

Symmetric Techniques for Advanced Protocols: What *are* They?

Léo Perrin¹

Inria, Paris

14th of March 2025



Trendy topics

MPC-friendly?

Arithmetization-Oriented?

Verification efficiency?

Algebraic attacks?

Trendy topics

MPC-friendly?

Arithmetization-Oriented?

Verification efficiency?

Algebraic attacks?

Symmetric crypto **for the blockchain...**

Trendy topics

MPC-friendly?

Arithmetization-Oriented?

Verification efficiency?

Algebraic attacks?

Symmetric crypto **for the blockchain...**

... **for neural networks???**

The conclusion of today: **symmetric cryptography** has always had to deal with specific **implementation criteria**, but the **new ones** are indeed a bit **stranger than before**.

Outline

- 1 What is the Purpose of a Symmetric Primitive
- 2 “Advanced” Protocols
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

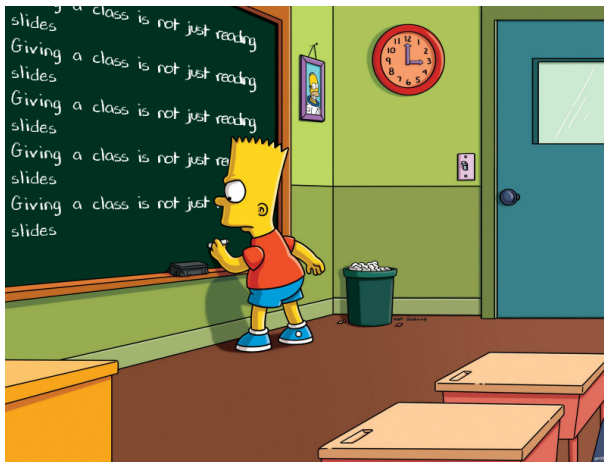
Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
 - Let's look at primitives we all know
 - A Small Cog in a Big Machine
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

Why do we need symmetric primitives?



Unstable Definitions

What is "efficient" varies

- What are the operations that we **can** use?
- What are the associated **costs**?

How to get the best security for a given price?

What is "secure" varies

- Should the primitive work in many context?
- Do we care about nonce-misuse?

How do we define the **security** that the primitive must provide?

Unstable Definitions

What is "efficient" varies

- What are the operations that we **can** use?
- What are the associated **costs**?

How to get the best security for a given price?

What is "secure" varies

- Should the primitive work in many context?
- Do we care about nonce-misuse?

How do we define the **security** that the primitive must provide?

What are the relevant forms of cryptanalysis?

Unstable Definitions

What is "efficient" varies

- What are the operations that we **can** use?
- What are the associated **costs**?

How to get the best security for a given price?

What is "secure" varies

- Should the primitive work in many context?
- Do we care about nonce-misuse?

How do we define the **security** that the primitive must provide?

What are the relevant forms of cryptanalysis?

Unstable Definitions

What is "efficient" varies

- What are the operations that we **can** use?
- What are the associated **costs**?

How to get the best security for a given price?

What is "secure" varies

- Should the primitive work in many context? Modularity vs. Single use
- Do we care about nonce-misuse? Robustness vs. "not our problem"

How do we define the **security** that the primitive must provide?

What are the relevant forms of cryptanalysis?

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
 - Let's look at primitives we all know
 - A Small Cog in a Big Machine
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

Web Encryption

Application

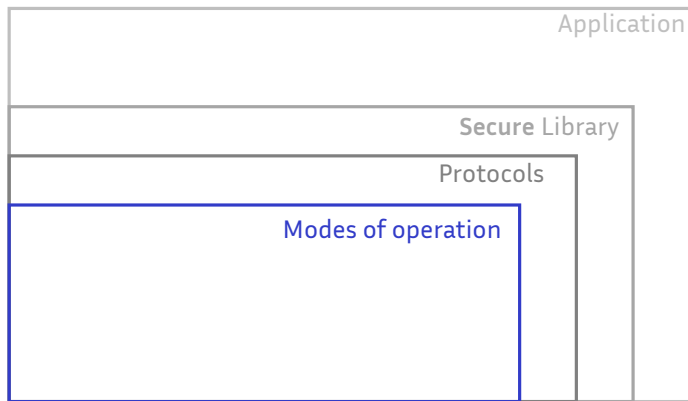
Web Encryption



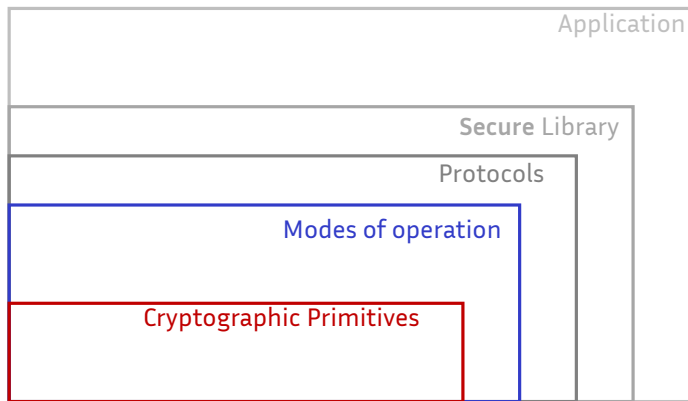
Web Encryption



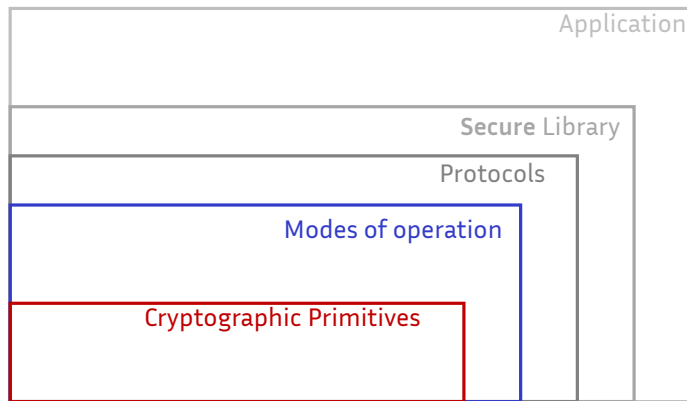
Web Encryption



Web Encryption

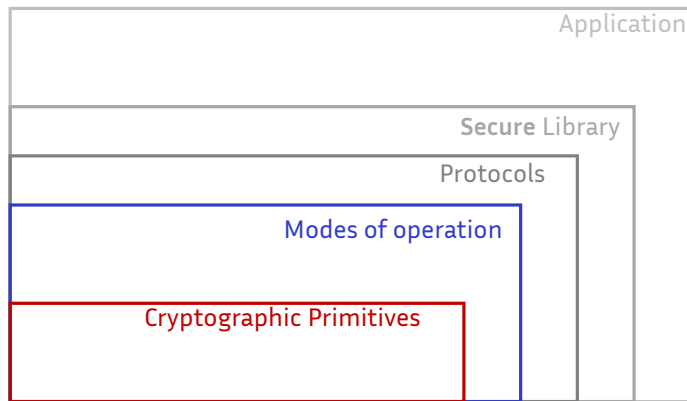


Web Encryption



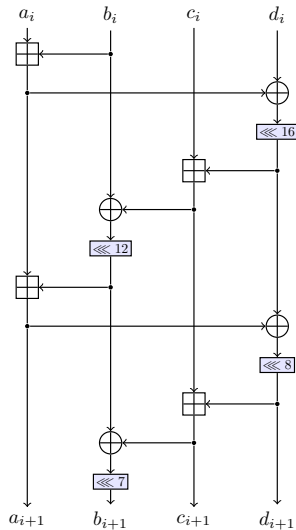
- We want **software efficient** (computer and smartphone but not micro-controllers) efficient **AEAD** for packets of a few tens to a few billion bytes.

Web Encryption



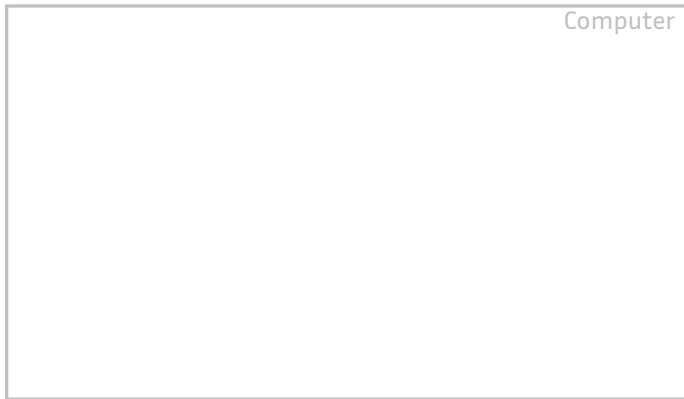
- We want **software efficient** (computer and smartphone but not micro-controllers) efficient **AEAD** for packets of a few tens to a few billion bytes.
- AES-GCM; Chacha-poly1305.

What Chacha looks like



- Addition / Rotation / XOR
- 256-bit key
- 512-bit state
- Defined over 32-bit words

RAM Encryption



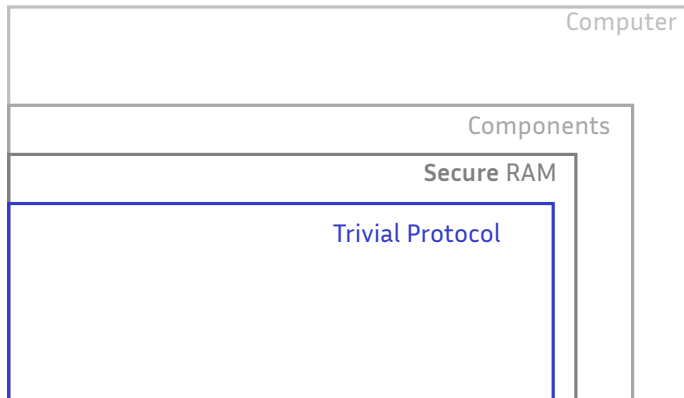
RAM Encryption



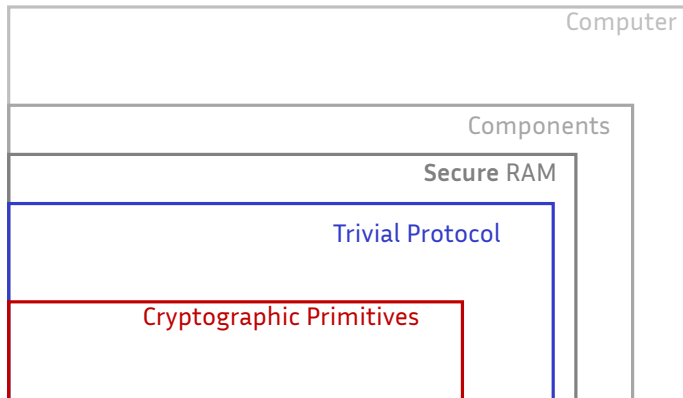
RAM Encryption



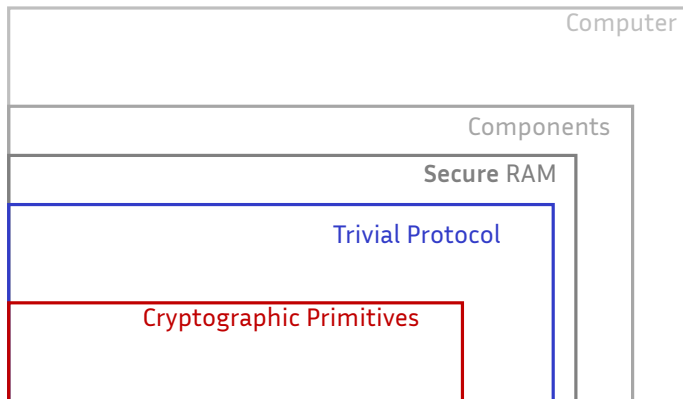
RAM Encryption



RAM Encryption

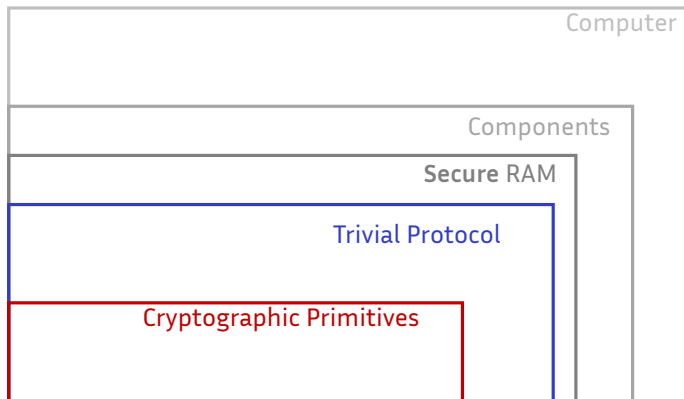


RAM Encryption



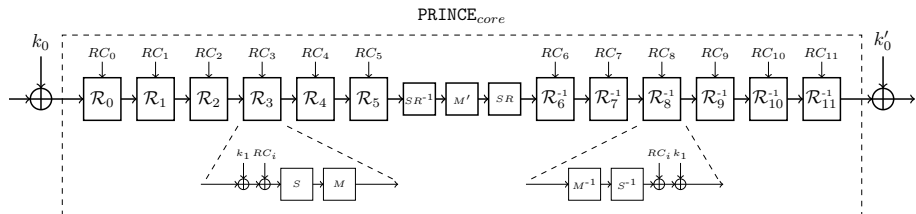
- We want **very low latency block encryption** for specific (and small) block sizes.

RAM Encryption



- We want **very low latency block encryption** for specific (and small) block sizes.
- PRINCE? QARMA? not so clear at this stage.

What PRINCE looks like



- 4-bit S-box optimized for hardware
- 2 different matrices
- FX construction
- "α-reflexion"
- inverse rounds used in the second half

Some Constants

- A symmetric primitive is a very **small** (but crucial) cog in a very big machine,

Some Constants

- A symmetric primitive is a very **small** (but crucial) cog in a very big machine,
- there are many **different** "big machines", and

Some Constants

- A symmetric primitive is a very **small** (but crucial) cog in a very big machine,
- there are many **different** "big machines", and
- this has a **huge influence** on what the primitive looks like.

Plan of this Section

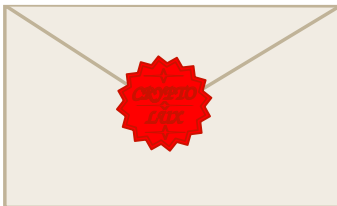
- 1 What is the Purpose of a Symmetric Primitive
- 2 “Advanced” Protocols**
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
 - General Introduction
 - Different Protocols for Different Goals
 - One Approach to Rule Them All (?): Arithmetization
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

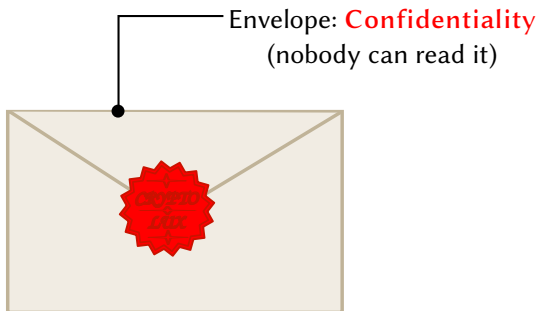
Securing Data

Usually, we secure **data** (at rest or in transit).



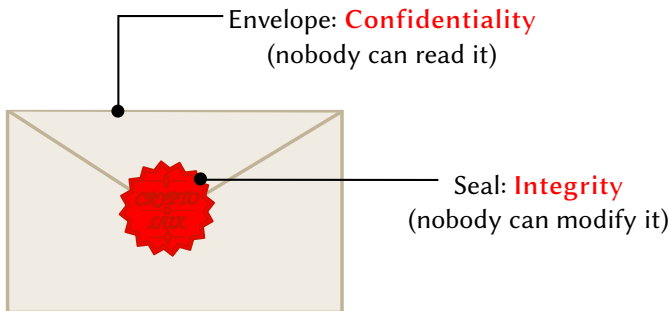
Securing Data

Usually, we secure **data** (at rest or in transit).



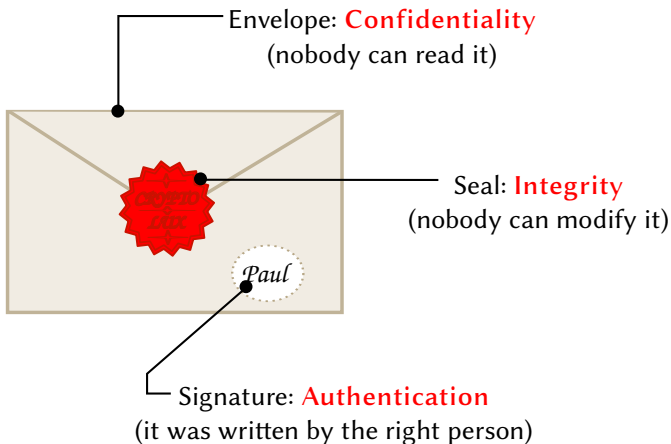
Securing Data

Usually, we secure **data** (at rest or in transit).



Securing Data

Usually, we secure **data** (at rest or in transit).



Securing Computation

More and more protocols intend to secure **computations**.

FHE Fully Homomorphic Encryption

MPC Multi Party Computations

ZK-* Zero Knowledge- [proof, argument...]

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
 - General Introduction
 - Different Protocols for Different Goals
 - One Approach to Rule Them All (?): Arithmetization
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

FHE

Goal

Allow a third party to perform some operations on encrypted ciphertext that correspond to meaningful operations on the corresponding plaintext.

FHE

Goal

Allow a third party to perform some operations on encrypted ciphertext that correspond to meaningful operations on the corresponding plaintext.

A form of commutation

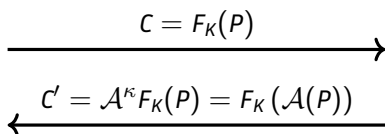
FHE

Goal

Allow a third party to perform some operations on encrypted ciphertext that correspond to meaningful operations on the corresponding plaintext. **A form of commutation**

Alice

Bob



F_K is a homomorphic cipher,
not a block cipher!

FHE

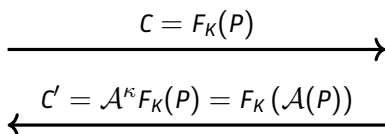
Goal

Allow a third party to perform some operations on encrypted ciphertext that correspond to meaningful operations on the corresponding plaintext.

A form of commutation

Alice

Bob



F_K is a homomorphic cipher,
not a block cipher!

An example of (not F)HE

XOR-ing a constant to a ciphertext obtained using a stream cipher XORs the same constant in the plaintext:

$$C \oplus t = (P \oplus K) \oplus t = (P \oplus t) \oplus K$$

Multi-Party Computations

Goal

Allow multiple parties to evaluate a function together even if some parties are not trustworthy.

Multi-Party Computations

Goal

Allow multiple parties to evaluate a function together even if some parties are not trustworthy.

Example

Shamir's secret sharing

Multi-Party Computations

Goal

Allow multiple parties to evaluate a function together even if some parties are not trustworthy.

Example

Shamir's secret sharing

Applications

- Masking (the side-channel attack counter-measure)
- MPC-in-the-head paradigm (e.g. for Picnic signatures)
- ...

Zero-Knowledge

Principle

I want to convince you I know a secret **without revealing it**

Zero-Knowledge

Principle

I want to convince you I know a secret **without revealing it**

A generic goal

To be able to prove/argue that a function was evaluated correctly without revealing its input.

Zero-Knowledge

Principle

I want to convince you I know a secret **without revealing it**

A generic goal

To be able to prove/argue that a function was evaluated correctly without revealing its input.
Ex: Sudoku time!

Zero-Knowledge

Principle

I want to convince you I know a secret **without revealing it**

A generic goal

To be able to prove/argue that a function was evaluated correctly without revealing its input.
Ex: Sudoku time!

Applications

- Offload computation to untrusted 3rd parties
- Electronic vote (mixnets)
- Signatures (e.g. with Solid)

Zero-Knowledge

Principle

I want to convince you I know a secret **without revealing it**

A generic goal

To be able to prove/argue that a function was evaluated correctly without revealing its input.
Ex: Sudoku time!

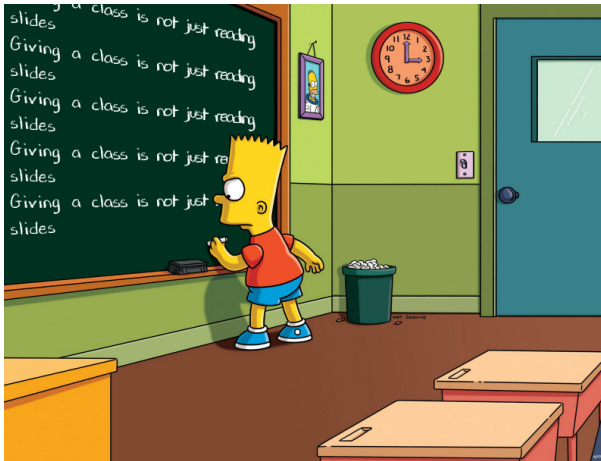
Applications

- Offload computation to untrusted 3rd parties
- Electronic vote (mixnets)
- Signatures (e.g. with Solid)
- BLOCKCHAIN!!!

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
 - General Introduction
 - Different Protocols for Different Goals
 - One Approach to Rule Them All (?): Arithmetization
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion

Arithmetization: General Principle



A Basic Example of Arithmetization

"Arithmetization" depends on the subtleties of the **protocol** you work with!

A Basic Example of Arithmetization

"Arithmetization" depends on the subtleties of the **protocol** you work with!

Verifying if $y = c(ax + b)^{10} + x$ in R1CS

$$1 \quad t_0 = ax$$

$$2 \quad t_1 = t_0 + b$$

$$3 \quad t_2 = t_1 \times t_1$$

$$4 \quad t_3 = t_2 \times t_2$$

$$5 \quad t_4 = t_3 \times t_3$$

$$6 \quad t_5 = t_2 \times t_4$$

$$7 \quad t_6 = ct_5$$

$$8 \quad y = t_6 + x$$

A Basic Example of Arithmetization

"Arithmetization" depends on the subtleties of the **protocol** you work with!

Verifying if $y = c(ax + b)^{10} + x$ in R1CS

$$1 \quad t_0 = ax$$

$$2 \quad t_1 = t_0 + b$$

$$3 \quad t_2 = t_1 \times t_1$$

$$4 \quad t_3 = t_2 \times t_2$$

$$5 \quad t_4 = t_3 \times t_3$$

$$6 \quad t_5 = t_2 \times t_4$$

$$7 \quad t_6 = ct_5$$

$$8 \quad y = t_6 + x$$

A Basic Example of Arithmetization

"Arithmetization" depends on the subtleties of the **protocol** you work with!

Verifying if $y = c(ax + b)^{10} + x$ in R1CS

$$1 \quad t_0 = ax$$

$$2 \quad t_1 = t_0 + b$$

$$3 \quad t_2 = t_1 \times t_1$$

$$4 \quad t_3 = t_2 \times t_2$$

$$5 \quad t_4 = t_3 \times t_3$$

$$6 \quad t_5 = t_2 \times t_4$$

$$7 \quad t_6 = ct_5$$

$$8 \quad y = t_6 + x$$

This verification costs **R1CS 4 constraints**

A Basic Example of Arithmetization

"Arithmetization" depends on the subtleties of the **protocol** you work with!

Verifying if $y = c(ax + b)^{10} + x$ in R1CS

$$1 \quad t_0 = ax$$

$$2 \quad t_1 = t_0 + b$$

$$3 \quad t_2 = t_1 \times t_1$$

$$4 \quad t_3 = t_2 \times t_2$$

$$5 \quad t_4 = t_3 \times t_3$$

$$6 \quad t_5 = t_2 \times t_4$$

$$7 \quad t_6 = ct_5$$

$$8 \quad y = t_6 + x$$

This verification costs **R1CS 4 constraints**

- How to turn a computation into an arithmetic circuit depends on the operations allowed
- Its cost is also arithmetization-dependent—**though low degree is usually welcome!**

A not basic at all example of arithmetization

The cost of each operation depends on the arithmetization!

Plonk \neq R1CS

A not basic at all example of arithmetization

The cost of each operation depends on the arithmetization!

Plonk \neq R1CS

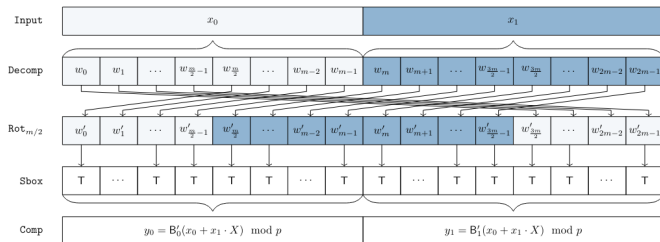
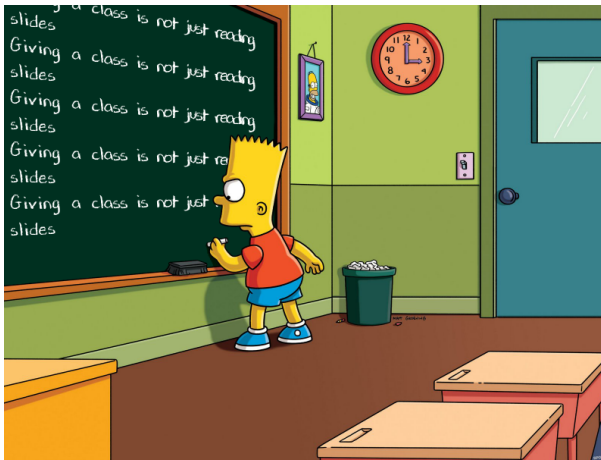


Figure 3: The Bar layer $B' : \mathbb{F}_{p^n} \rightarrow \mathbb{F}_{p^n}$ for $n = 2$ in detail, including the decomposition, the rotation, the S-box, and the composition.

source: *Skyscraper: Fast Hashing on Big Primes*,
<https://eprint.iacr.org/2025/058.pdf>

"Arithmetization-Oriented"? Evaluation vs. Verification

(the term was coined in [AAB⁺20])



Symmetric Techniques for Advanced Protocols

MPC

FHE

ZK

Symmetric Techniques for Advanced Protocols

MPC

FHE

ZK

Masking

BGV

R1CS

MPC-in-the-head
(signatures...)

FV

AIR
...

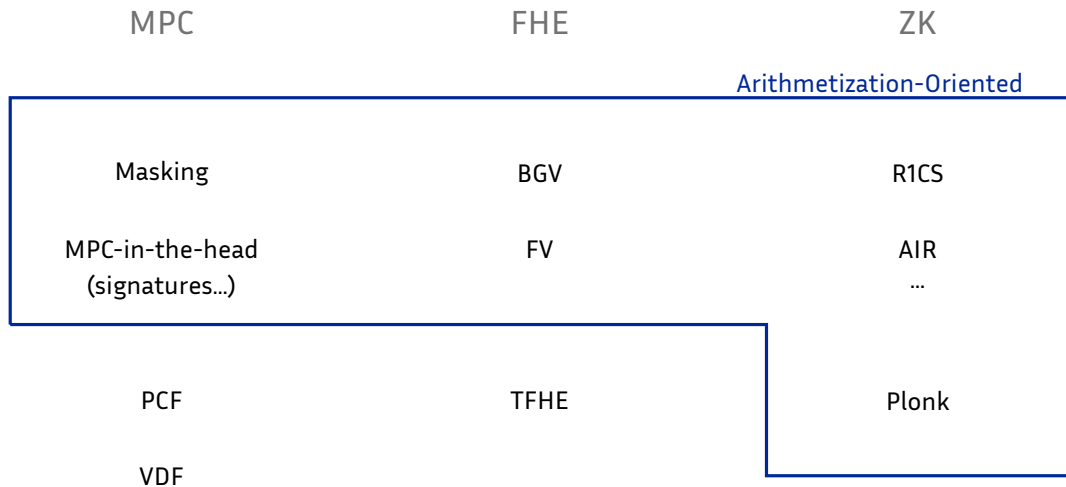
PCF

TFHE

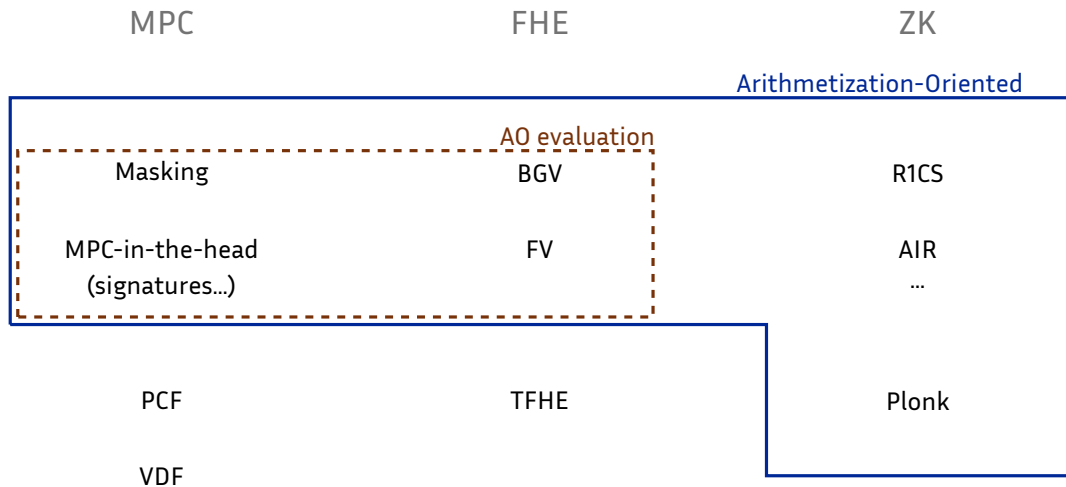
Plonk

VDF

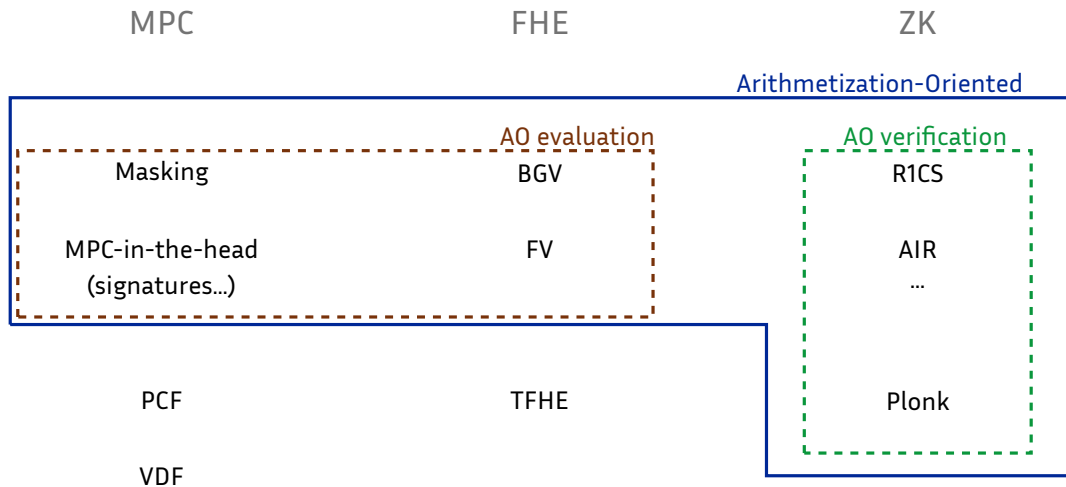
Symmetric Techniques for Advanced Protocols



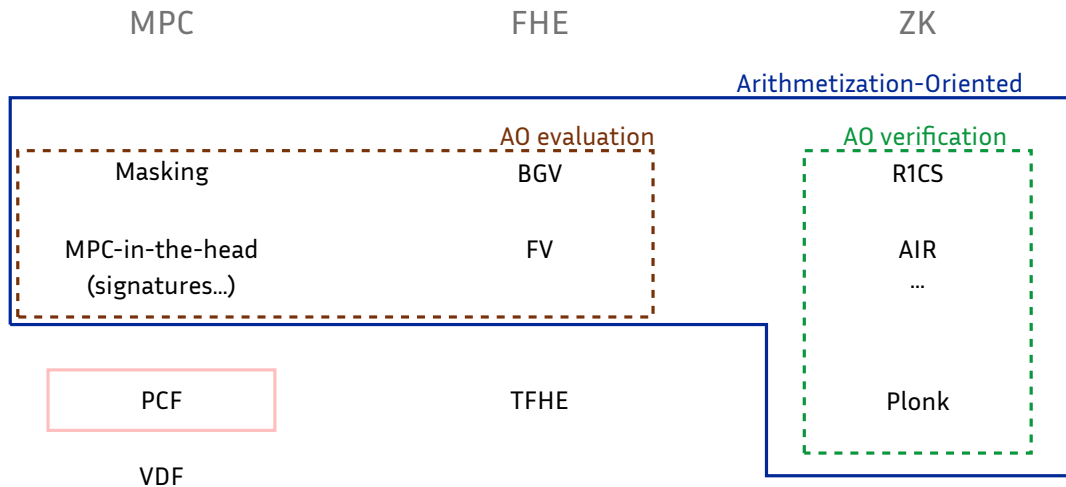
Symmetric Techniques for Advanced Protocols



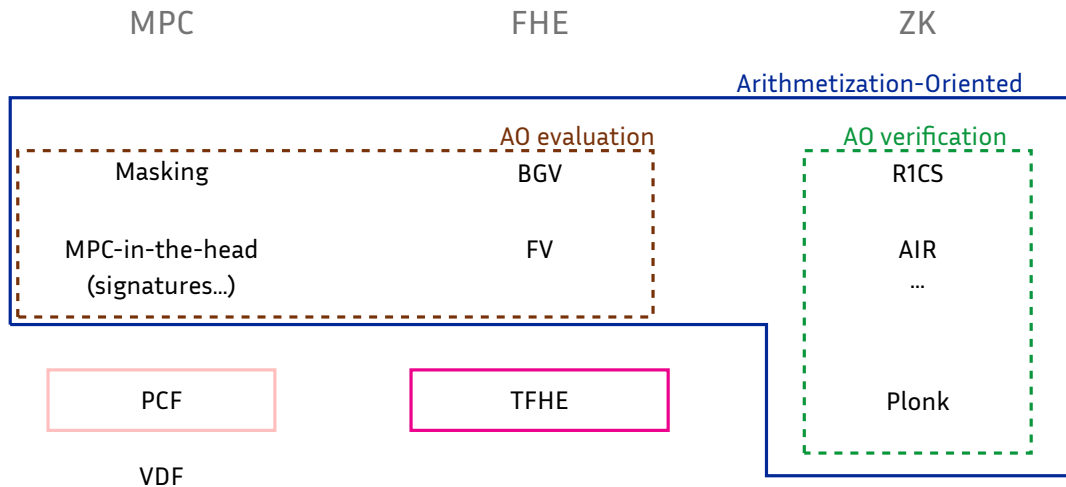
Symmetric Techniques for Advanced Protocols



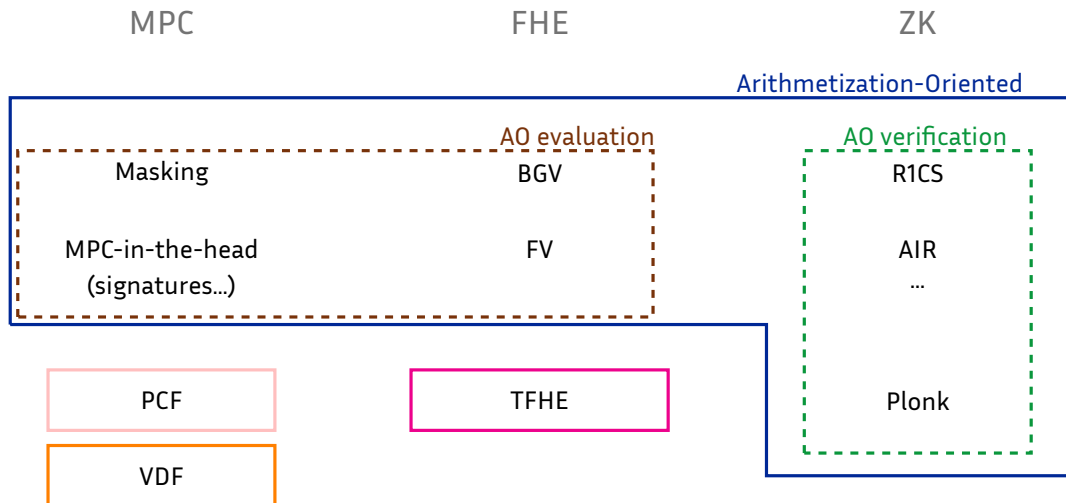
Symmetric Techniques for Advanced Protocols



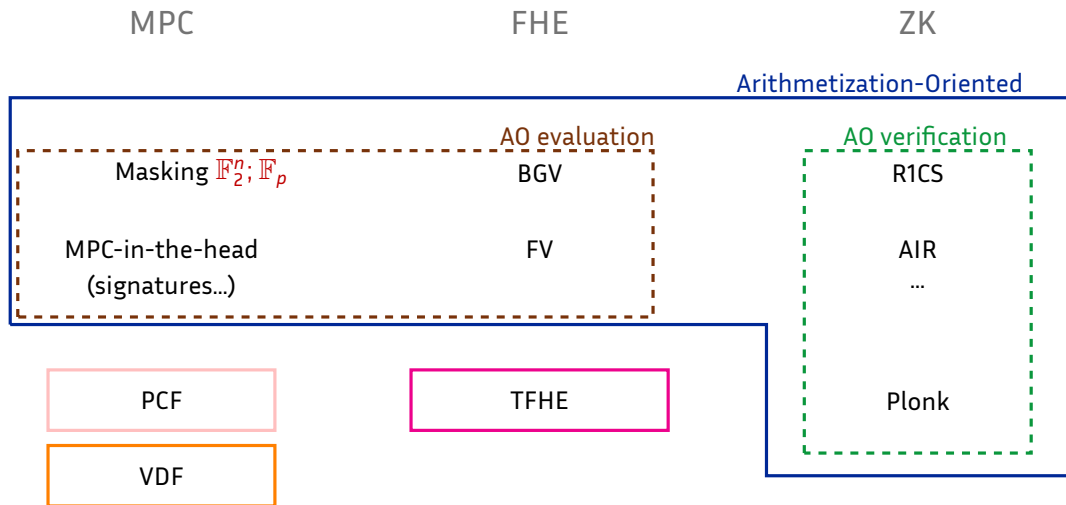
Symmetric Techniques for Advanced Protocols



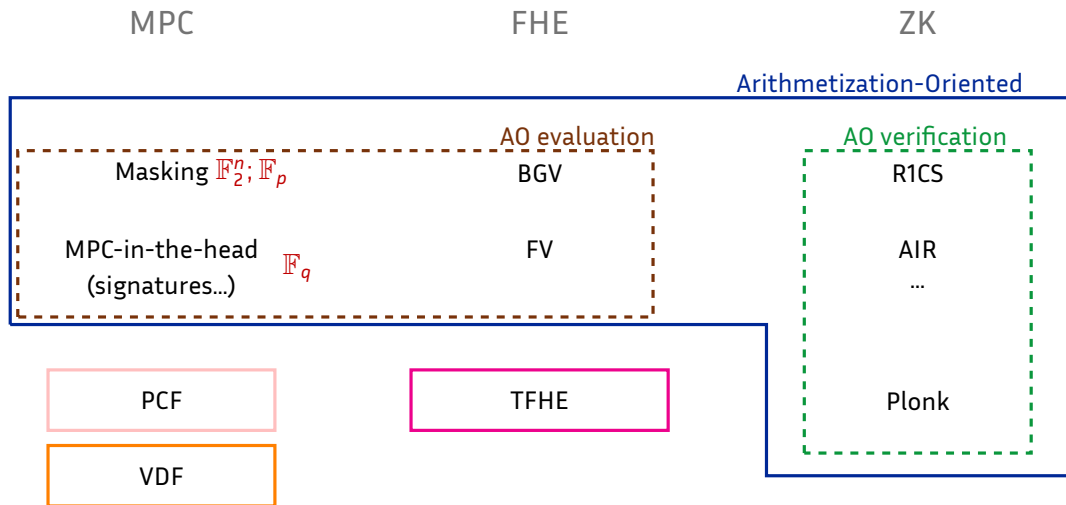
Symmetric Techniques for Advanced Protocols



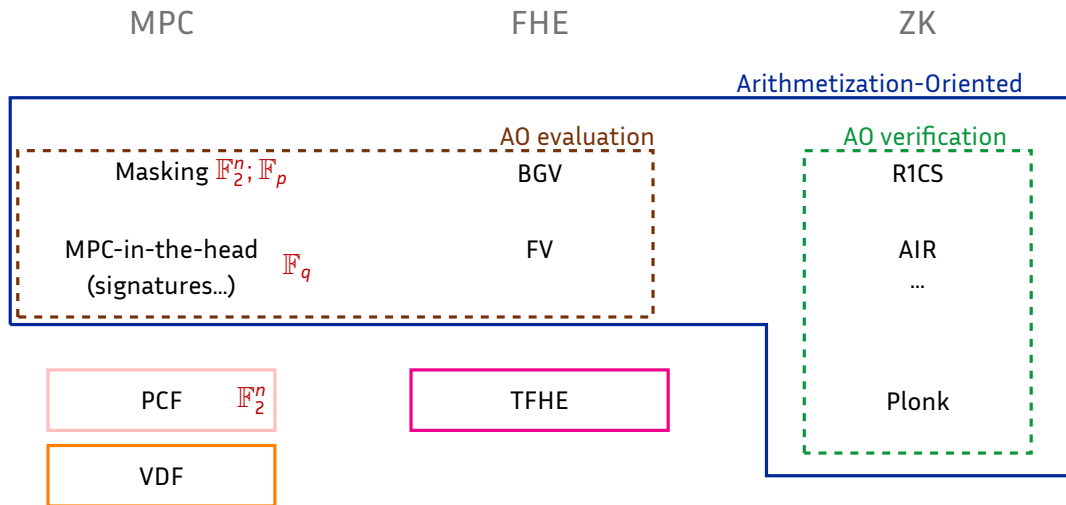
Symmetric Techniques for Advanced Protocols



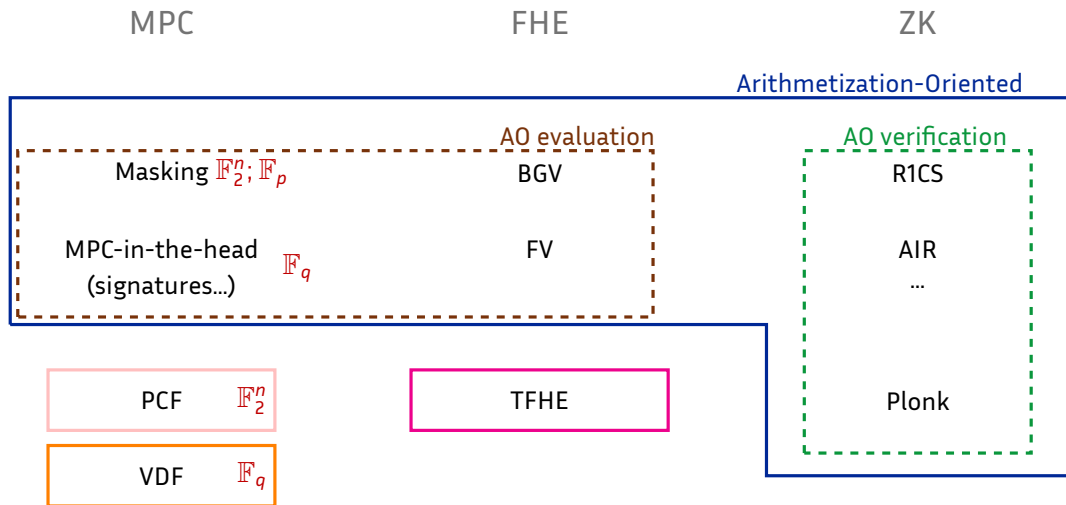
Symmetric Techniques for Advanced Protocols



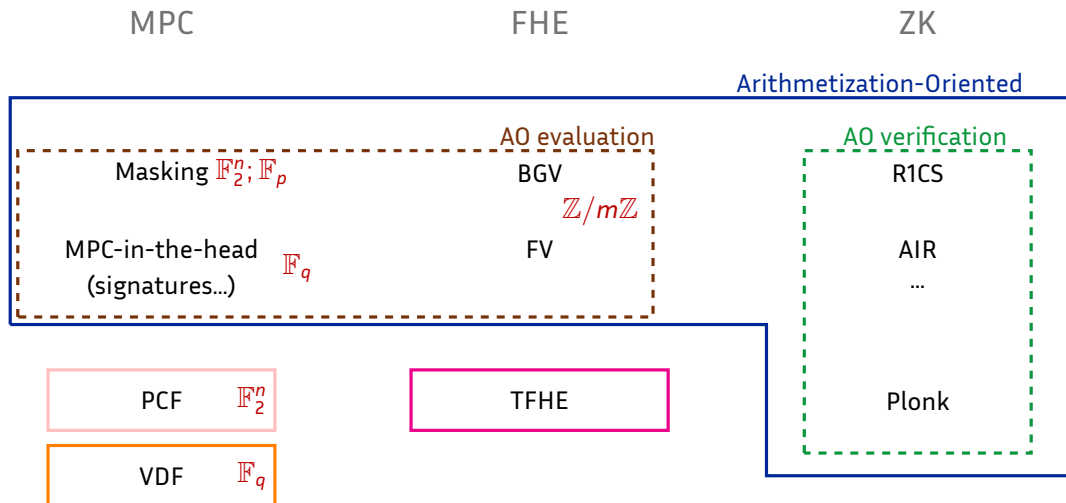
Symmetric Techniques for Advanced Protocols



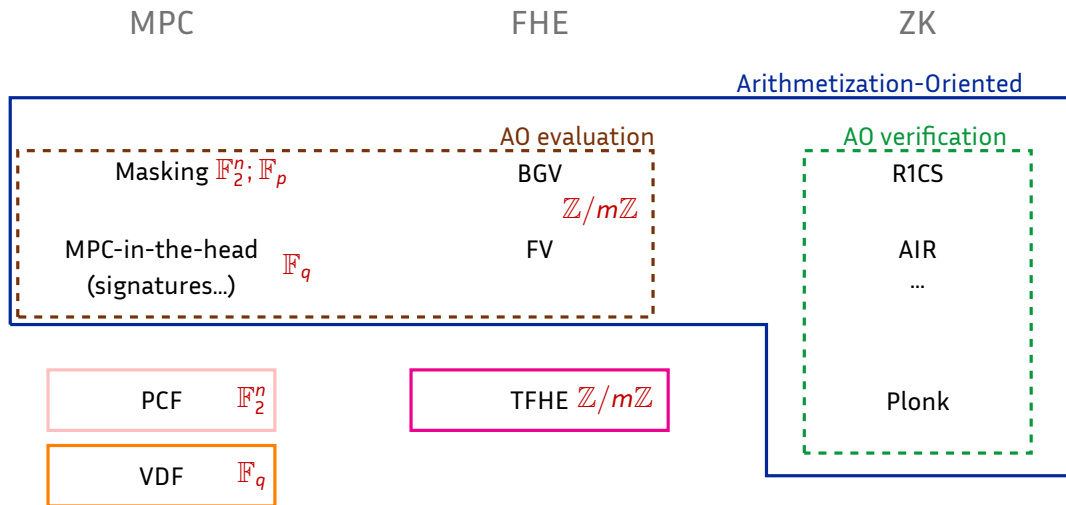
Symmetric Techniques for Advanced Protocols



Symmetric Techniques for Advanced Protocols



Symmetric Techniques for Advanced Protocols



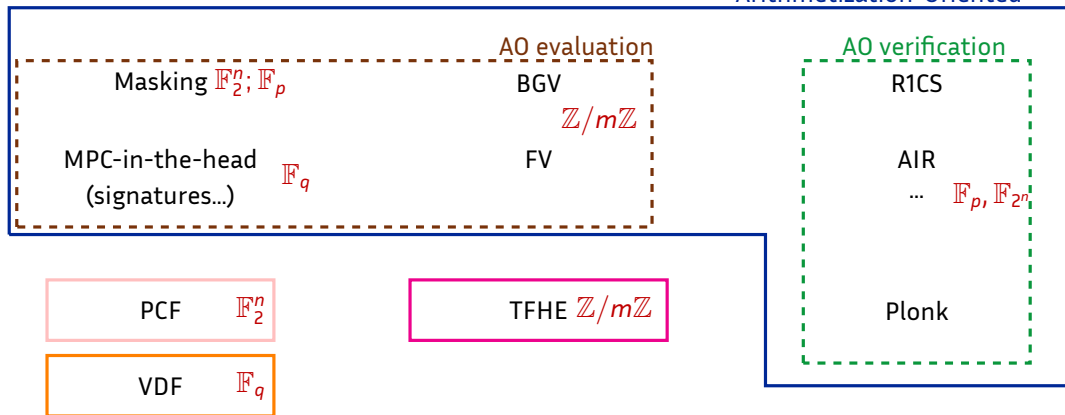
Symmetric Techniques for Advanced Protocols

MPC

FHE

ZK

Arithmetization-Oriented



A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

My Personal Opinion

- Indeed.

A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

My Personal Opinion

- Indeed. In particular, q prime means no Frobenius automorphisms, meaning linear operations are only **constant multiplications**.

A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

My Personal Opinion

- Indeed. In particular, q prime means no Frobenius automorphisms, meaning linear operations are only **constant multiplications**.
- Low degree arithmetization implies low degree algebraic modeling
beware of algebraic attacks!

A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

My Personal Opinion

- Indeed. In particular, q prime means no Frobenius automorphisms, meaning linear operations are only **constant multiplications**.
- Low degree arithmetization implies low degree algebraic modeling
beware of algebraic attacks!
- **However** good design approaches are *inherently* good design approaches

A Crucial Change?

\mathbb{F}_q and \mathbb{F}_2^n are not the same!

My Personal Opinion

- Indeed. In particular, q prime means no Frobenius automorphisms, meaning linear operations are only **constant multiplications**.
- Low degree arithmetization implies low degree algebraic modeling
beware of algebraic attacks!
- **However** good design approaches are *inherently* good design approaches

Working over \mathbb{F}_q (especially if low degree arithmetizations are needed) introduces new challenges, **but solutions will rely on tried and true methods**.

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols**
- 4 Conclusion

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
 - FHE: Stream ciphers for transciphering
 - MPC: low multiplicative depth, and PCF
 - ZK: Hash function with AO verification
- 4 Conclusion

Transciphering

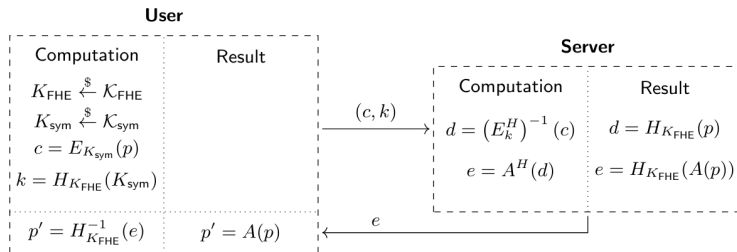


Fig. 1: The principle of transciphering, where E is a symmetric cipher (with secret key K_{sym} sampled from the space \mathcal{K}_{sym}), H is a fully homomorphic cipher (with private key K_{FHE} sampled from the space \mathcal{K}_{FHE}), E^H is a homomorphic evaluation of E , A corresponds to some arbitrary operations, and A^H to their homomorphic evaluation.

source: *Transistor: a TFHE-friendly Stream Cipher*

<https://eprint.iacr.org/2025/282>

The case of TFHE

Operates on $\mathbb{Z}/m\mathbb{Z}$, where m can be anything, though: more efficient if m is smaller.

Operations allowed

Linear Combinations $\sum_i \alpha_i x_i$, where the α_i are constant while x_i is input/key dependent.

- Costs almost nothing in terms of time/communication complexity...
- But **noise** increases

The case of TFHE

Operates on $\mathbb{Z}/m\mathbb{Z}$, where m can be anything, though: more efficient if m is smaller.

Operations allowed

Linear Combinations $\sum_i \alpha_i x_i$, where the α_i are constant while x_i is input/key dependent.

- Costs almost nothing in terms of time/communication complexity...
- But **noise** increases

PBS (Programmable BootStrap) $y \leftarrow S(x)$

- Very time consuming...
- But resets the noise to a **base level**

The case of TFHE

Operates on $\mathbb{Z}/m\mathbb{Z}$, where m can be anything, though: more efficient if m is smaller.

Operations allowed

Linear Combinations $\sum_i \alpha_i x_i$, where the α_i are constant while x_i is input/key dependent.

- Costs almost nothing in terms of time/communication complexity...
- But **noise** increases

PBS (Programmable BootStrap) $y \leftarrow S(x)$

- Very time consuming...
- But resets the noise to a **base level**
- Can be composed with **arbitrary table lookups!**

The case of TFHE

Operates on $\mathbb{Z}/m\mathbb{Z}$, where m can be anything, though: more efficient if m is smaller.

Operations allowed

Linear Combinations $\sum_i \alpha_i x_i$, where the α_i are constant while x_i is input/key dependent.

- Costs almost nothing in terms of time/communication complexity...
- But **noise** increases

PBS (Programmable BootStrap) $y \leftarrow S(x)$

- Very time consuming...
- But resets the noise to a **base level**
- Can be composed with **arbitrary table lookups!** ** S-box sounds **
- If the ring size is even, it is better if it is **nega-cyclic** ($S(x + 2^{n-1}) = -S(x)$)

TFHE: corresponding stream ciphers

Elisabeth-4 [CHMS22] ; $q = 2^4$

Uses a constant key register on which index-dependent non-linear functions are applied.

Can be linearized [GBJR23]

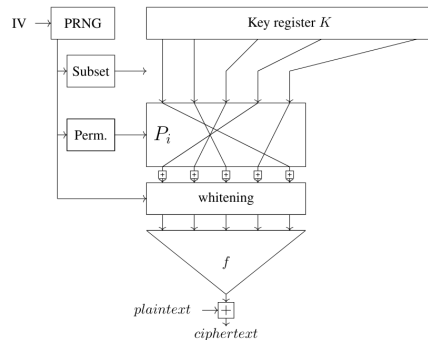


Fig. 1: The group filter permutator design

source: *Towards Case-Optimized Hybrid Homomorphic Encryption Featuring the Elisabeth Stream Cipher*

TFHE: corresponding stream ciphers

Elisabeth-4 [CHMS22] ; $q = 2^4$
Uses a constant key register on which index-dependent non-linear functions are applied.
Can be linearized [GBJR23]

Gabriel... [HMS23]
(Elisabeth-4 follow-ups)

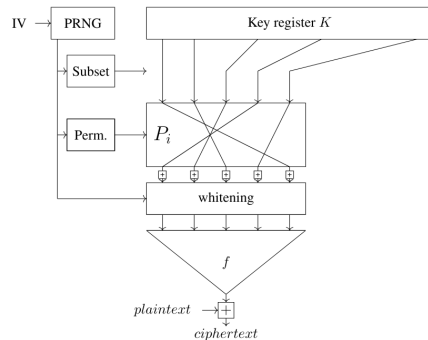


Fig. 1: The group filter permutator design

source: *Towards Case-Optimized Hybrid Homomorphic Encryption Featuring the Elisabeth Stream Cipher*

TFHE: corresponding stream ciphers

Elisabeth-4 [CHMS22] ; $q = 2^4$
Uses a constant key register on which index-dependent non-linear functions are applied.
Can be linearized [GBJR23]

Gabriel... [HMS23]
(Elisabeth-4 follow-ups)

FRAST [CCH⁺24] ; $q = 2^4$ A block cipher in a CTR-mode variant.

See you at the rump session :D

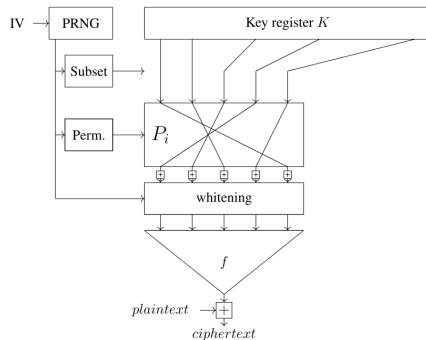


Fig. 1: The group filter permutator design

source: *Towards Case-Optimized Hybrid Homomorphic Encryption Featuring the Elisabeth Stream Cipher*

TFHE: corresponding stream ciphers

Elisabeth-4 [CHMS22] ; $q = 2^4$
Uses a constant key register on which index-dependent non-linear functions are applied.
Can be linearized [GBJR23]

Gabriel... [HMS23]
(Elisabeth-4 follow-ups)

FRAST [CCH⁺24] ; $q = 2^4$ A block cipher in a CTR-mode variant.

See you at the rump session :D

Transistor [BBB⁺25] ; $q = 2^4 + 1$
SNOW-like round structure
See you at Anne's invited talk :D

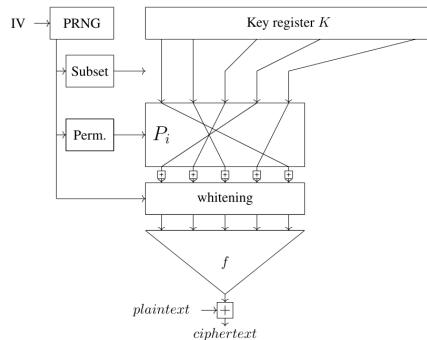


Fig. 1: The group filter permutator design

source: *Towards Case-Optimized Hybrid Homomorphic Encryption Featuring the Elisabeth Stream Cipher*

BGV/FV: corresponding stream ciphers

- ASTA $q = 2$ or large prime
Use very few rounds with a low degree.
Rely on large, randomly generated, nonce-dependent matrices.

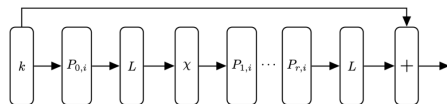


Figure 2: Generation of i -th block of DASTA.

source:

Dasta – Alternative Linear Layer for Rasta

BGV/FV: corresponding stream ciphers

- ASTA $q = 2$ or large prime
Use very few rounds with a low degree.
Rely on large, randomly generated, nonce-dependent matrices.

"Kreyvium" [CCF⁺16] $q = 2$
Basically Trivium!
Binary state updated with NLFSRs.

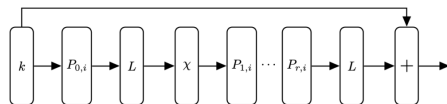


Figure 2: Generation of i -th block of DASTA.

source:

Dasta – Alternative Linear Layer for Rasta

BGV/FV: corresponding stream ciphers

- ASTA $q = 2$ or large prime
Use very few rounds with a low degree.
Rely on large, randomly generated, nonce-dependent matrices.

- "Kreyvium" [CCF⁺16] $q = 2$
Basically Trivium!
Binary state updated with NLFSRs.

- HERA [CHK⁺21] q large prime
A block cipher in a kind of CTR-mode variant.

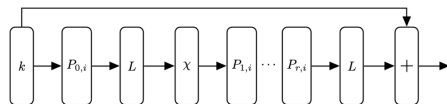


Figure 2: Generation of i -th block of DASTA.

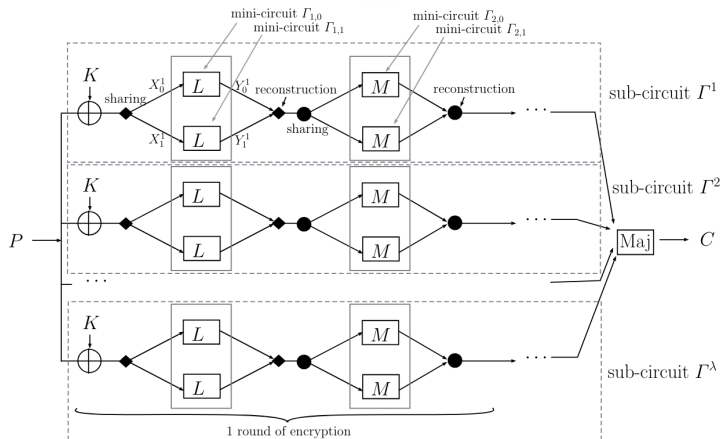
source:

Dasta – Alternative Linear Layer for Rasta

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
 - FHE: Stream ciphers for transcribing
 - MPC: low multiplicative depth, and PCF
 - ZK: Hash function with AO verification
- 4 Conclusion

Trojan Resilience



source: *MOE: Multiplication Operated Encryption with Trojan Resilience*
<https://tosc.iacr.org/index.php/ToSC/article/view/8834>

MPC-Friendly Encryption

LowMC [ARS⁺15] $q = 2$

SPN with partial layer of quadratic S-boxes.

Rely on large, randomly generated matrices.

Only one encryption/key; broken anyway

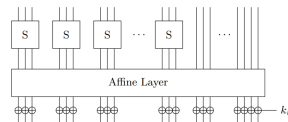


Fig. 1. Depiction of one round of encryption with LowMC.

source:

Ciphers for MPC and FHE

MPC-Friendly Encryption

LowMC [ARS⁺15] $q = 2$

SPN with partial layer of quadratic S-boxes.
Rely on large, randomly generated matrices.
Only one encryption/key; broken anyway

Ciminion [DGGK21] no specific constraints on q

3-branch Feistel network with a single
multiplication/round.

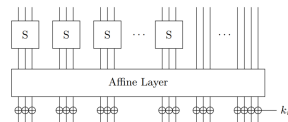


Fig. 1. Depiction of one round of encryption with LowMC.

source:

Ciphers for MPC and FHE

MPC-Friendly Encryption

LowMC [ARS⁺15] $q = 2$

SPN with partial layer of quadratic S-boxes.
Rely on large, randomly generated matrices.
Only one encryption/key; broken anyway

Ciminion [DGGK21] no specific constraints on q

3-branch Feistel network with a single
multiplication/round.

small-pSquare [GMM⁺24] $p = q = 127$

Generalized Feistel network with low degree round
function.
Optimized specifically for hardware masking.

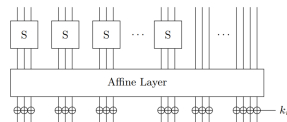


Fig. 1. Depiction of one round of encryption with LowMC.

source:

Ciphers for MPC and FHE

MPC-Friendly Encryption

LowMC [ARS⁺15] $q = 2$

SPN with partial layer of quadratic S-boxes.
 Rely on large, randomly generated matrices.
 Only one encryption/key; broken anyway

Ciminion [DGGK21] no specific constraints on q

3-branch Feistel network with a single
 multiplication/round.

small-pSquare [GMM⁺24] $p = q = 127$

Generalized Feistel network with low degree round
 function.
 Optimized specifically for hardware masking.

MOE [BFL⁺21] $q = 2^{128}$, $m = 2^{128}$

Dedicated structure with linear operations in \mathbb{F}_q and
 $\mathbb{Z}/q\mathbb{Z}$. Intended for hardware trojan resilience.

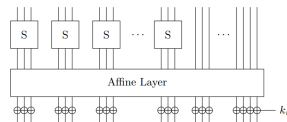


Fig. 1. Depiction of one round of encryption with LowMC.

source:

Ciphers for MPC and FHE

Pseudo-Correlated Functions

A new challenger!

At the start of some MPC protocols, it is necessary to share some bits that are correlated between the participants.

Very low multiplicative depth ·

Pseudo-Correlated Functions

A new challenger!

At the start of some MPC protocols, it is necessary to share some bits that are correlated between the participants.

Very low multiplicative depth · Very low data complexity ·

Pseudo-Correlated Functions

A new challenger!

At the start of some MPC protocols, it is necessary to share some bits that are correlated between the participants.

Very low multiplicative depth · Very low data complexity · **Only known plaintext, no chosen plaintext!**

Pseudo-Correlated Functions

A new challenger!

At the start of some MPC protocols, it is necessary to share some bits that are correlated between the participants.

Very low multiplicative depth · Very low data complexity · **Only known plaintext, no chosen plaintext!**

Crypto DarkMatter [BIP⁺18]

$$F_k(x) := \left(\sum_{i=0}^{n-1} k_i x_i \bmod 2 + \sum_{i=0}^{n-1} k_i x_i \bmod 3 \right) \bmod 2, \quad \text{for } x \in \{0, 1\}^n.$$

Pseudo-Correlated Functions

A new challenger!

At the start of some MPC protocols, it is necessary to share some bits that are correlated between the participants.

Very low multiplicative depth · Very low data complexity · **Only known plaintext, no chosen plaintext!**

Crypto DarkMatter [BIP⁺18]

$$F_k(x) := \left(\sum_{i=0}^{n-1} k_i x_i \bmod 2 + \sum_{i=0}^{n-1} k_i x_i \bmod 3 \right) \bmod 2, \quad \text{for } x \in \{0, 1\}^n.$$

VDLPN [BCG⁺20]

$$f_k(x) = \bigoplus_{i=1}^D \bigoplus_{j=1}^w \bigwedge_{\ell=1}^i (x_{i,j,\ell} \oplus k_{i,j,\ell}),$$

Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols**
 - FHE: Stream ciphers for transcribing
 - MPC: low multiplicative depth, and PCF
 - ZK: Hash function with AO verification**
- 4 Conclusion

ZK-Friendly Hash Functions

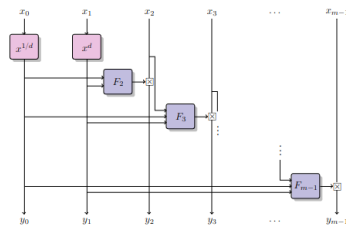
Poseidon [GLR⁺20] no specific constraints q
SPN with partial layer of low degree
monomial S-boxes.
Full rounds – partial round – full rounds.

ZK-Friendly Hash Functions

- Poseidon** [GLR⁺20] no specific constraints q
SPN with partial layer of low degree
monomial S-boxes.
Full rounds – partial round – full rounds.
- Rescue** [AAB⁺20] q large prime
SPN with low degree monomials and their
inverses.
Most "AES-like", also most secure at this stage.

ZK-Friendly Hash Functions

- Poseidon** [GLR⁺20] no specific constraints q
 SPN with partial layer of low degree monomial S-boxes.
 Full rounds – partial round – full rounds.
- Rescue** [AAB⁺20] q large prime
 SPN with low degree monomials and their inverses.
 Most "AES-like", also most secure at this stage.
- Griffin** [GHR⁺23] q large prime
 Feistel variant with multiplications instead.
 Particularly vulnerable to algebraic attacks!

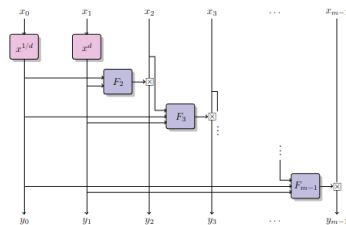


source: *Cryptanalysis and design of symmetric primitives defined over large finite fields*, PhD thesis of C.

Bouvier

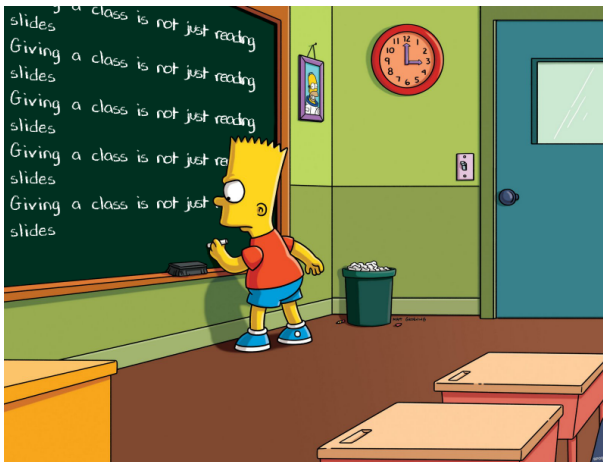
ZK-Friendly Hash Functions

- Poseidon** [GLR⁺20] no specific constraints q
 SPN with partial layer of low degree monomial S-boxes.
 Full rounds – partial round – full rounds.
- Rescue** [AAB⁺20] q large prime
 SPN with low degree monomials and their inverses.
 Most “AES-like”, also most secure at this stage.
- Griffin** [GHR⁺23] q large prime
 Feistel variant with multiplications instead.
 Particularly vulnerable to algebraic attacks!
- Anemoi** [BBC⁺23] $q = 2^n$ or large prime
 Uses the “Flystel”, a high degree S-box
 CCZ-equivalent to a function of low degree.



source: *Cryptanalysis and design of symmetric primitives defined over large finite fields*, PhD thesis of C. Bouvier

Arithmetization-Oriented Verification: CCZ-equivalence?



Plan of this Section

- 1 What is the Purpose of a Symmetric Primitive
- 2 "Advanced" Protocols
- 3 Symmetric Primitives for Advanced Protocols
- 4 Conclusion**

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**
- A lot of new designs (**Cambrian explosion**)...

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**
- A lot of new designs (**Cambrian explosion**)...
- ... but very little cryptanalysis.

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**
- A lot of new designs (**Cambrian explosion**)...
- ... but very little cryptanalysis.

We need more cryptanalysis!

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**
- A lot of new designs (**Cambrian explosion**)...
- ... but very little cryptanalysis.

We need more cryptanalysis! MORE!!

Conclusion

- The shape of symmetric primitives has always been dictated by **external constraints**
- New **advanced protocols** intended to secure **computations** need symmetric primitives
- The constraints they impose on the designs imply an **unusual look at first glance**
- The constraints they impose **vary**, and **we should be careful about lumping them together**
- A lot of new designs (**Cambrian explosion**)...
- ... but very little cryptanalysis.

We need more cryptanalysis! MORE!!

Coffee Break!

- 
- Abdelrahman Aly, Tomer Ashur, Eli Ben-Sasson, Siemen Dhooghe, and Alan Szeperienec.
Design of symmetric-key primitives for advanced cryptographic protocols.
IACR Trans. Symm. Cryptol., 2020(3):1–45, 2020.
- 
- Martin R. Albrecht, Christian Rechberger, Thomas Schneider, Tyge Tiessen, and Michael Zohner.
Ciphers for MPC and FHE.
In Elisabeth Oswald and Marc Fischlin, editors, *EUROCRYPT 2015, Part I*, volume 9056 of *LNCS*, pages 430–454, Sofia, Bulgaria, April 26–30, 2015. Springer Berlin Heidelberg, Germany.
- 
- Jules Baudrin, Sonia Belaïd, Nicolas Bon, Christina Boura, Anne Canteaut, Gaëtan Leurent, Pascal Paillier, Léo Perrin, Matthieu Rivain, Yann Rotella, and Samuel Tap.
Transistor: a TFHE-friendly stream cipher.
Cryptology ePrint Archive, Paper 2025/282, 2025.
- 
- Clémence Bouvier, Pierre Briaud, Pyrros Chaidos, Léo Perrin, Robin Salen, Vesselin Velichkov, and Danny Willems.

New design techniques for efficient arithmetization-oriented hash functions: Anemoi permutations and Jive compression mode.

In Helena Handschuh and Anna Lysyanskaya, editors, *CRYPTO 2023, Part III*, volume 14083 of *LNCS*, pages 507–539, Santa Barbara, CA, USA, August 20–24, 2023. Springer, Cham, Switzerland.



Elette Boyle, Geoffroy Couteau, Niv Gilboa, Yuval Ishai, Lisa Kohl, and Peter Scholl.
Correlated pseudorandom functions from variable-density lpn.

In *2020 IEEE 61st Annual Symposium on Foundations of Computer Science (FOCS)*, pages 1069–1080. IEEE, 2020.



Olivier Bronchain, Sebastian Faust, Virginie Lallemand, Gregor Leander, Léo Perrin, and François-Xavier Standaert.

MOE: Multiplication operated encryption with trojan resilience.

IACR Trans. Symm. Cryptol., 2021(1):78–129, 2021.



Dan Boneh, Yuval Ishai, Alain Passelègue, Amit Sahai, and David J. Wu.


Exploring crypto dark matter: New simple PRF candidates and their applications.

In Amos Beimel and Stefan Dziembowski, editors, *TCC 2018, Part II*, volume 11240 of *LNCS*, pages 699–729, Panaji, India, November 11–14, 2018. Springer, Cham, Switzerland.




Anne Canteaut, Sergiu Carпов, Caroline Fontaine, Tancrede Lepoint, María Naya-Plasencia, Pascal Paillier, and Renaud Sirdey.

Stream ciphers: A practical solution for efficient homomorphic-ciphertext compression.
In Thomas Peyrin, editor, *FSE 2016*, volume 9783 of *LNCS*, pages 313–333, Bochum, Germany, March 20–23, 2016. Springer Berlin Heidelberg, Germany.



Mingyu Cho, Woohyuk Chung, Jincheol Ha, Jooyoung Lee, Eun-Gyeol Oh, and Mincheol Son.
FRAS: TFHE-friendly cipher based on random S-boxes.

IACR Transactions on Symmetric Cryptology, 2024(3):1–43, Sep. 2024.



Jihoon Cho, Jincheol Ha, Seongkwang Kim, ByeongHak Lee, Joohee Lee, Jooyoung Lee, Dukjae Moon, and Hyojin Yoon.

Transciphering framework for approximate homomorphic encryption.

In Mehdi Tibouchi and Huaxiong Wang, editors, *ASIACRYPT 2021, Part III*, volume 13092 of *LNCS*, pages 640–669, Singapore, December 6–10, 2021. Springer, Cham, Switzerland.



Orel Cosseron, Clément Hoffmann, Pierrick Méaux, and François-Xavier Standaert.

Towards case-optimized hybrid homomorphic encryption - featuring the elisabeth stream cipher.

In Shweta Agrawal and Dongdai Lin, editors, *ASIACRYPT 2022, Part III*, volume 13793 of *LNCS*, pages 32–67, Taipei, Taiwan, December 5–9, 2022. Springer, Cham, Switzerland.



Christoph Dobraunig, Lorenzo Grassi, Anna Guinet, and Daniël Kuijsters.

Ciminion: Symmetric encryption based on Toffoli-gates over large finite fields.

In Anne Canteaut and François-Xavier Standaert, editors, *EUROCRYPT 2021, Part II*, volume 12697 of *LNCS*, pages 3–34, Zagreb, Croatia, October 17–21, 2021. Springer, Cham, Switzerland.



Henri Gilbert, Rachelle Heim Boissier, Jérémy Jean, and Jean-René Reinhard.

Cryptanalysis of elisabeth-4.

In Jian Guo and Ron Steinfeld, editors, *ASIACRYPT 2023, Part III*, volume 14440 of *LNCS*, pages 256–284, Guangzhou, China, December 4–8, 2023. Springer, Singapore, Singapore.



Lorenzo Grassi, Yonglin Hao, Christian Rechberger, Markus Schafnegg, Roman Walch, and Qingju Wang.


Horst meets fluid-SPN: Griffin for zero-knowledge applications.

In Helena Handschuh and Anna Lysyanskaya, editors, *CRYPTO 2023, Part III*, volume 14083 of *LNCS*, pages 573–606, Santa Barbara, CA, USA, August 20–24, 2023. Springer, Cham, Switzerland.



Lorenzo Grassi, Reinhard Lüftenegger, Christian Rechberger, Dragos Rotaru, and Markus Schofnegger.

On a generalization of substitution-permutation networks: The HADES design strategy.
In Anne Canteaut and Yuval Ishai, editors, *EUROCRYPT 2020, Part II*, volume 12106 of *LNCS*, pages 674–704, Zagreb, Croatia, May 10–14, 2020. Springer, Cham, Switzerland.



Lorenzo Grassi, Loïc Masure, Pierrick Méaux, Thorben Moos, and François-Xavier Standaert.

Generalized feistel ciphers for efficient prime field masking - full version.
Cryptology ePrint Archive, Report 2024/431, 2024.



Clément Hoffmann, Pierrick Méaux, and François-Xavier Standaert.

The patching landscape of elisabeth-4 and the mixed filter permutator paradigm.
In Anupam Chattopadhyay, Shivam Bhasin, Stjepan Picek, and Chester Rebeiro, editors, *INDOCRYPT 2023, Part I*, volume 14459 of *LNCS*, pages 134–156, Goa, India, December 10–13, 2023. Springer, Cham, Switzerland.