Lyra2
Efficient Password Hashing with high security against Time-Memory Trade-Offs (TMTO)

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Agenda

1. Introduction
   - Motivation
   - Objectives
2. Lyra2
   - The Bootstrapping phase
   - The Setup phase
   - The Wandering phase
   - The Wrap-up phase
3. Comparison
   - Performance
   - Security
4. Conclusions
   - Stage of the research

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Motivation

User authentication is one of the most **vital elements** in modern computer security.

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KNOW	HAVE	ARE
		
Passwords ID Questions Secret Images	Token (Smart) Card Phone	Face Iris Hand/Finger

Motivation *(Cont.)*

A study from 2007 shows that real users have passwords with a really **low entropy**, on average (approximate 40.5 bits [FH07])

It allows some "brute-force attacks":

- Dictionary
- Exhaustive search
- Pre-calculated tables (Rainbow tables, hash tables, ...)

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- Dictionary
- Exhaustive search
- Pre-calculated tables (Rainbow tables, hash tables, ...)

How increase the cost of these attacks?

Using **Password Hashing Schemes** (PHS):

PBKDF2
bcrypt
scrypt
Lyra [our]

Objectives

Preserves the flexibility and efficiency of Lyra, including:

- **The ability to configure** the desired amount of memory, processing time and parallelism to be used by the algorithm *(flexibility)*
- The capacity of providing a **high memory usage** with a processing time similar to that obtained with scrypt *(efficiency)*

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Improvements *(on security)*

When compared to its predecessor, Lyra2 add:

- A higher security level against attack venues involving time-memory trade-offs (**TMTO**)
- Includes tweaks for increasing the costs involved on the **construction of dedicated hardware** to attack the algorithm
- **Balance** resistance against **side-channel** attacks and attacks relying on cheaper (and, hence, slower) **storage devices**
- Allows legitimate users to benefit more effectively from the **parallelism** capabilities of their own platforms

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Overview *(Cryptographic Sponge)*

- We constructed Lyra2 upon **Cryptographic Sponge**

Why?

Elegant, Flexibly, **Secure**

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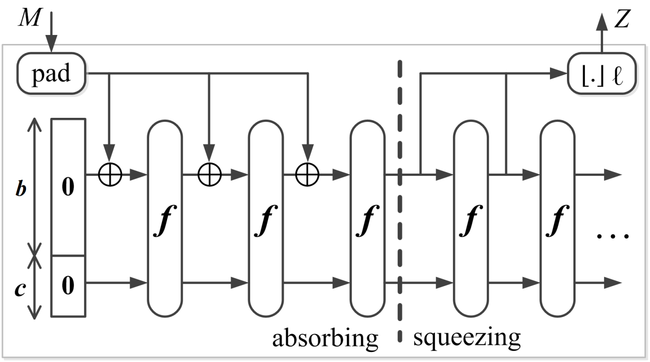

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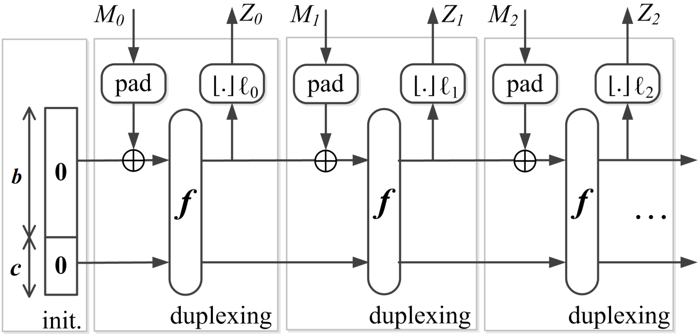

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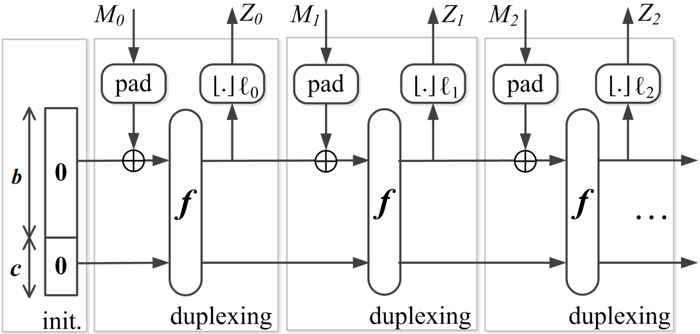

Instances

- Keccak (SHA-3), Quark, Photon, Spongent, Gluon ... [BDPA07]

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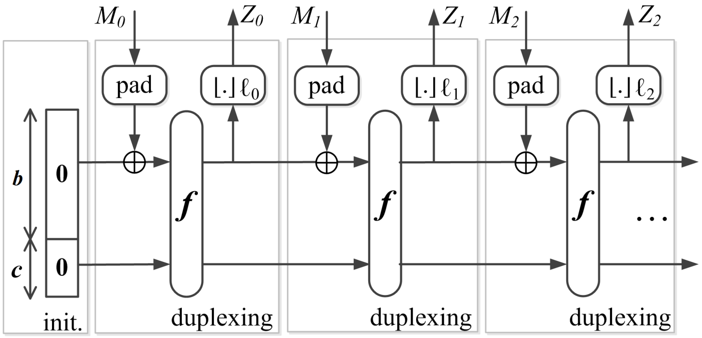

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PHC special recognition

"for its elegant sponge-based design" [PHC15]

Overview

- Based on four phases
  - **Bootstrapping**: Init. the sponge's state and local variables
  - **Setup**: Initializes a memory matrix
  - **Wandering**: Iteratively overwrites of the memory matrix
  - **Wrap-up**: Output computation

The Bootstrapping phase

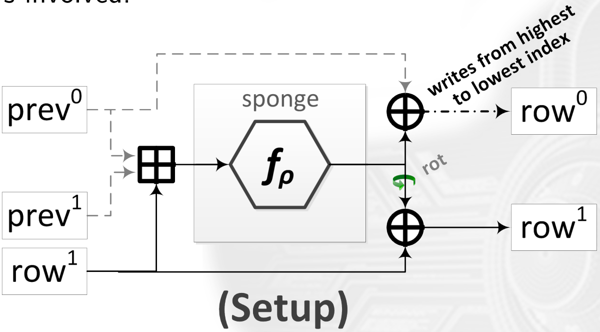
Initializes the sponge's state and local variables

- Absorb: *pwd*, *salt*, and *parameters*
- Initializes variables *(counters)*

The Setup phase

Initializes a memory matrix

- Deterministically *(i.e., protected against side-channel attacks)*
- Rows involved:



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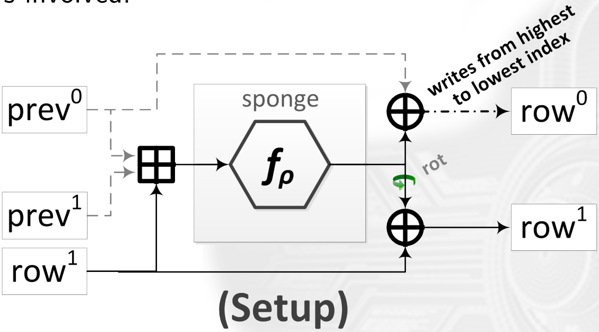
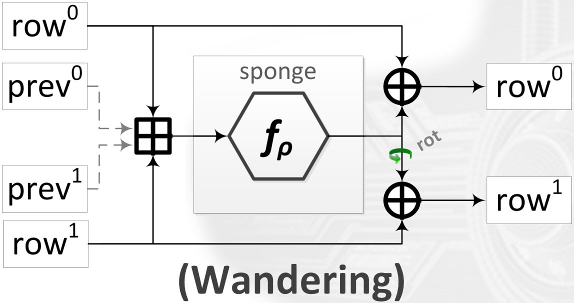


- Make **pipelining** harder, and increase the **latency in hardware**

The Wandering phase

Iteratively overwrites pseudorandom rows of the memory matrix

- Pseudorandomly *(increase TMTO)*
- Also the columns are picked pseudorandomly *(decrease performance: GPUs and platf. with small cache)*
- Rows involved:



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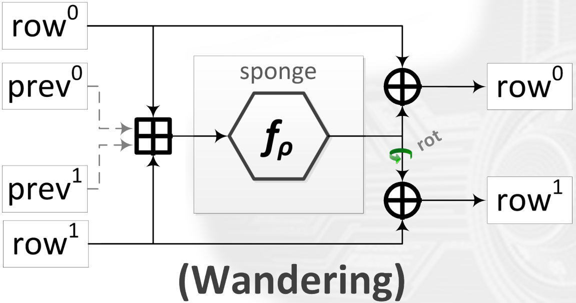

- Prioritise **legitimate platforms**, and increase the **cost of ded. hardware**

The Wrap-up phase

Output computation

- Provides *k*-long bitstring as output

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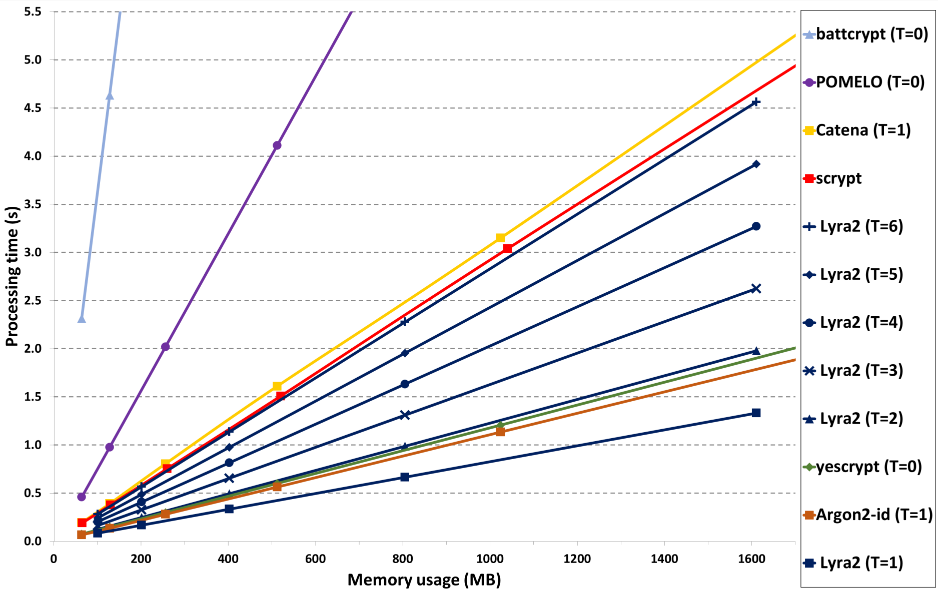
Performance



Slow-Memory and Cache-timing attacks

Slow-Memory

X

Cache-timing
(side-channel)

Slow-Memory and Cache-timing attacks

Slow-Memory

X

Cache-timing
(side-channel)

PHC special recognition

"alternative approach to side-channel resistance" [PHC15]

Low-Memory attack

- When the memory used by the attacker is **smaller than the half** amount of memory used during the legitimate process (i.e., $\frac{R}{2^{n+2}}$, where $n \geq 0$)
- The "dependence tree" grows significantly, resulting in the follow **complexity**:

$$\mathcal{O}(2^{2nT} R^{2+n/2}), \text{ for } n \gg 1$$

Propose with the **best TMTO** on PHC context!

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Stage of the research

- In our doctoral work we present a new PHS that **maintaining the efficiency and flexibility** of its predecessor, and **increases its security** in terms of:
  - TMTO
  - Costs involved on the construction of dedicated hardware
  - Balance between side-channel ans slow memory attacks
  - Possibility to explore parallelism on legitimate platforms

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Publications and other results

- PHC special recognition [PHC15]
- Vertcoin move from scrypt to Lyra2 [a4314, Day14]
- Sgminer add support to Lyra2 in its releases [Cry15]
- Publications:
  - Lyra was published at JCEN [AABS14]
  - Abstract of Lyra2 was presented at LatinCrypt'14 [AS14]
  - Lyra2 was published at IEEE trans. on Computers [ASBS16]

Thank you!

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