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Contributions to secure and privacy-preserving use of electronic credentials

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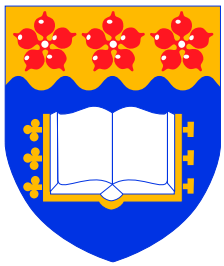

Contributions to Secure and Privacy-Preserving Use of Electronic Credentials

A thesis submitted in fulfilment of the
requirements for the award of the degree

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Siamak Fayyaz Shahandashti

School of Computer Science and Software Engineering
Faculty of Informatics
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Dedicated to

my wife: Sara
my mum: Behdokht
and my dad: Ali

Certification

I, Siamak Fayyaz Shahandashti, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Computer Science and Software Engineering, Faculty of Informatics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Siamak Fayyaz Shahandashti
October 5, 2009

Abstract

In this thesis, we make contributions to secure and privacy preserving use of electronic credentials in three different levels.

First, we address the case in credential systems where a credential owner wants to show her credential to a verifier without taking the risk that the ability to prove ownership of her credential is transferred to the verifier. We define *credential ownership proof* protocols for credentials signed by standard signature schemes. We also propose proper security definitions for the protocol, aiming to protect the security of both the credential issuer and the credential owner against concurrent attacks. We give two generic constructions of credential ownership proofs based on identity-based encryption and identity-based identification schemes. Furthermore, we show that signatures with credential ownership proofs are equivalent to identity-based identification schemes, in the sense that any secure construction of each implies a secure construction of the other. Moreover, we show that the GQ identification protocol yields an efficient credential ownership proof for credentials signed by the RSA signature scheme and prove the protocol concurrently-secure.

Then, we give a generic construction for universal (mutli) designated-verifier signature schemes from a large class of signature schemes, referred to as Class $\mathbb{C}$. The resulting schemes are efficient and have two important properties. Firstly, they are provably DV-unforgeable, non-transferable and also non-delegatable. Secondly, the signer and the designated verifier can independently choose their cryptographic settings. We also propose a generic construction for (hierarchical) identity-based signature schemes from any signature scheme in $\mathbb{C}$ and prove that the construction is secure against adaptive chosen message and identity attacks. We discuss possible extensions of our constructions to identity-based ring signatures and identity-based designated-verifier signatures from any signature in $\mathbb{C}$. Furthermore, we show that it is possible to combine the above constructions to obtain signatures with combined functionalities.

Finally, inspired by the recent developments in attribute-based encryption, we propose *threshold attribute-based signatures* (t-ABS). In a t-ABS, signers are associated with a set of attributes and verification of a signed document against a verification attribute set succeeds if the signer has a threshold number of (at least t) attributes in common with the verification attribute set. A t-ABS scheme enables a signature holder to prove possession of signatures by revealing only the relevant (to the verification attribute set) attributes of the signer, hence providing *signer-attribute privacy* for the signature holder. We define t-ABS schemes, formalize their security and propose two t-ABS schemes: a basic scheme secure against selective forgery and a second one secure against existential forgery, both provable in the standard model, assuming hardness of the computational Diffie-Hellman problem. We

show that our basic t-ABS scheme can be augmented with two extra protocols that are used for efficiently issuing and verifying t-ABS signatures on committed values. We call the augmented scheme a threshold attribute based c-signature scheme (t-ABCS). We show how a t-ABCS scheme can be used to realize a secure *threshold attribute-based anonymous credential system* (t-ABACS) providing signer-attribute privacy. We propose a security model for t-ABACS and give a concrete scheme using t-ABCS scheme. Using the simulation paradigm, we prove that the credential system is secure if the t-ABCS scheme is secure.

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Publications

The following publications have arised from the research carried out during the PhD candidature and hence the material in this thesis is largely based on them.

[SSB07] Siamak F Shahandashti, Reihaneh Safavi-Naini, and Joonsang Baek. Concurrently-Secure Credential Ownership Proofs. In Feng Bao and Steven Miller, editors, *ASI-ACCS '07*, pages 161–172. ACM, 2007.

[SS08] Siamak F Shahandashti and Reihaneh Safavi-Naini. Construction of Universal Designated-Verifier Signatures and Identity-Based Signatures from Standard Signatures. In Ronald Cramer, editor, *Public Key Cryptography (PKC '08)*, volume 4939 of *Lecture Notes in Computer Science*, pages 121–140. Springer, 2008.

[SS09b] Siamak F Shahandashti and Reihaneh Safavi-Naini. Threshold Attribute-Based Signatures and Their Application to Anonymous Credential Systems. In Bart Preneel, editor, *AfricaCrypt '09*, volume 5580 of *Lecture Notes in Computer Science*, pages 198–216. Springer, 2009.

[SS09a] Siamak F Shahandashti and Reihaneh Safavi-Naini. Generic Constructions for Universal Designated-Verifier Signatures and Identity-Based Signatures from Standard Signatures. *IET Information Security*, (to appear), 2009.

Free personal versions of the above publications are available via the World-Wide Web as follows:

[SSB06] Siamak F Shahandashti, Reihaneh Safavi-Naini, and Joonsang Baek. Concurrently-Secure Credential Ownership Proofs. Available through corresponding author's home page: `http://sites.google.com/site/siamax/`. Full version of [SSB07].

[SS07] Siamak F Shahandashti and Reihaneh Safavi-Naini. Construction of Universal Designated-Verifier Signatures and Identity-Based Signatures from Standard Signatures. Cryptology ePrint Archive, Report 2007/462, 2007. `http://eprint.iacr.org/2007/462`. Full version of [SS08].

[SS09c] Siamak F Shahandashti and Reihaneh Safavi-Naini. Threshold Attribute-Based Signatures and Their Application to Anonymous Credential Systems. Cryptology ePrint Archive, Report 2009/126, 2009. `http://eprint.iacr.org/2009/126`. Full version of [SS09b].

Notation

Xyz	algorithm Xyz
XYZ	security notion XYZ
$\mathcal{X}yz$	oracle $\mathcal{X}yz$
`Xyz`	string `Xyz`
ε	the empty string
$\mathbb{P}\mathrm{oly}\,(k)$	the set of all algorithms polynomial time in k
St_{X}	internal state information of algorithm X
$\|$	concatenation
$\setminus$	set subtraction
$\|x\|$	bit length of the quantity x
$\|S\|$	cardinality of the set S
$\varphi(\cdot)$	Euler's totient function
$x \leftarrow a$	value a is assigned to variable x
$x \xleftarrow{N} a$	value a mod N is assigned to variable x
$x \xleftarrow{\$} X$	a member is chosen randomly from set X and assigned to variable x
$x \leftarrow \mathsf{X}\,(a; r : \mathcal{O})$	algorithm X with access to oracle $\mathcal{O}$, input a, and random tape r is run and the output is assigned to variable x
$A \multimap(X)\mapsto B \mid C$	A sends X to B if condition C holds
$(s, t) \leftarrow [\mathsf{X}\,(x) \leftrightarrow \mathsf{Y}(y)]\,(a)$	interactive protocol between X with private input x and Y with private input y is run with public input a, X outputs s and Y outputs y
$\mathsf{Tr}\,[\mathsf{X}\,(x) \leftrightarrow \mathsf{Y}(y)]\,(a)$	transcript of a protocol run with public input a between X with private input x and Y with private input y
$\mathsf{ZK\text{-}PoK}\{x : a = g^x\}$	zero knowledge proof of knowledge of x such that $a = g^x$, where a and g are public inputs to the protocol
$\mathsf{X}\,(a)$ [desc.] Return x	algorithm X with input a and description [desc.] is run and x is returned as output

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