Lattice-based digital signature scheme: qTESLA

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Introduction

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- Based on decisional ring-LWE problem
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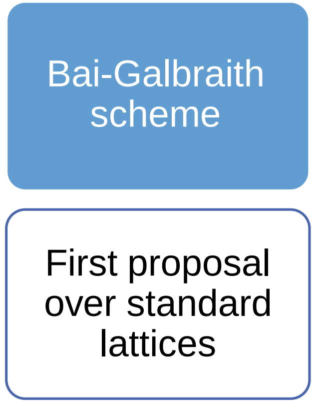

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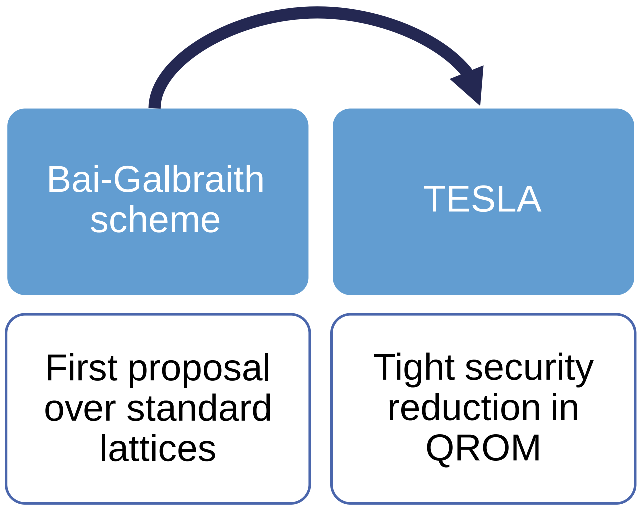

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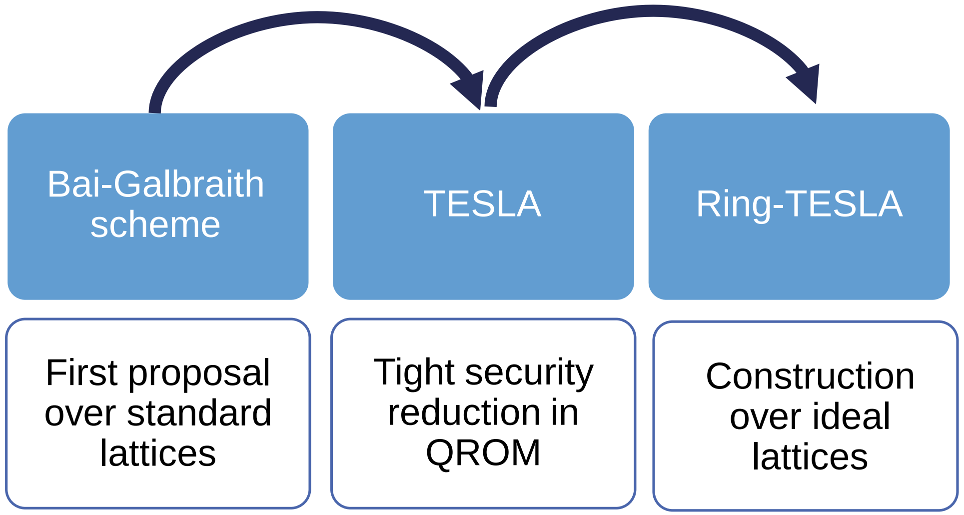

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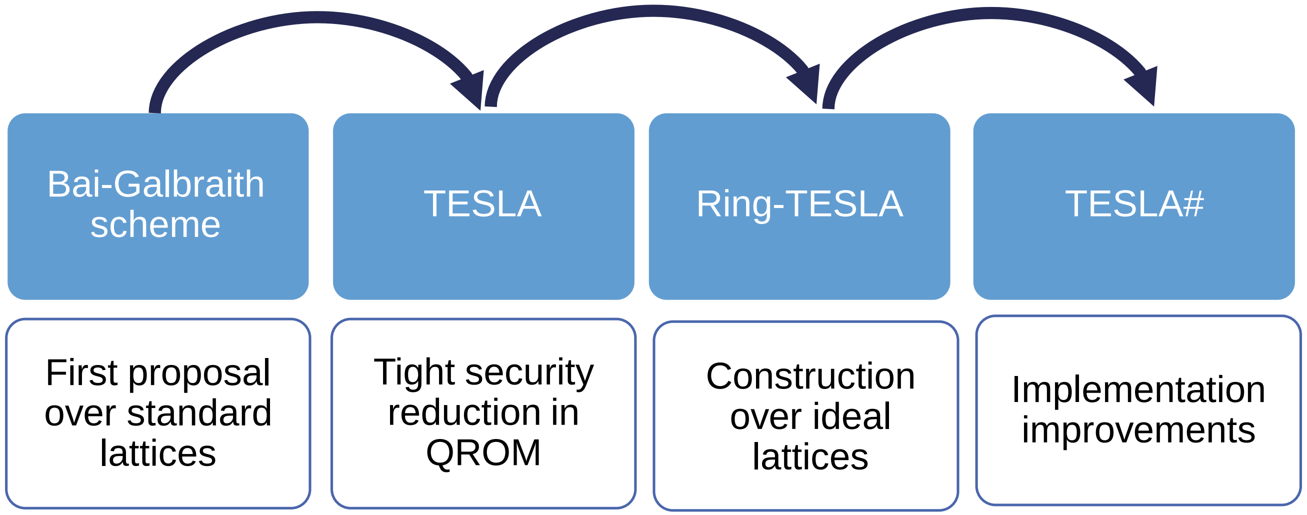

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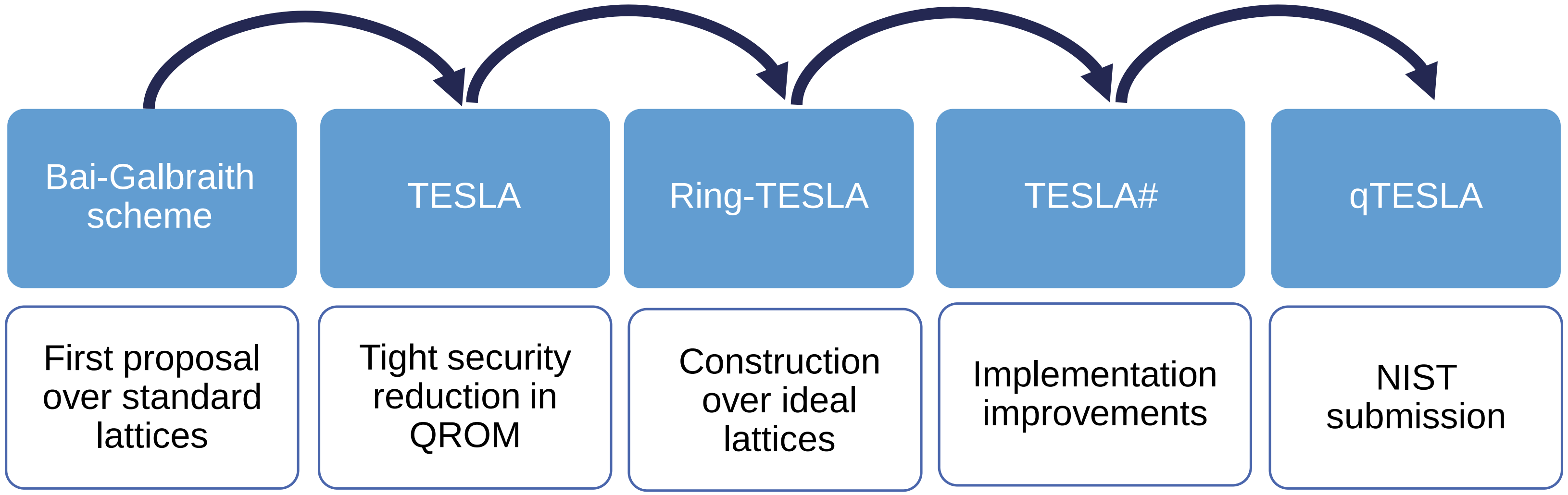

qTESLA – Key generation

- Secret key:
  - $s, e_1, \dots, e_k \overset{\sigma}{\leftarrow} \mathbb{Z}[x]/\langle x^n + 1\rangle$, “small enough”
  - $seed_a, seed_y$
- Public key:
  - $t_1 \leftarrow a_1 s + e_1 \bmod q, \dots, t_k \leftarrow a_k s + e_k \bmod q$ with $a_1, \dots, a_k \leftarrow GenA(seed_a)$
  - $seed_a$

qTESLA – Signing

Require: message m, and secret key $sk = (s, e_1, ..., e_k, \text{seed}_a, \text{seed}_y)$
Ensure: signature (c', z)

1: counter $\leftarrow 0$
2: rand $\leftarrow \text{PRF}_1(\text{seed}_y, m)$
3: $y \leftarrow \text{PRF}_2(\text{rand}, \text{counter})$
4: $a_1, ..., a_k \leftarrow \text{GenA}(\text{seed}_a)$
5: **for** $i = 1, ..., k$ **do**
6: $\quad v_i = a_i y \mod q$
7: **end for**
8: $c' \leftarrow H([v_1]_M, ..., [v_k]_M, m)$
9: $c \leftarrow \text{Enc}(c')$
10: $z \leftarrow y + sc$
11: **if** $z \notin \mathcal{R}_{q,[B-L_S]}$ **then**
12: $\quad$ counter++
13: $\quad$ Restart at step 3
14: **end if**
15: **for** $i = 1, ..., k$ **do**
16: $\quad w_i \leftarrow v_i - e_i c \mod q$
17: $\quad$ **if** $\|[w_i]_L\|_\infty > 2^d - L_E \vee \|w_i\|_\infty > \lfloor q/2 \rfloor - L_E$ **then**
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“correctness check“

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Advantages of qTESLA

- Flexible choice of parameters
  - 2 approaches to instantiate qTESLA
    - Heuristic
    - Provable-secure
- Ease of implementation
  - Structurally simple
  - Easy-to-implement underlying arithmetic
  - Gaussian sampling is not required for signing, only for key generation
- Security against implementation attacks
  - Cache-side-channel free for signature generation
  - Isochronous Gaussian sampling and arithmetic operations
  - Countermeasures against fault attacks (by-product of checking the candidate signature)

Parameter sets

- Two parameter sets
  - Provably-secure
    - Enabling tight security reduction from R-LWE in the quantum random oracle model
    - More conservative
  - Heuristic
    - Extrapolation of the concrete complexity of solving the underlying lattice problem, without targeting a tight formal security
    - Suitable for applications where performance or signature/key sizes are the main concern

Quick background story

- Initially, exclusively provably-secure parameters
  - Choose parameters guided by the security reduction

- A mistake was found by V. Lyubashevsky (thanks!)
  - Security reduction still holds
  - Bit security estimates unchanged
  - But “provable-security” property is lost for those parameters

Potential tweaks

- Tweak 1: include “provably-secure” parameters, as originally intended
- Tweak 2: fine-tune current “heuristic” parameters to get better performance

Preliminary results

Key and signature sizes (in bytes) – NIST security category 3

Parameter set	Approach	Public key	Secret key	Signature
qTESLA-128	Heuristic	2 976	1 856	2 720
qTESLA-p-128	Provable	19 872	7 744	3 104

Performance (in kilocycles) of the reference implementation on a 2.40 GHz Intel Core i5-6300U (Skylake) processor – NIST security category 3

Parameter set	Approach	keygen	sign	verify
qTESLA-128	Heuristic	2 234	1 279	229
qTESLA-p-128	Provable	4 334	2 420	732

Coming soon!

- Updated version of the specs document
- Optimized implementations for heuristic and provable-secure parameters

Thanks!

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qTESLA website:
https://tesla.informatik.tu-darmstadt.de/de/tesla

Nina says hi!