Bimal Roy (Ed.)

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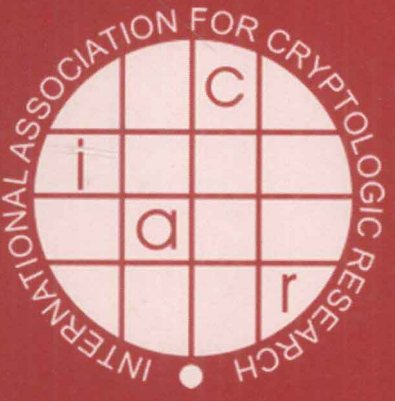

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Proceedings

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Preface

Asiacrypt, the annual conference of cryptology sponsored by IACR is now 11 years old. Asiacrypt 2005 was held during December 4–8, 2005, at Hotel Taj Coromandel, Chennai, India. This conference was organized by the International Association for Cryptologic Research (IACR) in cooperation with the Indian Institute of Technology (IIT), Chennai.

This year a total of 237 papers were submitted to Asiacrypt 2005. The submissions covered all areas of cryptographic research representing the current state of work in the crypto community worldwide. Each paper was blind reviewed by at least three members of the Program Committee and papers co-authored by the PC members were reviewed by at least six members. This first phase of review by the PC members was followed by a detailed discussion on the papers. At the end of the reviewing process 37 papers were accepted and were presented at the conference. The proceedings contain the revised versions of the accepted papers. In addition we were fortunate to have Prof. Andrew Yao and Prof. Bart Preneel as invited speakers.

Based on a discussion and subsequent voting among the PC members, the Best Paper Award for this year's Asiacrypt was conferred to Pascal Paillier and Damien Vergnaud for the paper entitled "Discrete-Log-Based Signatures May Not Be Equivalent to Discrete Log."

I would like to thank the following people. First, the General Chair, Prof. Pandu Rangan. Next, Springer for publishing the proceedings in the *Lecture Notes in Computer Science* series. I would also like to thank the submitting authors, the Program Committee members, the external reviewers, and the local Organizing Committee consisting of Mr. Veeraraghavan and Mr. E. Boopal. I acknowledge the partial financial support provided by Microsoft Research Labs, India. I thank Dr. Debrup Chakraborty for his help in managing the submissions and the final preparation of the proceedings. Thanks also goes to Mr. Sanjit Chatterjee for his assistance in the process.

December 2005 Bimal Roy

Asiacrypt 2005

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Discrete-Log-Based Signatures May Not Be Equivalent to Discrete Log

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Abstract. We provide evidence that the unforgeability of several discrete-log based signatures like Schnorr signatures cannot be equivalent to the discrete log problem in the standard model. This contradicts in nature well-known proofs standing in weakened proof methodologies, in particular proofs employing various formulations of the Forking Lemma in the random oracle Model. Our impossibility proofs apply to many discrete-log-based signatures like ElGamal signatures and their extensions, DSA, ECDSA and KCDSA as well as standard generalizations of these, and even RSA-based signatures like GQ. We stress that our work sheds more light on the provable (in)security of popular signature schemes but does not explicitly lead to actual attacks on these.

1 Introduction

It is striking to observe that after more that two decades of active research on the matter, the standard-model security of discrete-log based signatures like Schnorr, ElGamal or DSA remains mysteriously unknown. Although dedicated proof techniques do exist in weakened models (*e.g.* the random oracle model (ROM) [19,4,8] or the generic group model (GGM) [7]), none of them provides intuition about the actual security of discrete-log signatures. Even though they have withstood concerted cryptanalytic effort fairly well, we suspect that the real-life security of many of these signature schemes is actually weaker than expected. We provide evidence that most discrete-log-based signatures defined over some prime-order group $\mathbb{G}$ cannot be equivalent to extracting discrete logs over $\mathbb{G}$ in the standard model. Our results are partial in the sense that we disprove equivalence via *algebraic* reductions. In brief, algebraic reductions can only apply group operations on group elements. This restriction is not overly restrictive as we do not know any example of a cryptographic reduction which is not algebraic. Our results suggest that most discrete-log based signature schemes just cannot reach a maximal security level *i.e.* equivalence towards their primitive problem, or that if some of them do, it is through non-algebraic reductions exploiting intricate and subtle relations within the group $\mathbb{G}$.

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Most interestingly, our work highlights a possible separation between the standard model and the random oracle model in which it is well-known that forging Schnorr signatures (for instance) is equivalent to extracting discrete logs. An interpretation is that random-oracle-based proofs leave unfair advantage to security reductions by probing and modifying the adversary's internal computations and thereby letting the random oracle play a crucial role that cannot be justified in real life. Previous works have observed similar separations in specific contexts [2,18].

The Fiat-Shamir paradigm of transforming identification schemes into digital signature schemes [13] is popular because it yields efficient protocols. However all known results for the security of Fiat-Shamir-transformed signature schemes like Schnorr take place in the ROM[1]. Even worse, they impose the loss of a factor nearly q_H (the number of queries the forger makes to the random oracle) in either execution time or success probability of reductions that convert a forger into an algorithm that extracts discrete logarithms. While no proof exists that the loss of this factor is necessary, the problem seems inherent to the way signature schemes are constructed from identification protocols.

We prove in this paper that any random-oracle-based reduction from computing discrete logarithms to forging Schnorr signatures *must* lose a factor at least $\sqrt{q_H}$. This shows that a proof of equivalence in the ROM, if algebraic, *will never be tight*. We believe our work gives a new perspective as to why no efficient proof of equivalence to the discrete log problem has ever been found for Schnorr signatures despite considerable research efforts.

We emphasize that although our work disproves that Schnorr, ElGamal, DSA, GQ, etc. are maximally secure, no actual attack or weakness of either of these signature schemes arises from our impossibility results. Nothing stated here refutes that forging signatures is likely to be intractable in practice.

1.1 Our Contributions

Our results are manyfold. Introducing a simple way to simulate forgeries, we are able to relate security properties of many signature schemes (Schnorr, (Meta) ElGamal, DSA[2], ECDSA, KCDSA, GQ) to *one-more* computational problems, in a positive or *negative* sense. In the positive sense, we prove the unbreakability of these signatures (meaning that the signing key cannot be recovered) under chosen-message attacks, thereby identifying security properties that have remained unknown for these schemes.

Starting from the same simulation technique, we show that no algebraic reduction can exist that would relate the unforgeability (under any kind of attacks) of these signatures to their primitive problem. This result is extendable to the

[1] It is known that the Fiat-Shamir transform provides a separation between the ROM and the standard model, see [14].

[2] Note that this work constitutes the first proper security analysis of DSA and ECDSA in the standard model. Previous to this work the only known security result on DSA schemes was that of Brown on ECDSA which assumed a generic group [7].