the focus on the security of IoT, which could successfully contribute to achieving a highly reliable IoS by preventing, detecting, or mitigating autonomously attacks against it. The authors review the characteristics of IoT environments, cryptography-based security mechanisms and (distributed) denial of service (D/DoS) attacks targeting IoT networks. Moreover, they extensively analyze the intrusion detection and mitigation mechanisms proposed for IoT and evaluate these from various points of view. Open research issues for more reliable and available IoT and IoS are discussed at the end of the chapter.

The final chapter “TCP Performance over Current Cellular Access: A Comprehensive Analysis” moves from the area of services into the area of underlying communication protocols. More specifically, it treats unresolved questions and problems regarding the interaction between the transmission control protocol (TCP) and mobile broadband technologies such as the long-term evolution (LTE). To this end, the chapter collects the behavior of distinct TCP implementations (both loss-based and delay-based) under various network conditions in different LTE deployments and compares them in terms of the achieved throughput and utilization of radio resources.

The book editors wish to thank all reviewers for their excellent and rigorous reviewing work, as well as their responsiveness during the critical stages to consolidate the contributions provided by the authors. We are most grateful to all authors who have entrusted their excellent work, the fruits of many years’ research in each case, to us and for their patience and continued demanding revision work in response to reviewers’ feedback. We also thank them for adjusting their chapters to the specific book template and style requirements, completing all the bureaucratic but necessary paperwork, and meeting all the publishing deadlines.

March 2018

Ivan Ganchev
R. D. van der Mei
Hans van den Berg

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