Status report — Slovakia

Secure implementation of post-quantum cryptography
SPS Project Number: 984520
2nd meeting

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Outline

McEliece calculator

- NTL based C++ implementation of MECS by M. Repka;
- Basic functions (KeyGen, Enc, Dec) + support for various measurements;
- Suitable for education and research.

Bitpunch: standalone McEliece implementation

Team project, SW adaptation of (Shoufan et.al, 2009).

What was achieved:

- Standalone McEliece implementation in C without external libraries;
- Parametric, modular, extensible;
- Suitable for research experiments.

Bitpunch: standalone McEliece implementation

What still needs more work:

- Better APIs, integration with other crypto libraries;
- "Schoolbook" implementation means slow speed;
- Unit-testing framework;
- Lightweight version for microprocessors;
- SCA countermeasures.

Comparison of MECS SW implementations

Tested implementations:

1. MECS Calculator by M. Repka
2. Bitpunch MECS by F. Uhrecky et.al.
3. Flea 0.1.1, HyMES adaptation by F. Strenzke, `www.cryptosource.de`
4. Java BouncyCastle McEliecePKCS class, `www.bouncycastle.org`

Testing platform:

CPU	Intel Core i5-2430M CPU @ 2.40GHz $\times$ 4
RAM	2 $\times$ 4GB DDR3 1333MHz
OS	Ubuntu 14.04.1 LTS, Linux 3.13.0-34-generic
GCC	4.8.2 (Ubuntu 4.8.2-19ubuntu1)

Comparison of MECS SW implementations

MECS parameters: $m = 11$, $t = 50$, $n = 2048$, $k = 1498$

	KeyGen [ms]	Enc [μs]	Dec [ms]	Library Size	
				Shared [kB]	Static [kB]
Calculator	1395	124	36.6	92 (+2MB)	116 (+4MB)
Bitpunch	866	62	3.9	64	96
Flea wo.H	46	34	0.6	160	232
Flea w. H	44	34	0.2		
BouncyCastle	1096	201	8.6	583 (whole BC 3MB)	

New results in Lee codes

- P. Horak, O. Grošek: A new approach towards the Golomb-Welch conjecture.
- A different view of Lee Codes using homomorphisms.
- New theoretical results:
  - the non-existence of linear $PL(n, 2)$ codes for $n \leq 12$;
  - the first quasi-perfect Lee codes for dimension $n = 3$;
  - for fixed n, there are only finitely many quasi-perfect Lee codes over Z.
- Application to MECS is an open question...

Construction of matrices with row and column weight $n/2$

- WIP: T. Fabšic, K. Nemoga, O. Grošek and P. Zajac
- How to efficiently construct non-singular matrices with row and column weight exactly $n/2$?
- How many of them do exist?
- At first, we restrict ourselves to circulant matrices...

Circulant matrices with row weight $n/2$

Lemma

Let $n = 0 \pmod 4$. Every circulant $(n \times n)$-matrix over $\mathbb{Z}_2$ with $\frac{n^2}{2}$ ones is non-invertible.

Are there other similar impossibility results?

Circulant matrices with row weight $n/2$, $n = 2 \pmod 4$

- Express circulant matrices as polynomials...
- Consider $c(x) = q(x) + b^2(x) + x^s b^2(x)$, where:
  - $q(x) = x^{n-2} + x^{n-4} + \cdots + x^2 + 1$.
  - $b(x) \in \mathbb{Z}_2[x]$, $\deg(b(x)) < n/2$
  - $\gcd(b(x), q(x)) = 1$
  - $s \in \mathbb{Z}_n$, $\gcd(s, n) = 1$
- The construction defines a set A of circulant invertible matrices with row weight $n/2$, $|A| = 2 \times \psi(x^{\frac{n}{2}} + 1) \times \phi(n)$

Connection to MECS

- Special class of scrambling matrices...
- Possible generalizations for use in construction and analysis of QC-codes, especially QC-MDPC codes

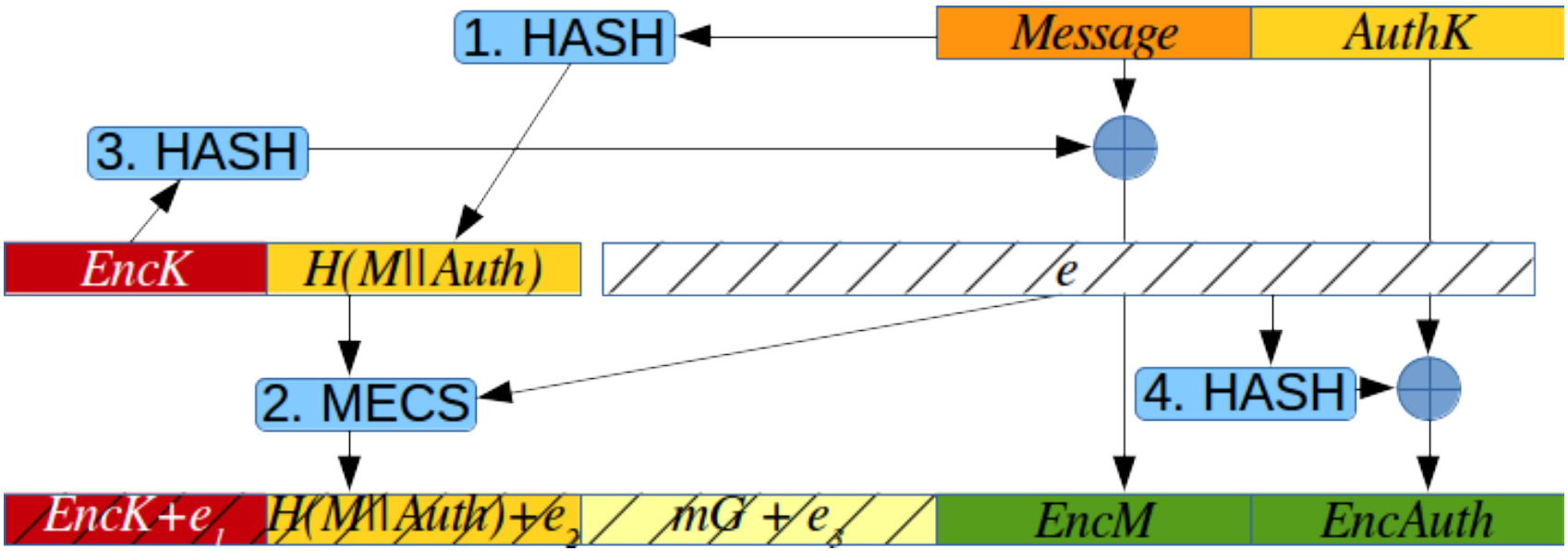
Overview of the MECS

- WIP: M.Repka and P. Zajac
- Goal: State of the art in secure implementation of MECS (from the engineering point-of-view)
- A lot of open questions...
- Standardisation required:
  - Parameters and security levels;
  - APIs for basic MECS, CCA2-conversions, and hybrid cryptosystems;
  - Support for code and algorithmic variants (e.g. resend API for MDPC codes? list decoding?);
  - ...

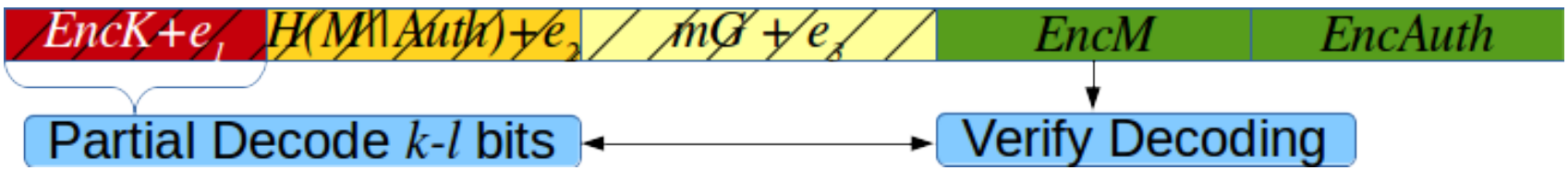
A flaw in some CCA2 conversions

- P. Zajac: A note on CCA2-protected McEliece cryptosystem with a systematic public key, `http://eprint.iacr.org/2014/651`
- An observation based on problem with implementing (Shoufan et.al, 2009): unspecified parameter *l* (hash length).
- Counterintuitive property: Longer hash leads to a less secure system.

Pointcheval variant with systematic matrix



Attack



"Brute forcing" *EncK*:

$$2^{H(t/n)(k-l)}$$

instead of expected 2^{k-l}.

Publicity and Training

"Best Practices in Cryptology and Information Security" Course
Bratislava, June 25 - 27, 2014

Summary

- Implementations: MECS Calculator, Bitpunch MECS;
- Research:
  - New theoretical results in Lee codes;
  - Study of cyclic matrices with row weight $n/2$;
  - Study of SW and security engineering aspects of MECS;
- Training: "Best Practices in Cryptology and Information Security".