Lecture Notes in Computer Science

12100

Founding Editors

Gerhard Goos

Karlsruhe Institute of Technology, Karlsruhe, Germany

Juris Hartmanis

Cornell University, Ithaca, NY, USA

Editorial Board Members

Elisa Bertino

Purdue University, West Lafayette, IN, USA

Wen Gao

Peking University, Beijing, China

Bernhard Steffen

TU Dortmund University, Dortmund, Germany

Gerhard Woeginger

RWTH Aachen, Aachen, Germany

Moti Yung

Columbia University, New York, NY, USA

More information about this series at http://www.springer.com/series/7410

Jintai Ding · Jean-Pierre Tillich (Eds.)

Post-Quantum Cryptography

11th International Conference, PQCrypto 2020 Paris, France, April 15–17, 2020 Proceedings



Editors
Jintai Ding D
University of Cincinnati
Cincinnati, OH, USA

Jean-Pierre Tillich D Inria Paris, France

ISSN 0302-9743 ISSN 1611-3349 (electronic) Lecture Notes in Computer Science ISBN 978-3-030-44222-4 ISBN 978-3-030-44223-1 (eBook) https://doi.org/10.1007/978-3-030-44223-1

LNCS Sublibrary: SL4 – Security and Cryptology

© Springer Nature Switzerland AG 2020

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.

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.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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

Preface

PQCrypto 2020, the 11th International Conference on Post-Quantum Cryptography, was held in Paris, France, during April 15–17, 2020. The aim of the POCrypto conference series is to serve as a forum for researchers to present results and exchange ideas on cryptography in an era with large-scale quantum computers. Following the same model as its predecessors, PQCrypto 2020 adopted a two-stage submission process in which authors registered their paper one week before the final submission deadline. The conference received 91 submissions with authors from 25 countries. Each paper (that had not been withdrawn by the authors) was reviewed in private by at least three Program Committee members. The private review phase was followed by an intensive discussion phase, conducted online. At the end of this process, the Program Committee selected 29 papers for inclusion in the technical program and publication in these proceedings. The accepted papers cover a broad spectrum of research within the conference's scope, including code-, hash-, isogeny-, and lattice-based cryptography, multivariate cryptography, and quantum cryptanalysis. Along with the 29 contributed technical presentations, the program featured outstanding invited talks and a presentation on NIST's post-quantum cryptography standardization. Organizing and running this year's edition of the PQCrypto conference series was a team effort and we are indebted to everyone who helped make PQCrypto 2020 a success. In particular, we would like thank all members of the Program Committee and the external reviewers who were vital in compiling the technical program. Evaluating and discussing the submissions was a labor-intensive task and we truly appreciate the work that went into this. In the name of the community, let us say that we are all indebted to Antoine Joux from Sorbonne University and Nicolas Sendrier from Inria for organizing this meeting.

February 2020 Jintai Ding
Jean-Pierre Tillich

Organization

General Chairs

Antoine Joux Sorbonne University, France

Nicolas Sendrier Inria, France

Program Chairs

Jintai Ding University of Cincinnati, USA

Jean-Pierre Tillich Inria, France

Steering Committee

Daniel J. Bernstein University Illinois at Chicago, USA, and Ruhr

University Bochum, Germany

Johannes Buchmann Technische Universität Darmstadt, Germany

Claude Crépeau McGill University, Canada Jintai Ding University of Cincinnati, USA Philippe Gaborit University of Limoges, France

Tanja Lange Technische Universiteit Eindhoven, The Netherlands

Daniele Micciancio University of California at San Diego, USA

Michele Mosca Waterloo University and Perimeter Institute, Canada

Nicolas Sendrier Inria, France

Tsuyoshi Takagi University of Tokyo, Japan Bo-Yin Yang Academia Sinica, Taiwan

Program Committee

Reza Azarderakhsh Florida Atlantic University and PQSecure

Technologies, USA

Jean-Philippe Aumasson Teserakt AG, Switzerland

Yoshinori Aono National Institute of Communication Technology,

Japan

Magali Bardet University of Rouen, France

Daniel J. Bernstein University Illinois at Chicago, USA, and Ruhr

University Bochum, Germany

Olivier Blazy University of Limoges, France

André Chailloux Inria, France

Chen-Mou Cheng Osaka University and Kanazawa University, Japan

Jung Hee Cheon Seoul National University, South Korea

Tung Chou Osaka University, Japan, and Academia Sinica, Taiwan

Dung Duong University of Wollongong, Australia

Organization

viii

Scott Fluhrer Cisco Systems, USA

Philippe Gaborit University of Limoges, France Tommaso Gagliardoni Kudelski Security, Switzerland

Steven Galbraith The University of Auckland, New Zealand Xiao-Shan Gao Chinese Academy of Sciences, China

Tim Güneysu Ruhr University Bochum and DFKI, Germany David Jao University of Waterloo and evolutionQ, Canada

Jiwu Jing Chinese Academy of Sciences, China

Thomas Johansson Lund University, Sweden Antoine Joux Sorbonne University, France

Kwangjo Kim KAIST, South Korea

Elena Kirshanova I. Kant Baltic Federal University, Russia Yi-Kai Liu NIST and University of Maryland, USA

Prabhat Mishra University of Florida, USA

Michele Mosca Waterloo University and Perimeter Institute, Canada

María Naya-Plasencia Inria, France

Khoa Nguyen Nanyang Technological University, Singapore

Ruben Niederhagen Fraunhofer SIT, Germany

Ray Perlner NIST, USA

Christophe Petit University of Birmingham, UK Rachel Player University of London, UK Thomas Pöppelmann Infineon Technologies, Germany

Thomas Prest PQShield, UK Nicolas Sendrier Inria, France

Junji Shikata Yokohama National University, Japan Daniel Smith-Tone NIST and University of Louisville, USA

Rainer Steinwandt Florida Atlantic University, USA

Damien Stehlé ENS de Lyon, France
Tsuyoshi Takagi University of Tokyo, Japan
Routo Terada University of São Paulo, Brasil

Serge Vaudenay EPFL, Switzerland

Keita Xagawa NTT Secure Platform Laboratories, Japan

Bo-Yin Yang Academia Sinica, Taiwan

Zhenfeng Zhang Institute of Software, Chinese Academy of Sciences,

China

Additional Reviewers

Nicolas AragonWouter CastryckBenjamin CurtisFlorian BacheMing-Shing ChenBernardo DavidSubhadeep BanikDing-Yuan ChengLuca De Feo

Khashayar Barooti Ilaria Chillotti Rafael Pablo Del Pino

Loic BidouxWonhee ChoAmit DeoNina BindelGwangbae ChoiHülya EvkanXavier BonnetainAlain CouvreurXiutao Feng

Tim Fritzmann Georg Land Hwajeong Seo Leon Groot Bruinderink Keewoo Lee Arnaud Sipasseuth Yongha Son Oian Guo Seungbeom Lee Yasufumi Hashimoto Matthieu Leauesne Junichi Tomida Minki Hhan Sarah McCarthy David Urbanik Seungwan Hong Romy Minko Valentin Vasseur James Howe Erik Mårtensson Javier Verbel Zhenyu Huang Alexander Nilsson Revnaldo Villena Loïs Huguenin-Dumittan Fernando Virdia Richard Petri Aaron Hutchinson Ben Pring Daniel Volva Yasuhiko Ikematsu Renato Renner Yacheng Wang Mitsugu Iwamoto Jan Richter-Brockmann Yuntao Wang Yohei Watanabe Saqib A. Kakvi Yolan Romailler Elif Bilge Kavun Julian Wälde Miruna Rosca Duhyeong Kim Haiyang Xue Rei Safavi-Naini Brian Koziel Masaya Yasuda Amin Sakzad Peter Kutas John Schanck Greg Zaverucha

Norman Lahr André Schrottenloher

Organization and Sponsors

The conference was organized by Inria and Sorbonne University, with the support of the ERC Almacrypt¹.

The organizers thank the following companies and institutions for their generous financial support:

Amazon Web Services, USA Cisco Systems, USA Infineon Technologies, Germany PQShield, UK Worldline, France

¹ European Union's H2020 Program under grant agreement number ERC-669891.

Contents

Code-Based Cryptography	
Randomized Decoding of Gabidulin Codes Beyond the Unique Decoding Radius	3
Julian Renner, Thomas Jerkovits, Hannes Bartz, Sven Puchinger, Pierre Loidreau, and Antonia Wachter-Zeh	
About Low DFR for QC-MDPC Decoding	20
QC-MDPC Decoders with Several Shades of Gray	35
Implementation	
Isochronous Gaussian Sampling: From Inception to Implementation: With Applications to the Falcon Signature Scheme James Howe, Thomas Prest, Thomas Ricosset, and Mélissa Rossi	53
Benchmarking Post-quantum Cryptography in TLS	72
Efficient Key Generation for Rainbow	92
Isogeny-Based Cryptography	
CSIDH on the Surface	111
LegRoast: Efficient Post-quantum Signatures from the Legendre PRF Ward Beullens and Cyprien Delpech de Saint Guilhem	130
The Supersingular Isogeny Problem in Genus 2 and Beyond	151
Sashimi: Cutting up CSI-FiSh Secret Keys to Produce an Actively Secure Distributed Signing Protocol Daniele Cozzo and Nigel P. Smart	169

Lattice-	Based	Crvi	otogra	aphy

Defeating NewHope with a Single Trace	189
Decryption Failure Is More Likely After Success	206
Compact Privacy Protocols from Post-quantum and Timed Classical Assumptions	226
Efficient Post-quantum SNARKs for RSIS and RLWE and Their Applications to Privacy	247
Short Zero-Knowledge Proof of Knowledge for Lattice-Based Commitment Yang Tao, Xi Wang, and Rui Zhang	268
COSAC: COmpact and Scalable Arbitrary-Centered Discrete Gaussian Sampling over Integers	284
Multivariate Cryptography	
Combinatorial Rank Attacks Against the Rectangular Simple Matrix Encryption Scheme	307
A Structural Attack on Block-Anti-Circulant UOV at SAC 2019	323
Generalization of Isomorphism of Polynomials with Two Secrets and Its Application to Public Key Encryption	340
Practical Cryptanalysis of k-ary C*	360
A Rank Attack Against Extension Field Cancellation	381
Multivariate Encryption Schemes Based on Polynomial Equations over Real Numbers	402

Quantum Algorithms	
Improved Quantum Circuits for Elliptic Curve Discrete Logarithms	425
The Power of Few Qubits and Collisions – Subset Sum Below Grover's Bound	445
On Quantum Distinguishers for Type-3 Generalized Feistel Network Based on Separability	461
Security Proofs	
Many a Mickle Makes a Muckle: A Framework for Provably Quantum-Secure Hybrid Key Exchange	483
A Note on the Instantiability of the Quantum Random Oracle	503
Collapseability of Tree Hashes	524
Encryption Schemes Using Random Oracles: From Classical to Post-Quantum Security	539

Contents

xiii

559