Reduction of Key Sizes on Rainbow-like Multivariate Signature Schemes

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INE410111 — Research Methodology in Computer Science

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Context

- Guarantee protection and privacy of messages sent digitally
- Security of digital signature schemes is based on problems from number theory
- There exist quantum algorithms [Sho97] that solve these problems efficiently
- Post-quantum cryptography aims to create cryptosystems based on problems immune to quantum speedups

Motivation

- Imminent threat from quantum computers
- Several active branches of post-quantum cryptography
  - Focus on cryptosystems that are based on the difficulty of solving systems of equations
- Standardization calls by institutions such as NIST and IRTF
- Development of quantum computers by corporations, such as Google and Intel

Multivariate cryptography

- Cryptography based on systems of multivariate quadratic equations over finite fields

decryption / signature generation

$$
\begin{tikzcd}
h \in \mathbb{F}^m \arrow[r, "\mathcal{S}^{-1}"] & x \in \mathbb{F}^m \arrow[r, "\mathcal{F}^{-1}"] & y \in \mathbb{F}^n \arrow[r, "\mathcal{T}^{-1}"] & z \in \mathbb{F}^n \arrow[lll, bend left, "\mathcal{P}"]
\end{tikzcd}
$$

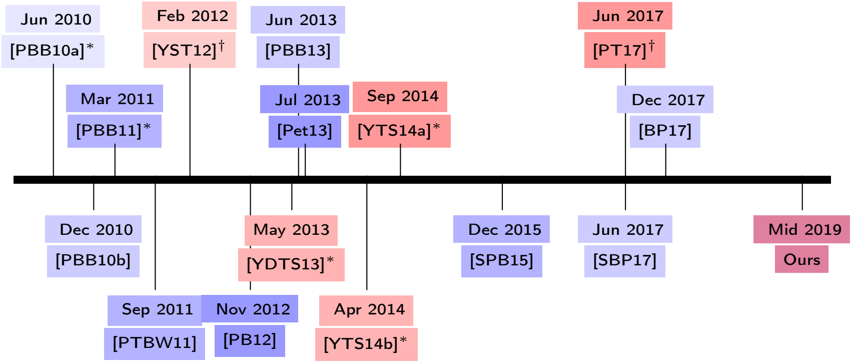
encryption / signature verification

- Fast operations, small signature sizes and large keys, compared to classical schemes

Underlying issue

- Focus on the Rainbow signature scheme, due to Ding and Schmidt [DS05], submitted to NIST for standardization
- Easy description, good balance between signature and key sizes
- Keys in the order of 10 KB, while classical schemes feature sub-1 KB
- Introduction of structures in the keys may lower security

Related works



Schemes in blue optimise public keys, while red ones reduce private keys. Darker tones mean greater success. Asterisks denote reparametrized works and crosses denote broken schemes.

Hypothesis

- To the best of our knowledge, works have reduced either private or public keys
- Do there exist any restrictions in doing both at the same time?
- Is it possible to generate a structured public key from a similarly composed private key?
- Introduction of matrix symmetries as possible arrangements may lower security

Objectives

- Establishment of fit matrix structures to be introduced
- Measurement of security achieved by keys created with those matrices
- Development of a method in which private and public keys are structurally related
- Description of a new signature scheme with carefully chosen parameters for devices with distinct requirements

Methodology

- Review schemes that reduce key sizes, cryptanalysis of these, and study matrix-like symmetric structures
- Create an algorithm to generate a compact private-public key pair
- Apply currently known cryptanalytic methods to test security of signatures created by these keys
- Compare performance and security with related works
- Publish and present results through papers, dissertation etc.

Expected results

- Identify the relationship between matrix types and their effect on security
- Deep analysis on how to maintain structure when generating a key pair
- Present a Rainbow-like signature scheme that features reduction of private and public key sizes
- International collaboration and scientific contributions

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