Universal Signature Aggregators

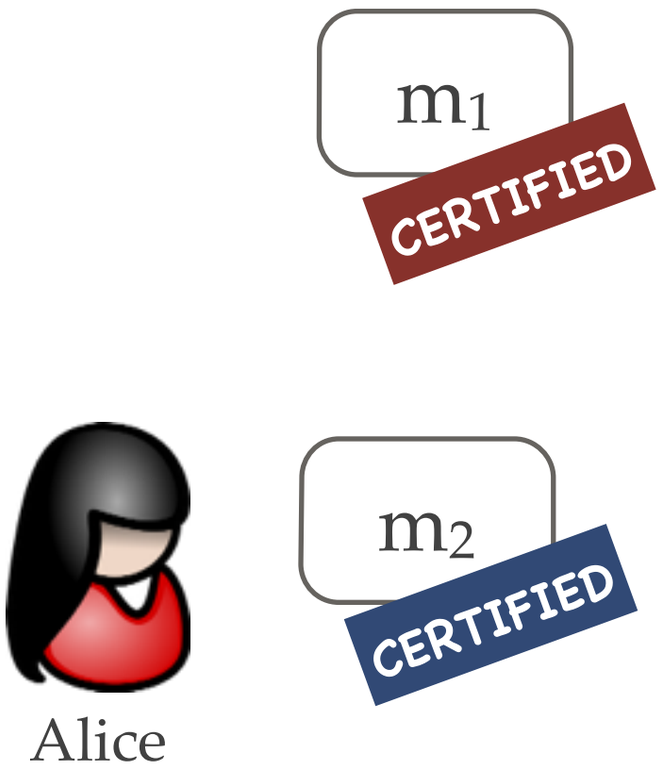
Susan Hohenberger (JHU)
Venkata Koppula (UT Austin)
Brent Waters (UT Austin)

Signature Aggregation (BGLS-03)

Signature Aggregation (BGLS-03)

Alice

Signature Aggregation (BGLS-03)



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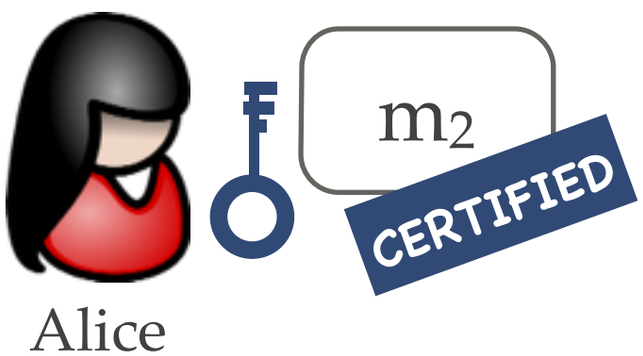

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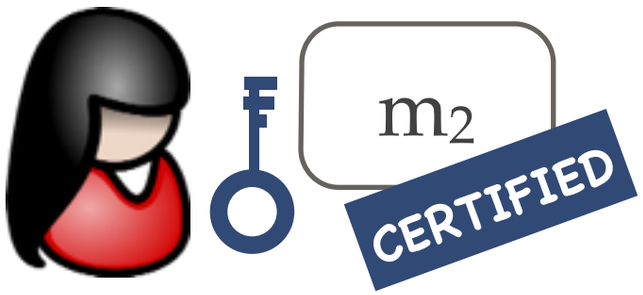

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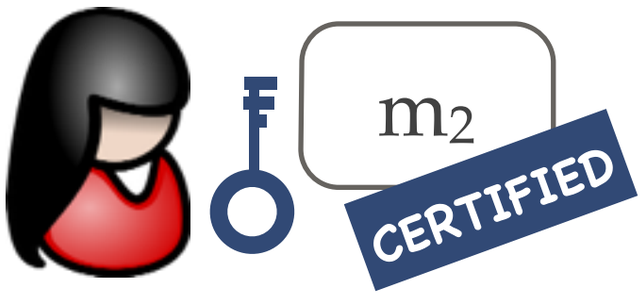

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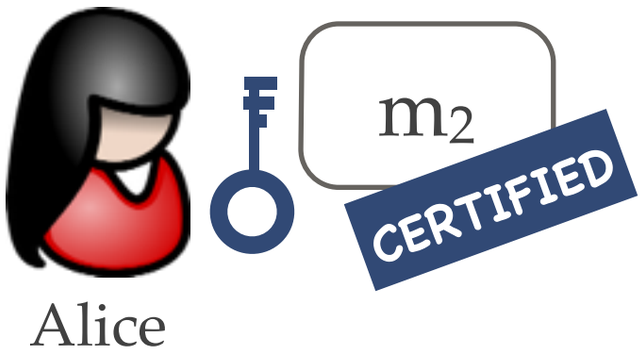

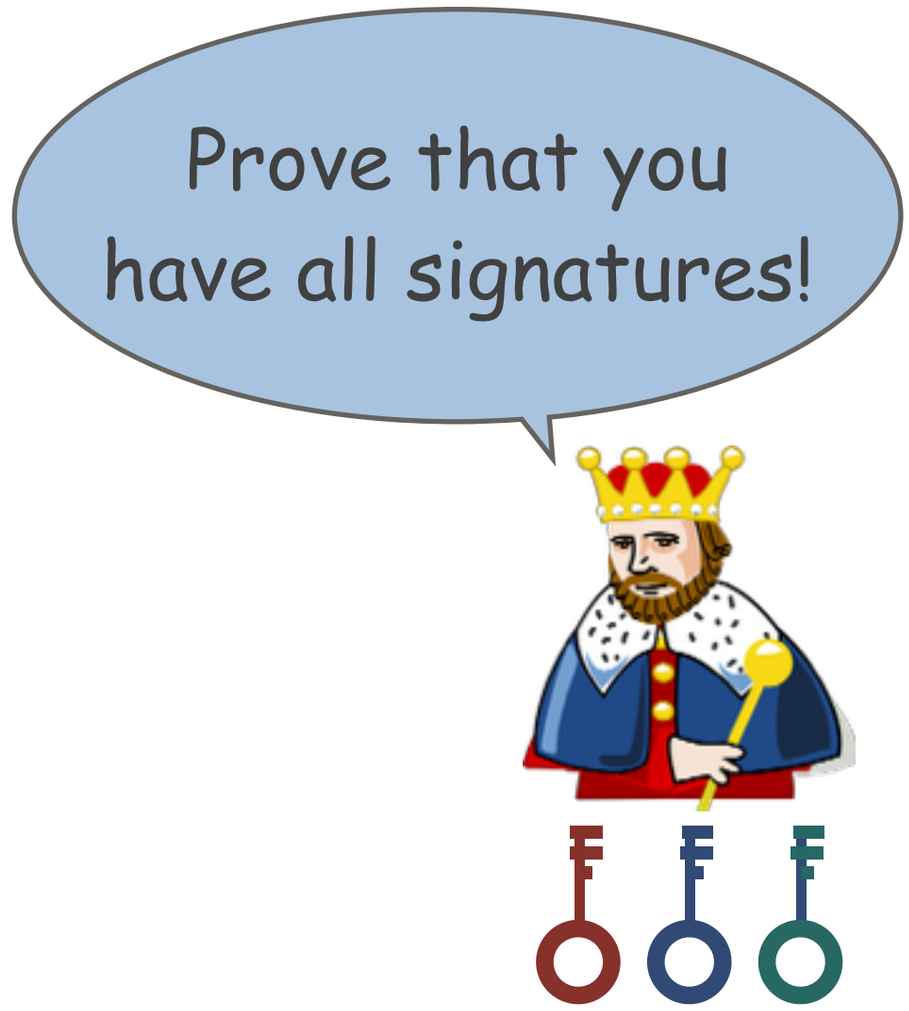

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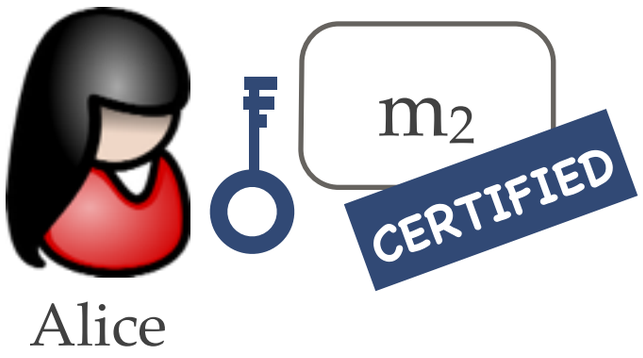

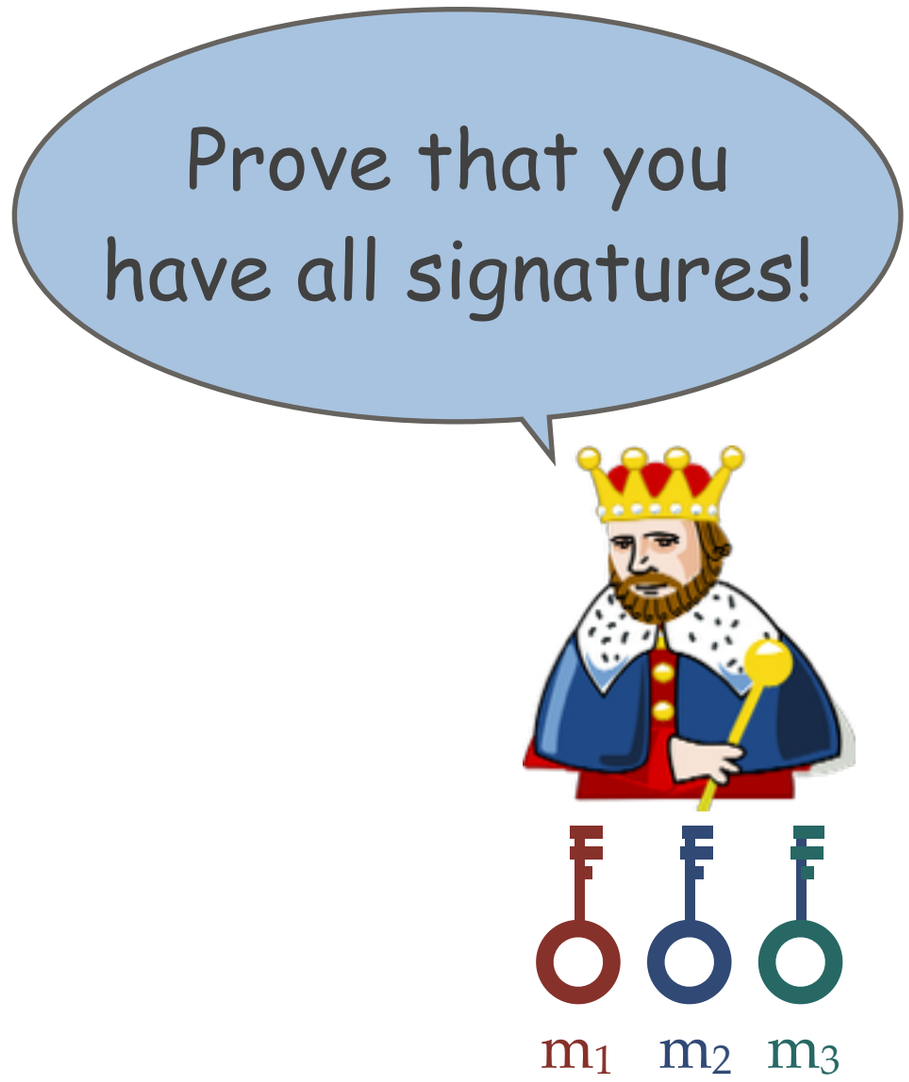

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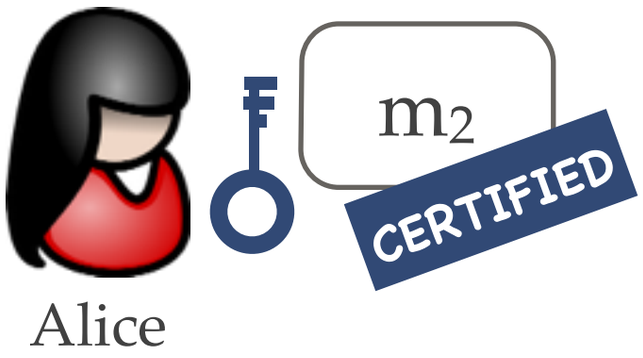

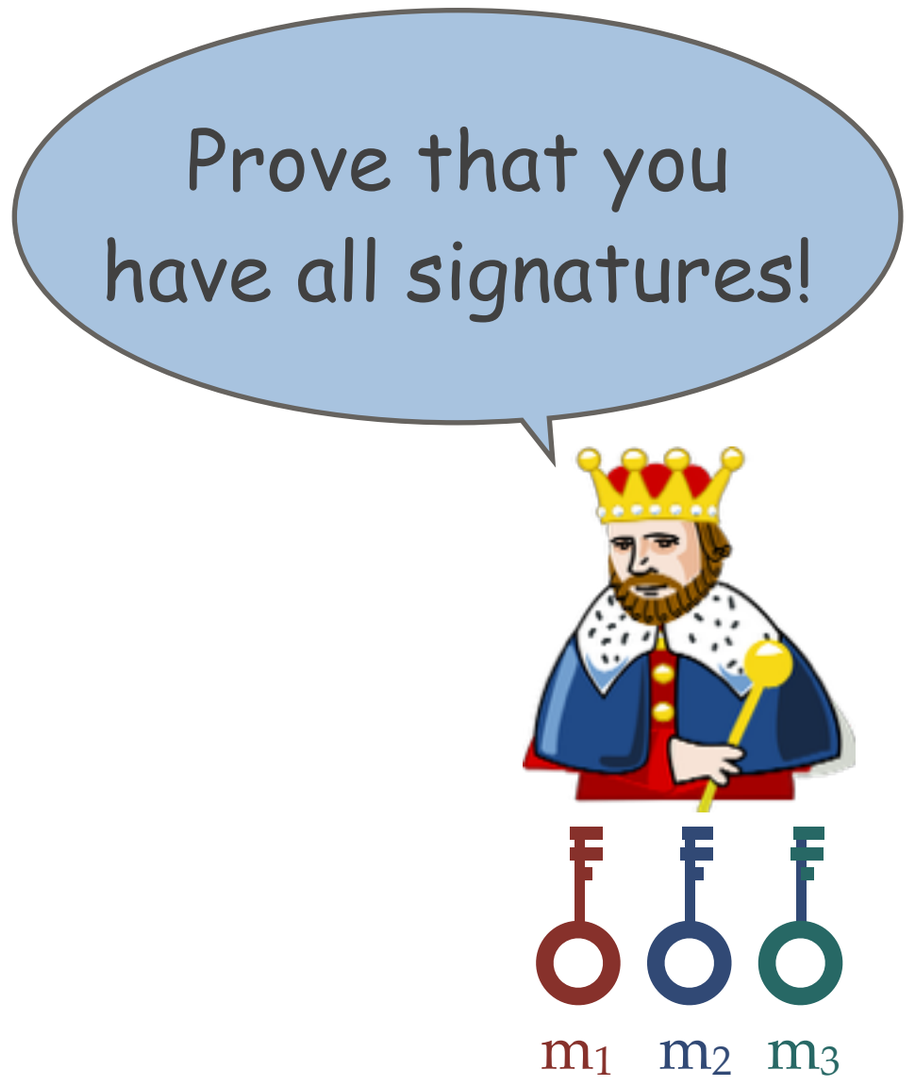

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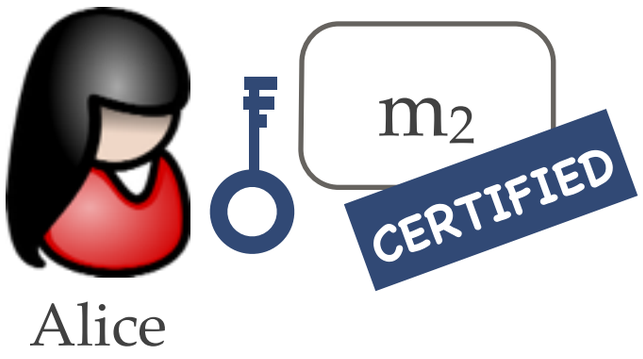
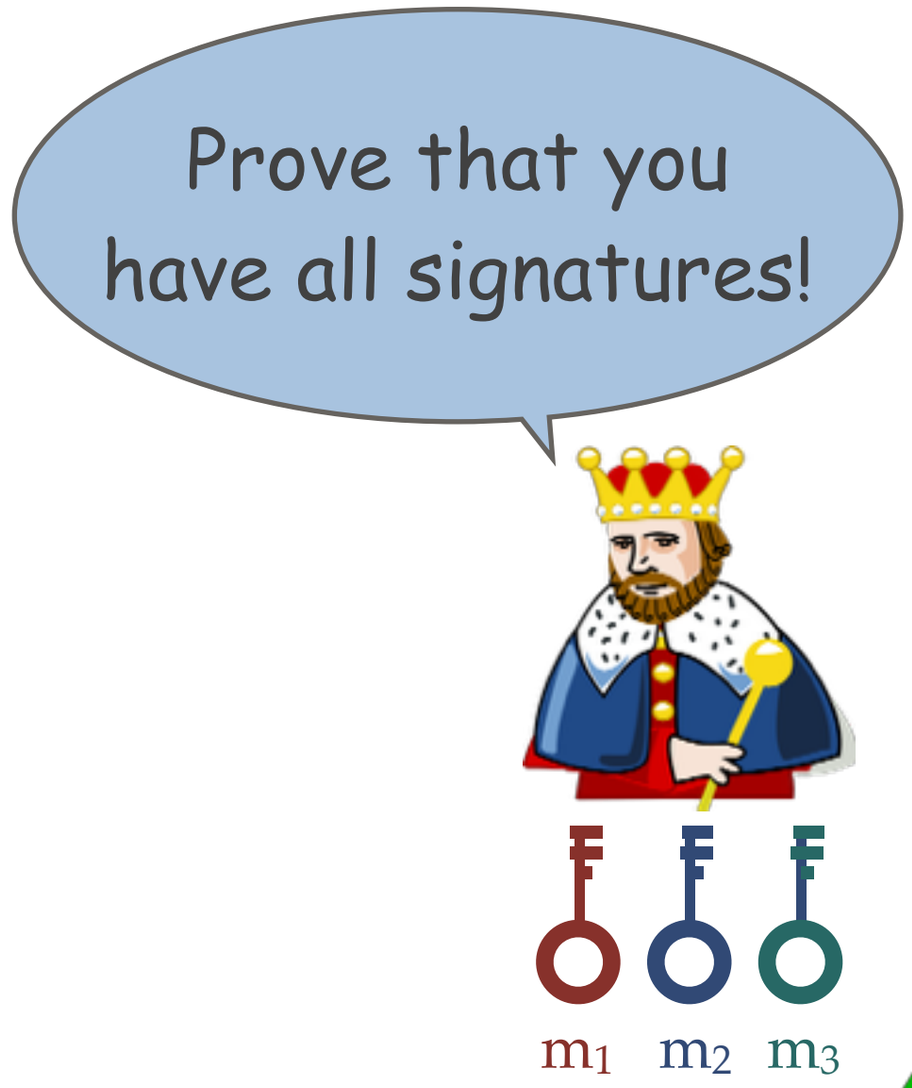
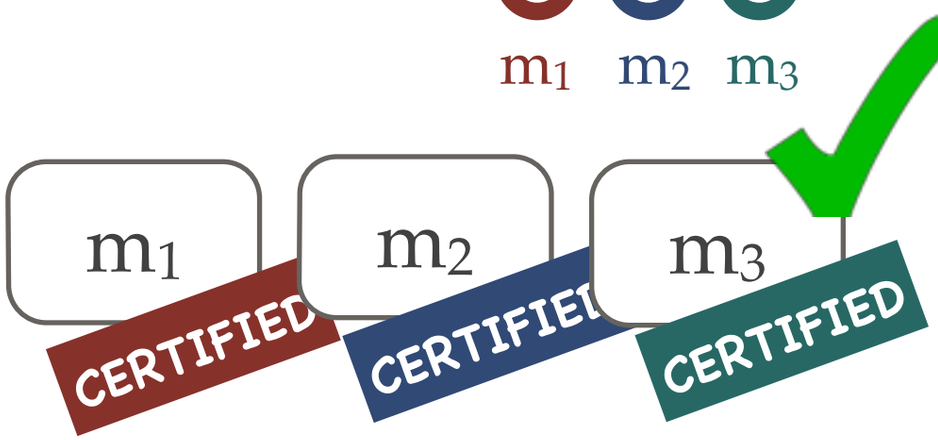
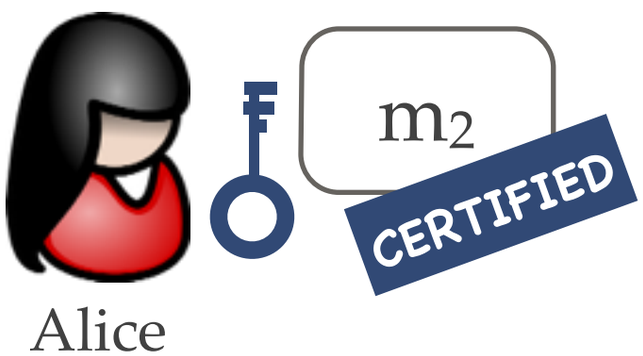






Signature Aggregation (BGLS-03)

Aggregate Signatures
Boneh, Gentry, Lynn, Shacham
Eurocrypt 03



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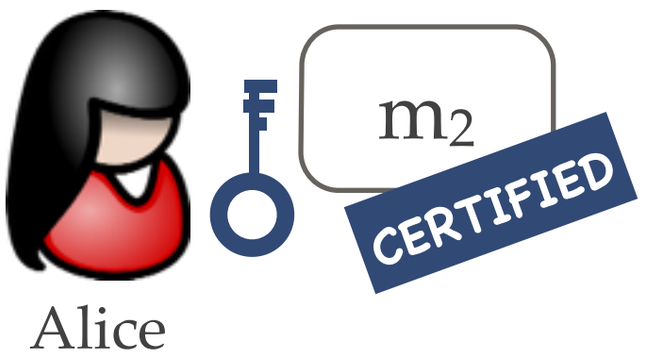

Aggregator

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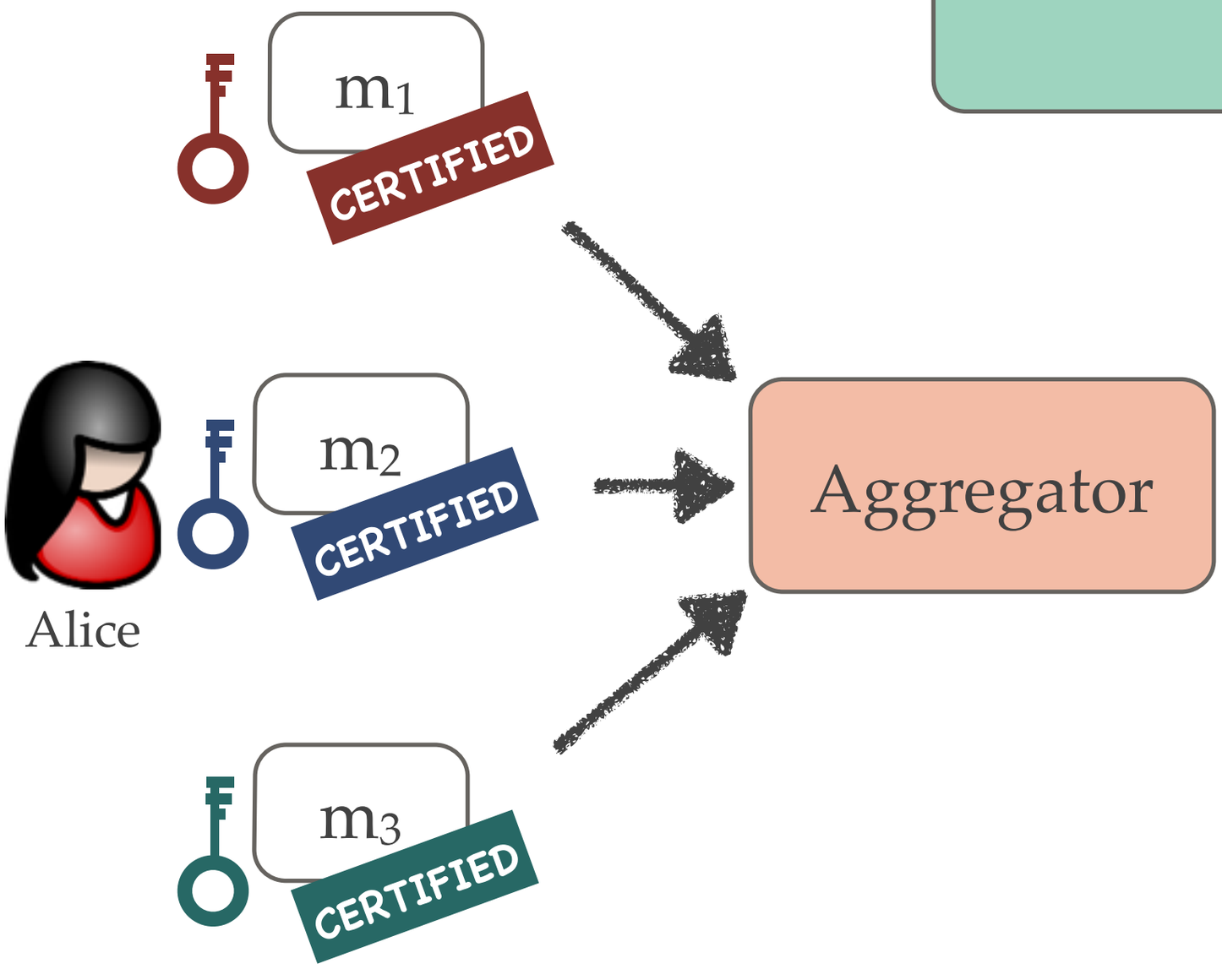

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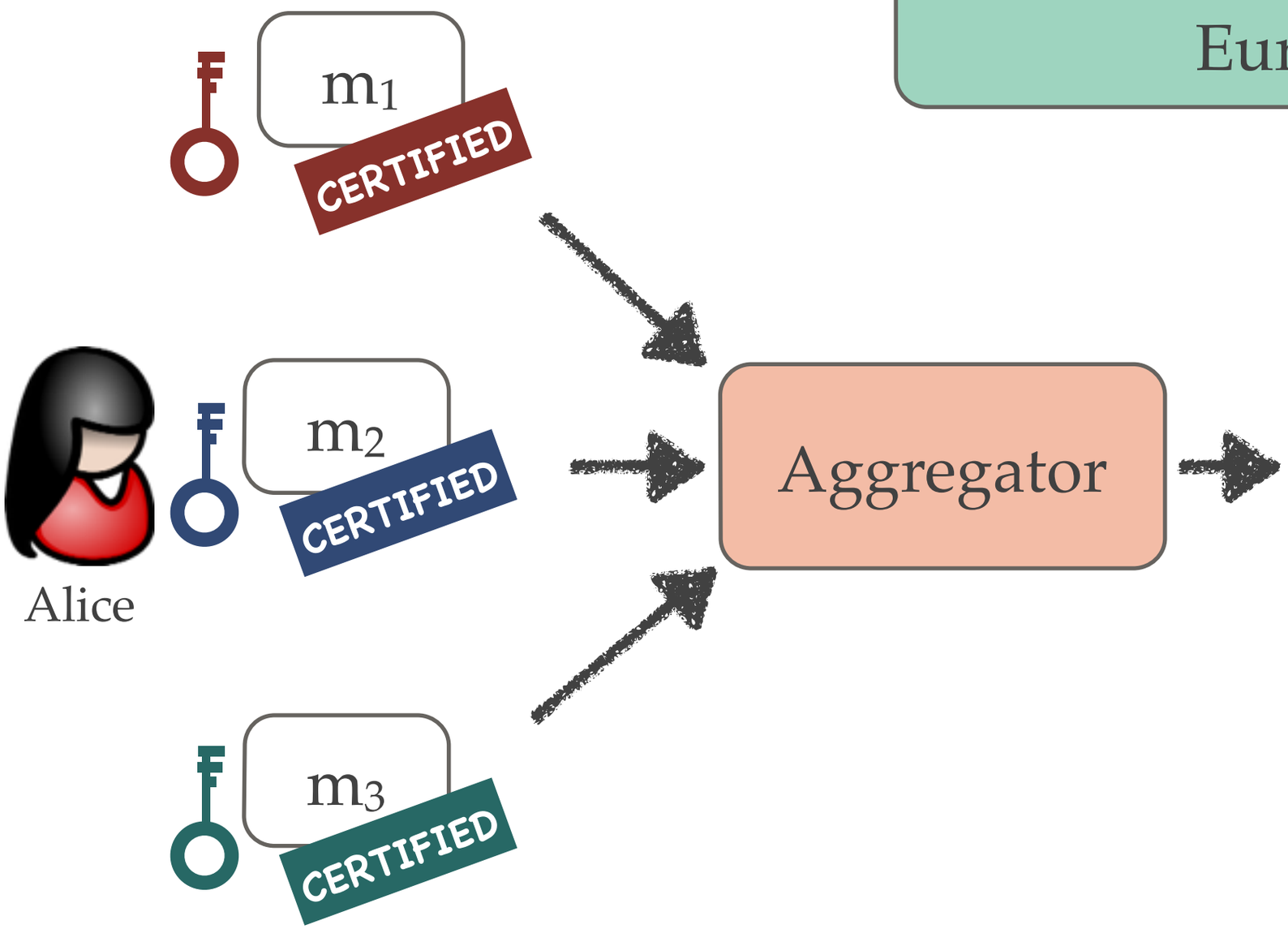

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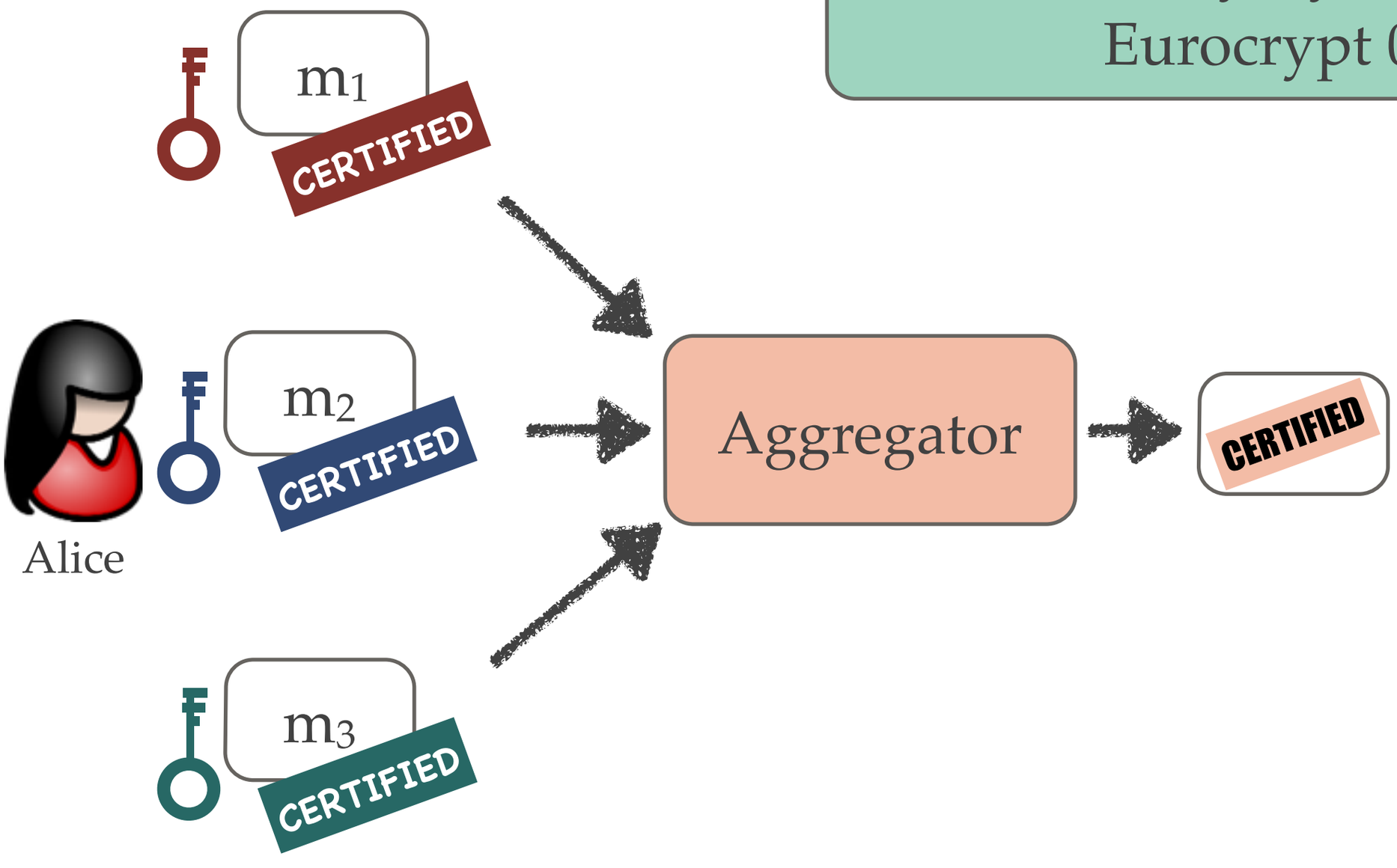

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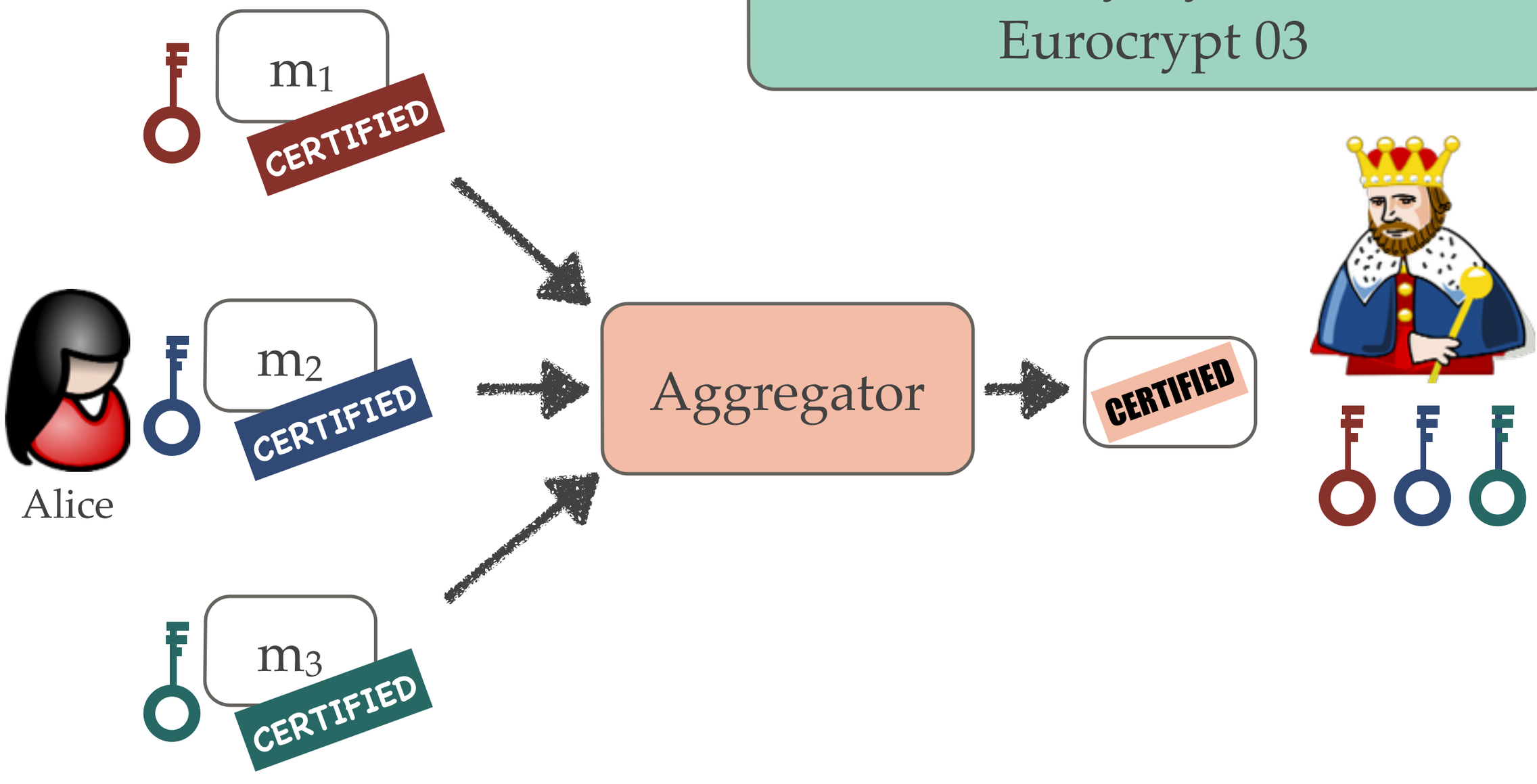

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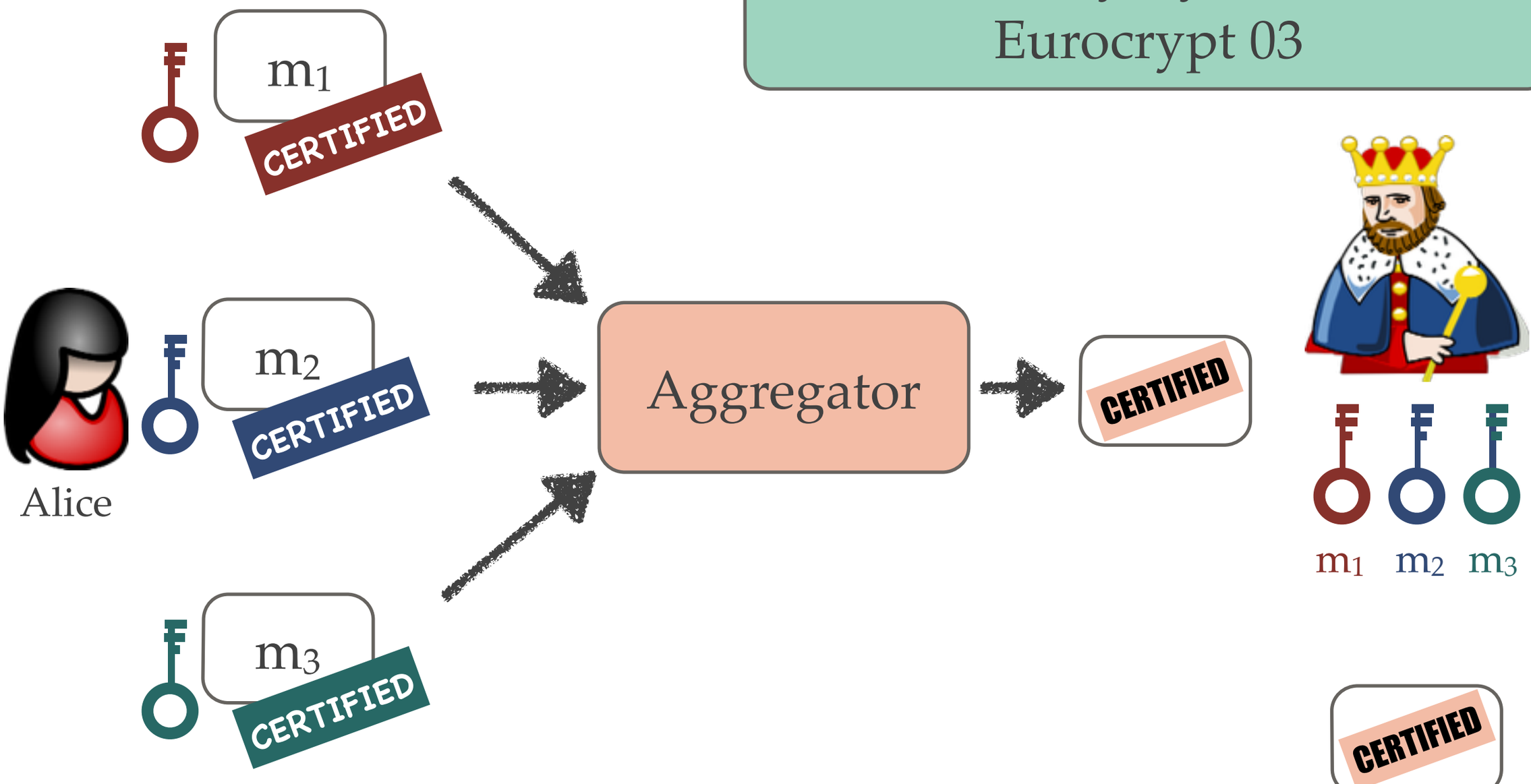

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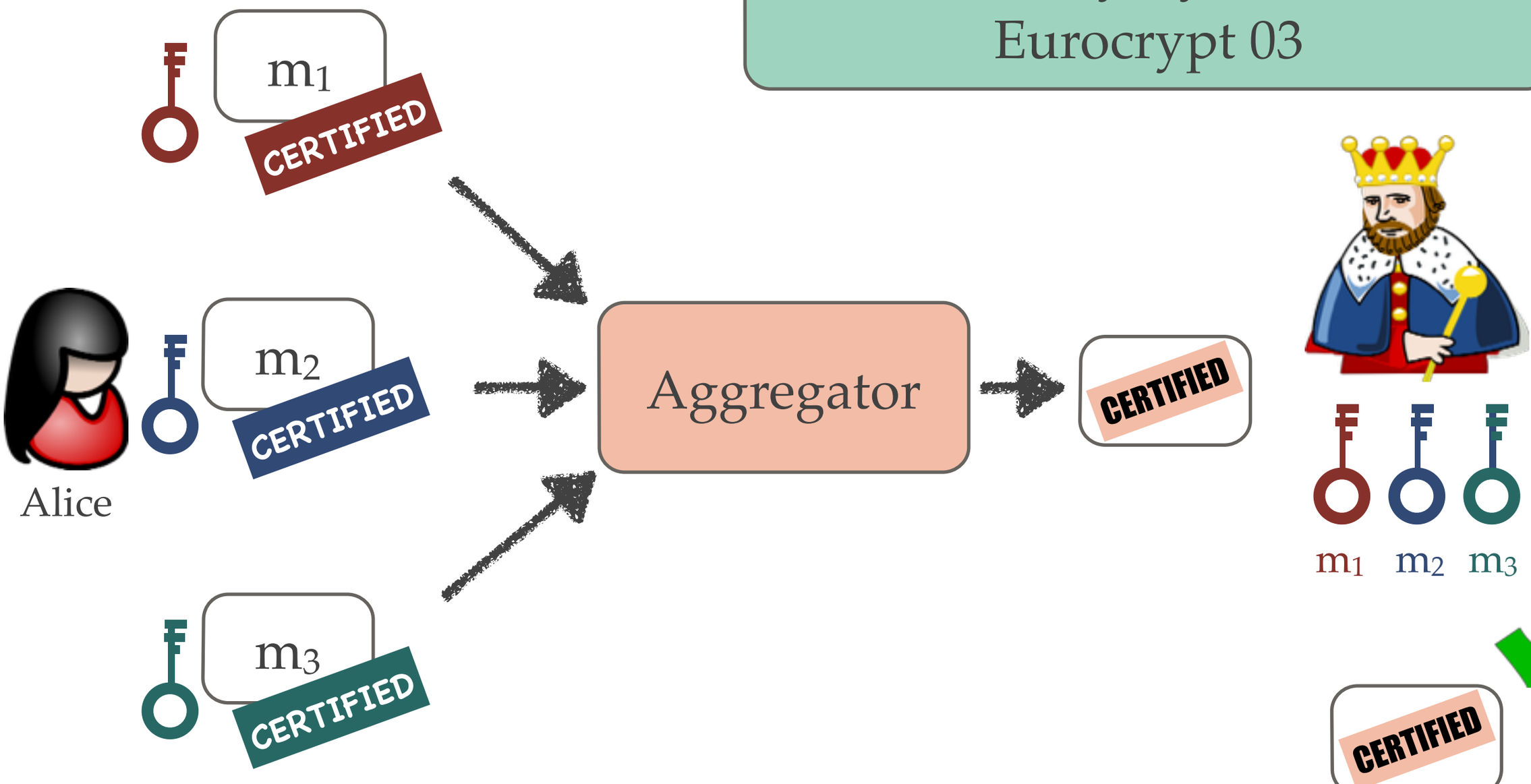

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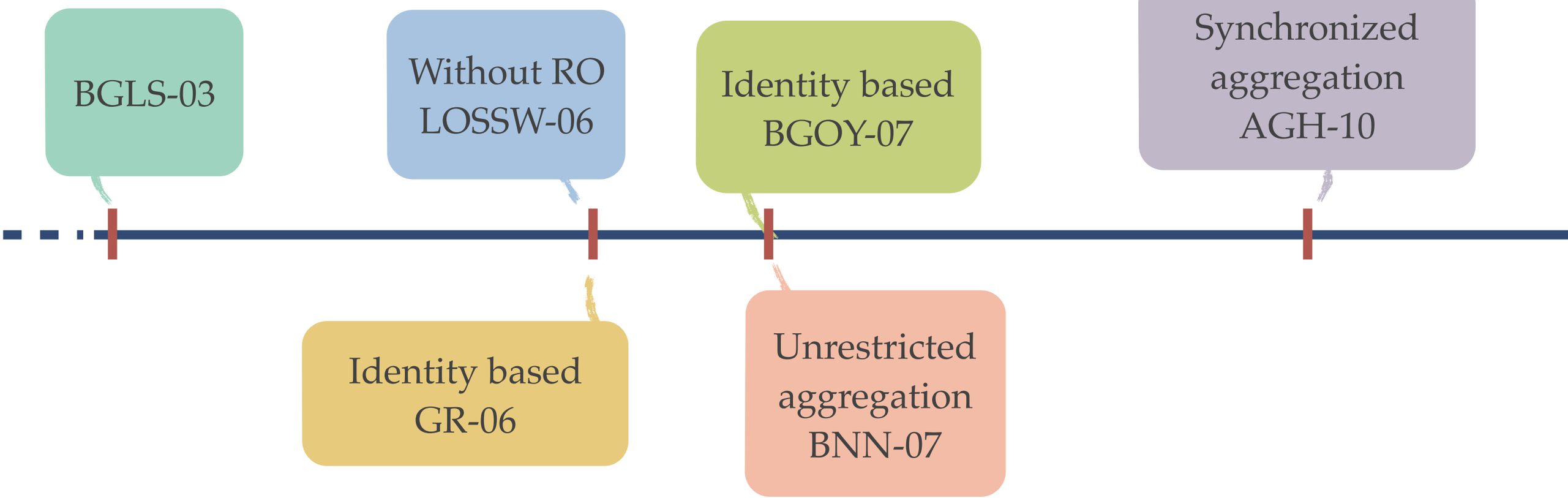
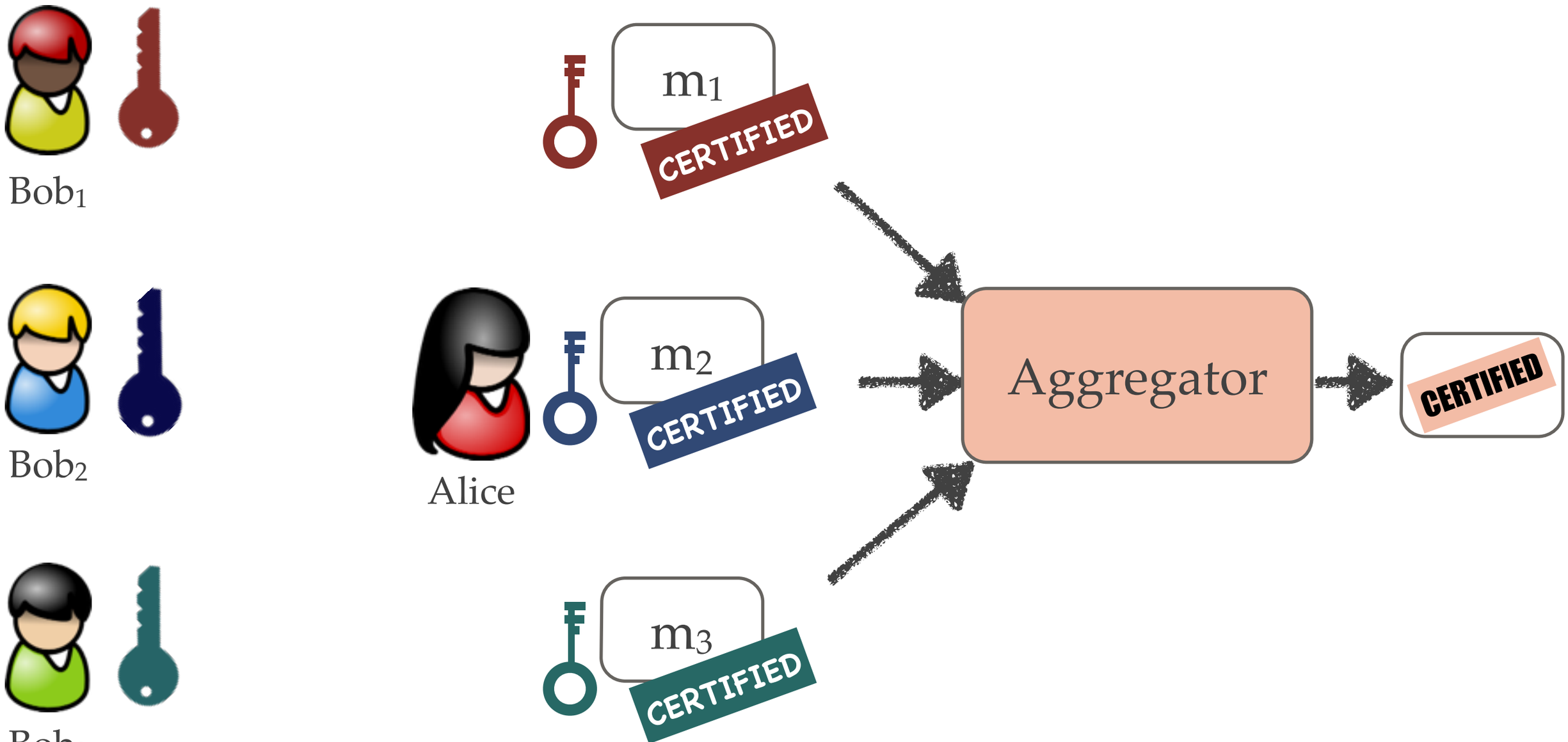


All signers must adopt a common signature system that allows aggregation.

Limitations of Existing Schemes



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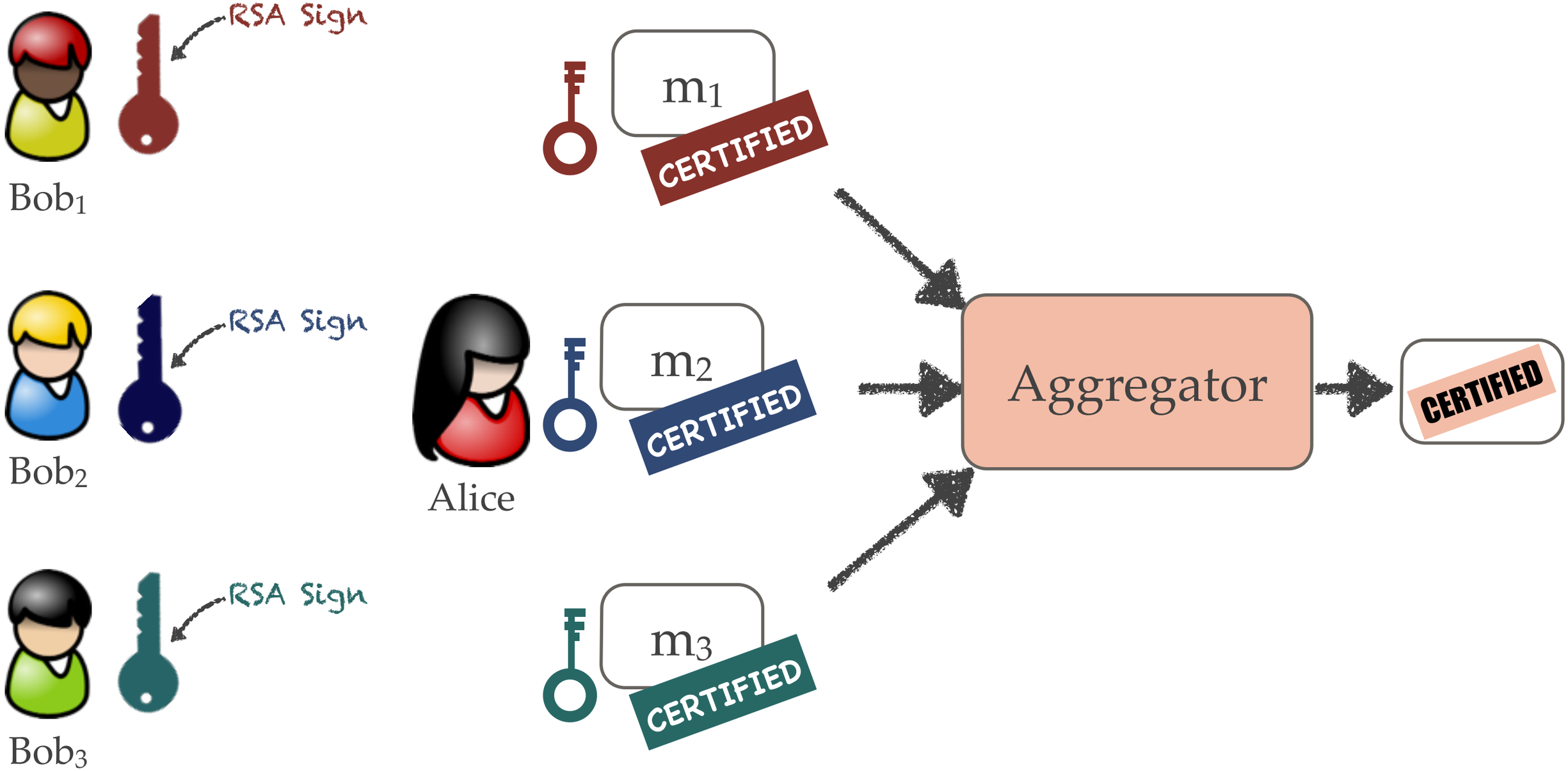

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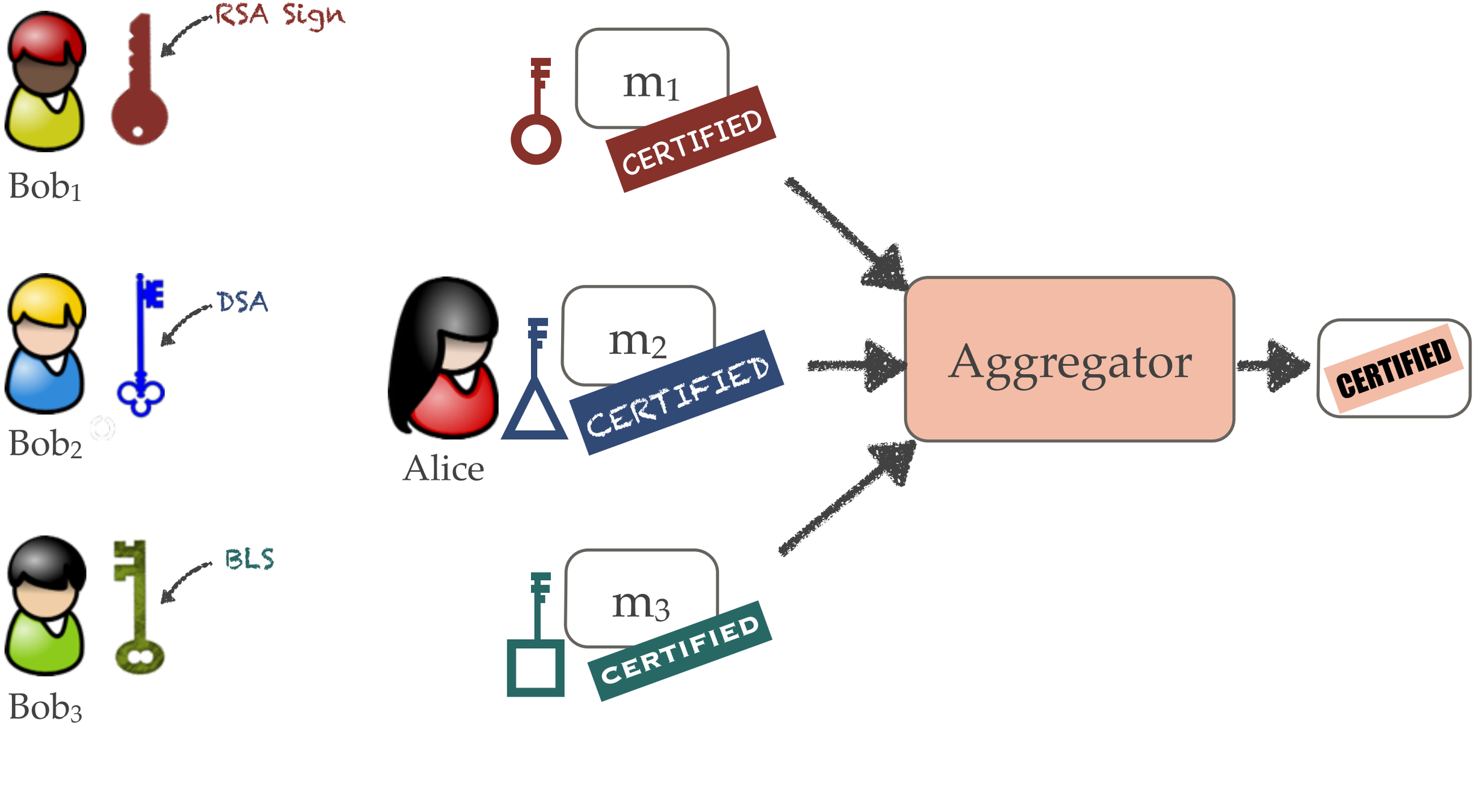

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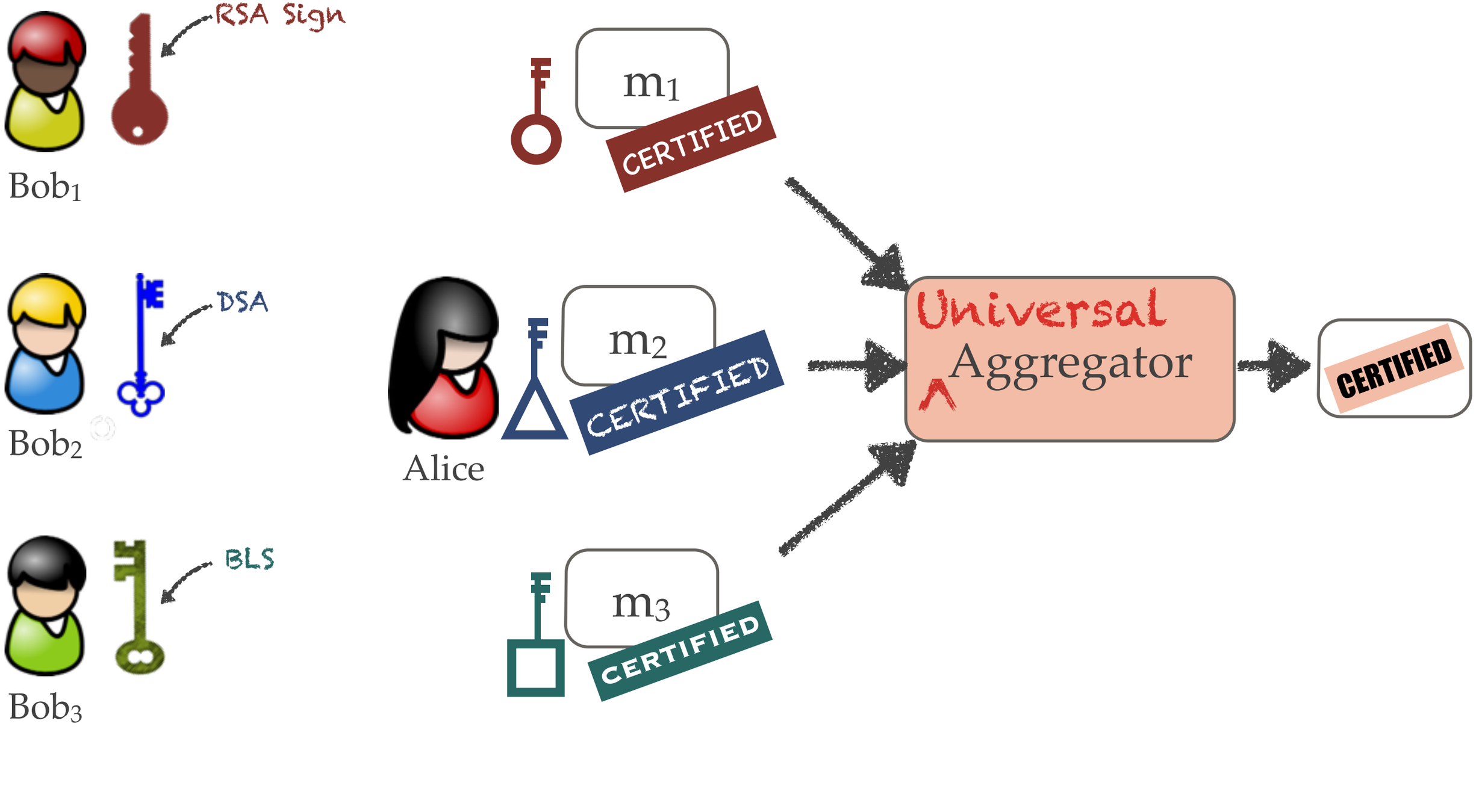


?

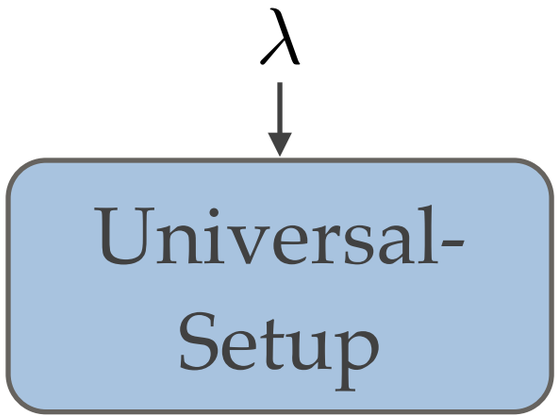
Can we have a `Universal Aggregator' that can aggregate signatures from a `large' class of signature schemes?

Universal Signature Aggregators

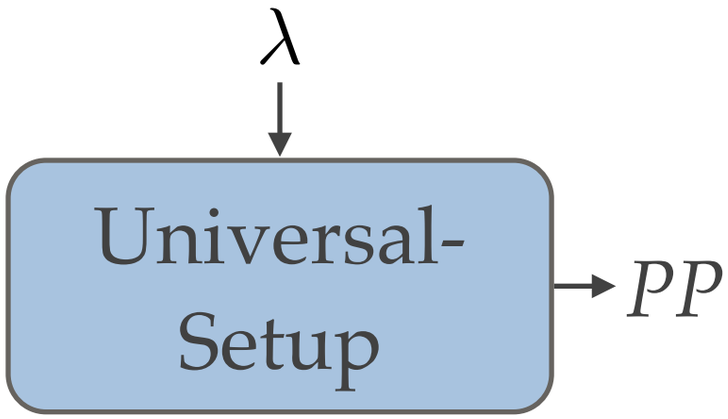
Universal Signature Aggregators

Universal-Setup

Universal Signature Aggregators



Universal Signature Aggregators



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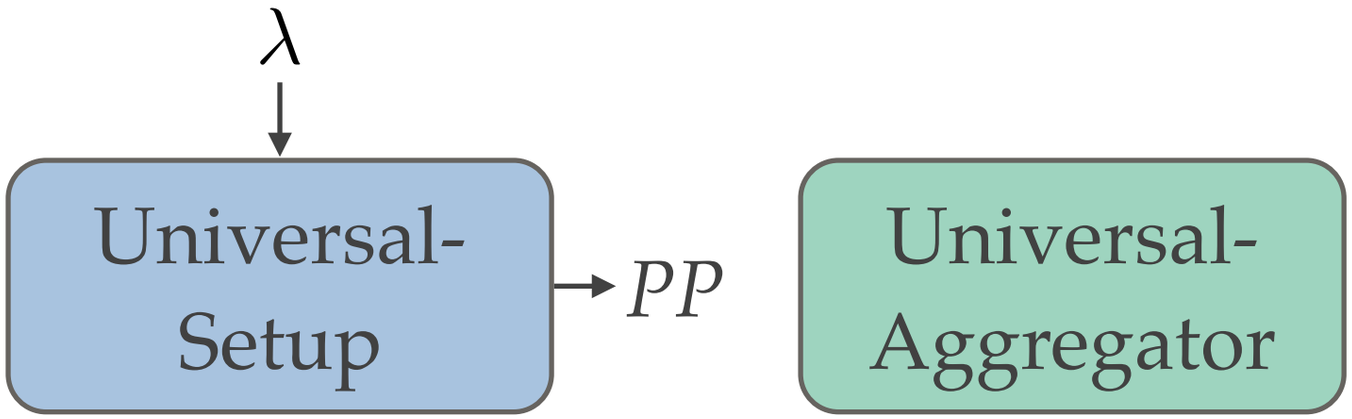

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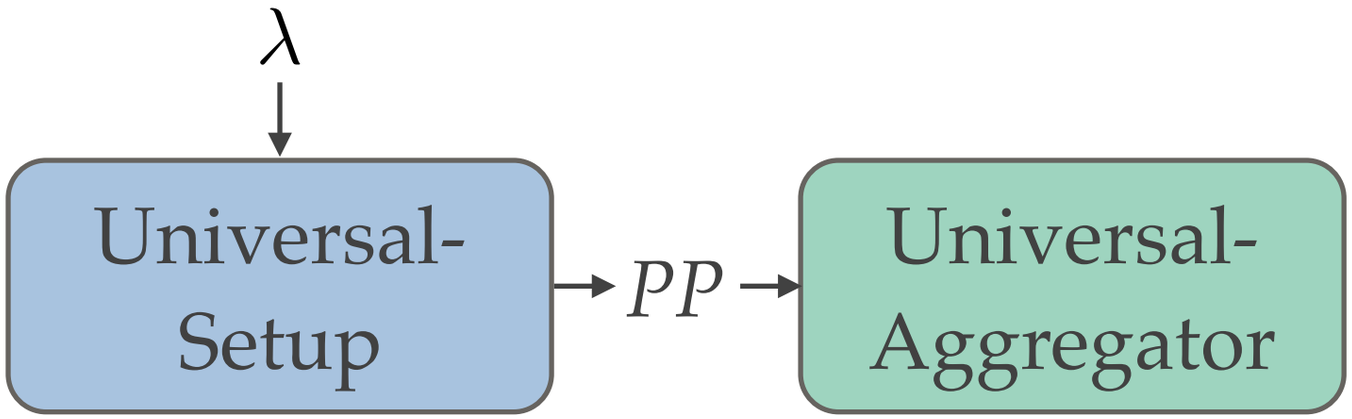

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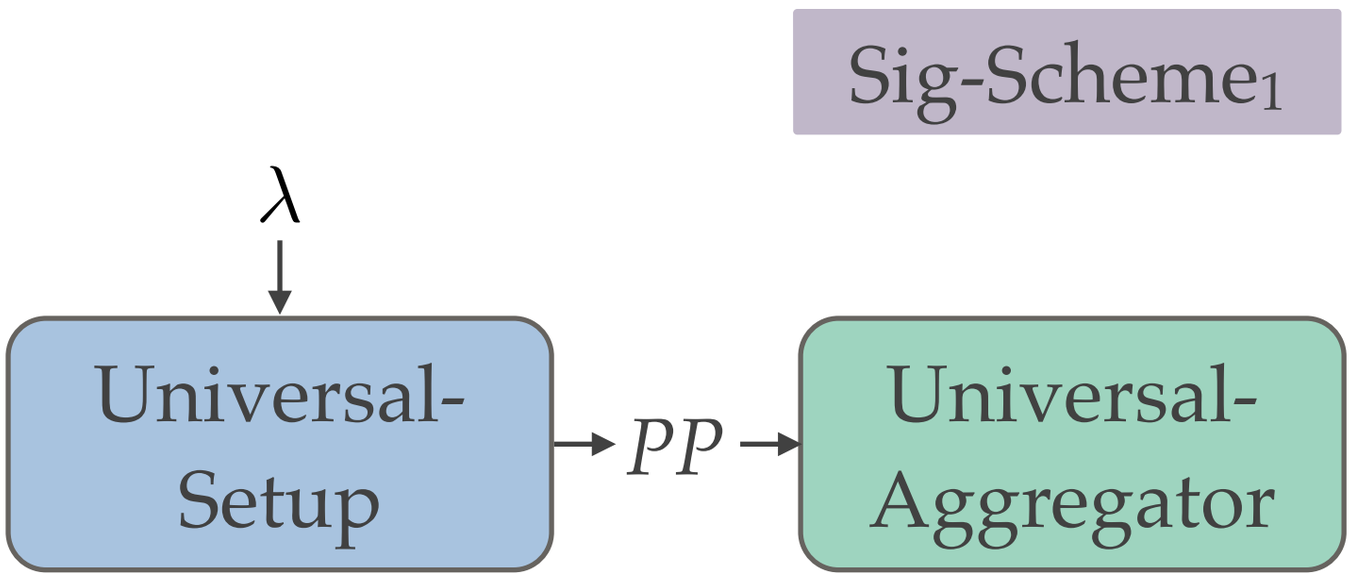

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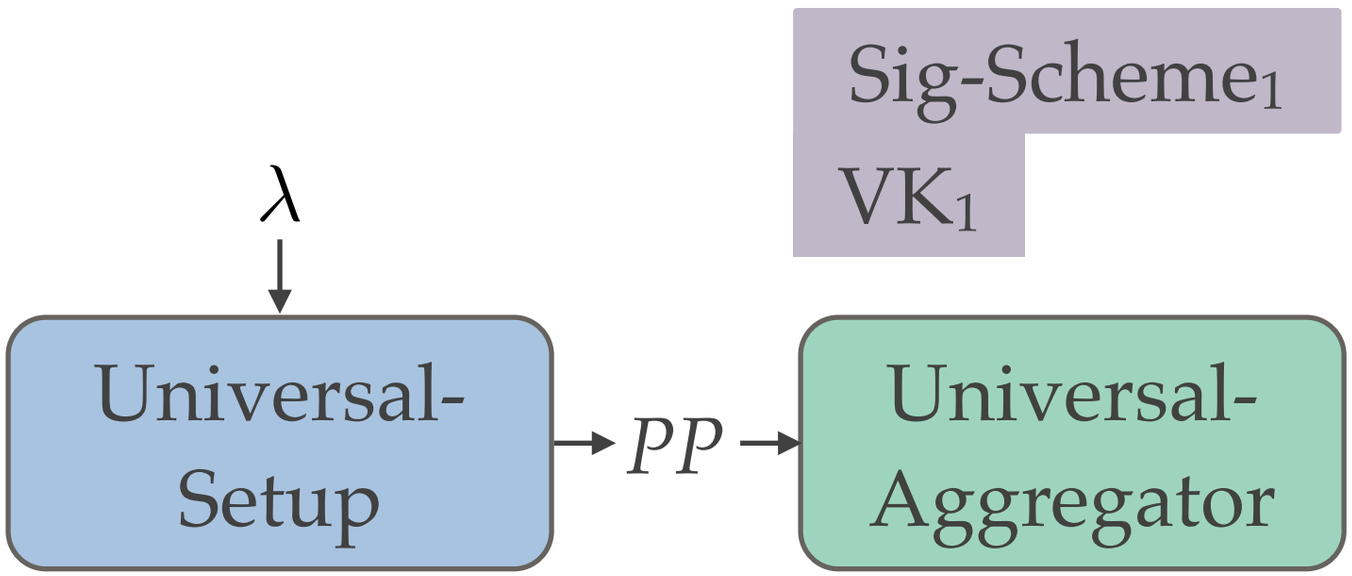

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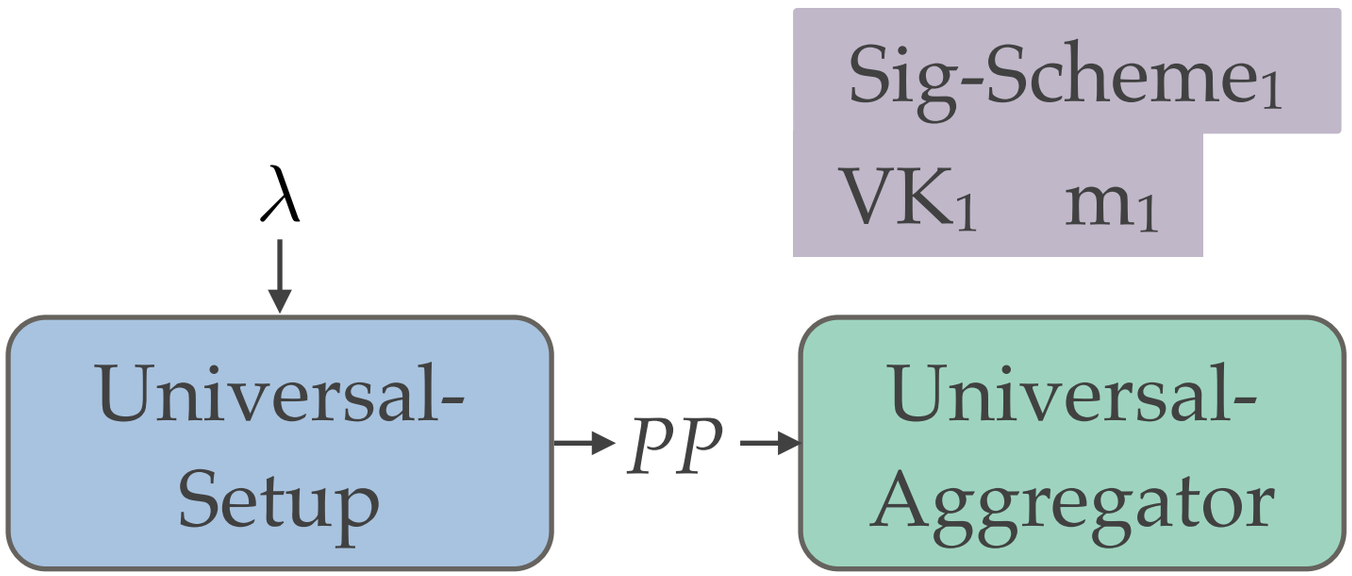

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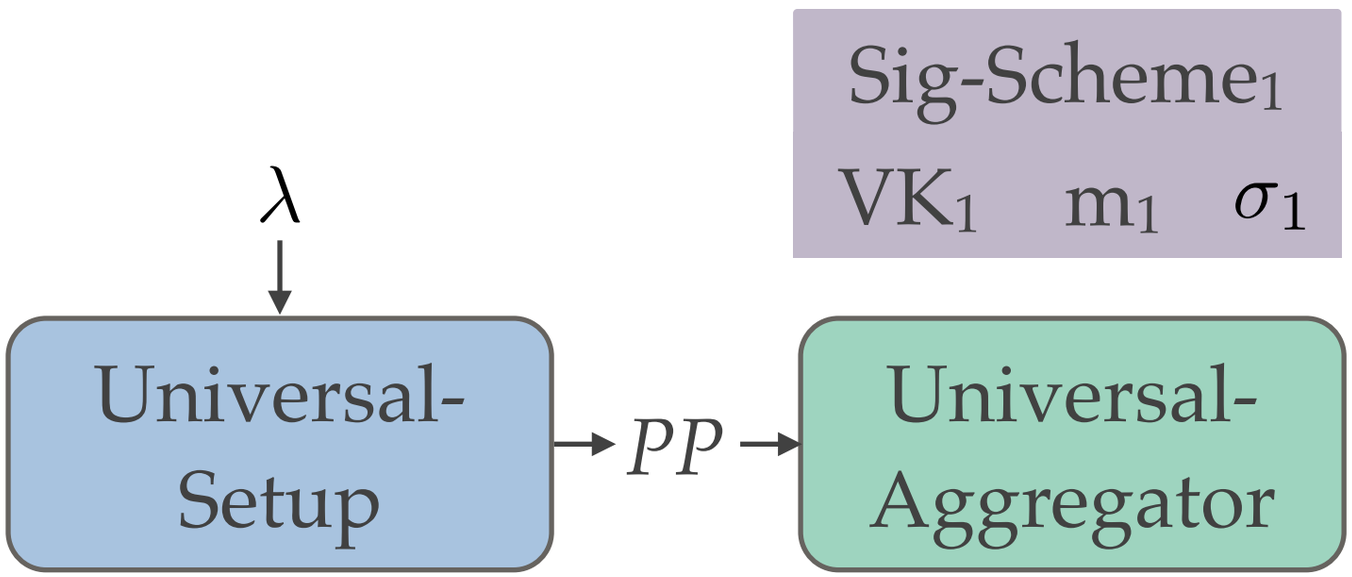

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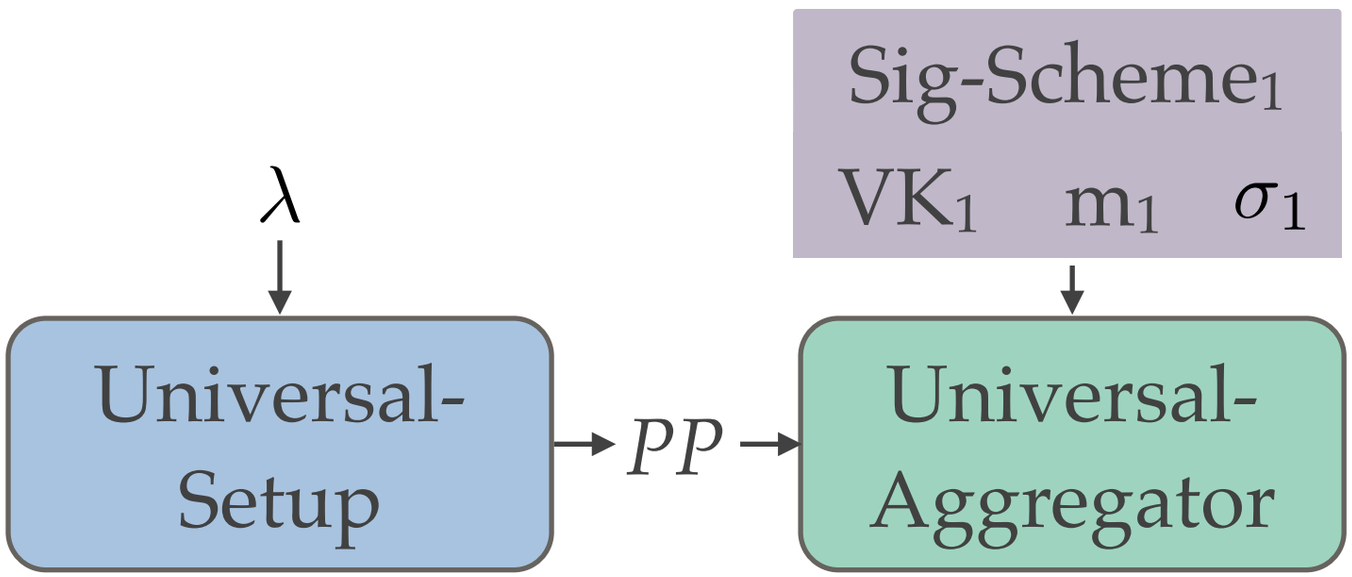

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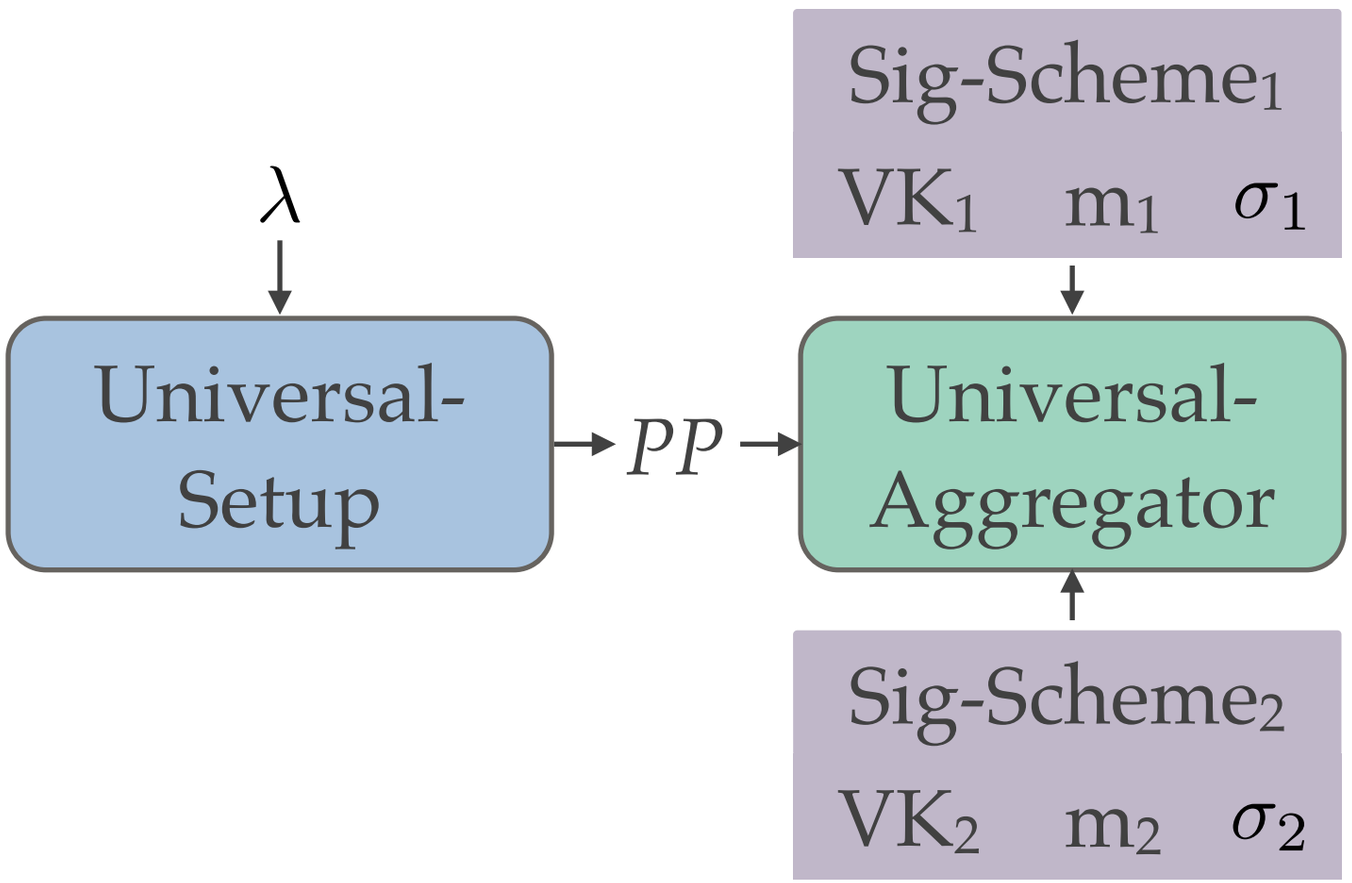

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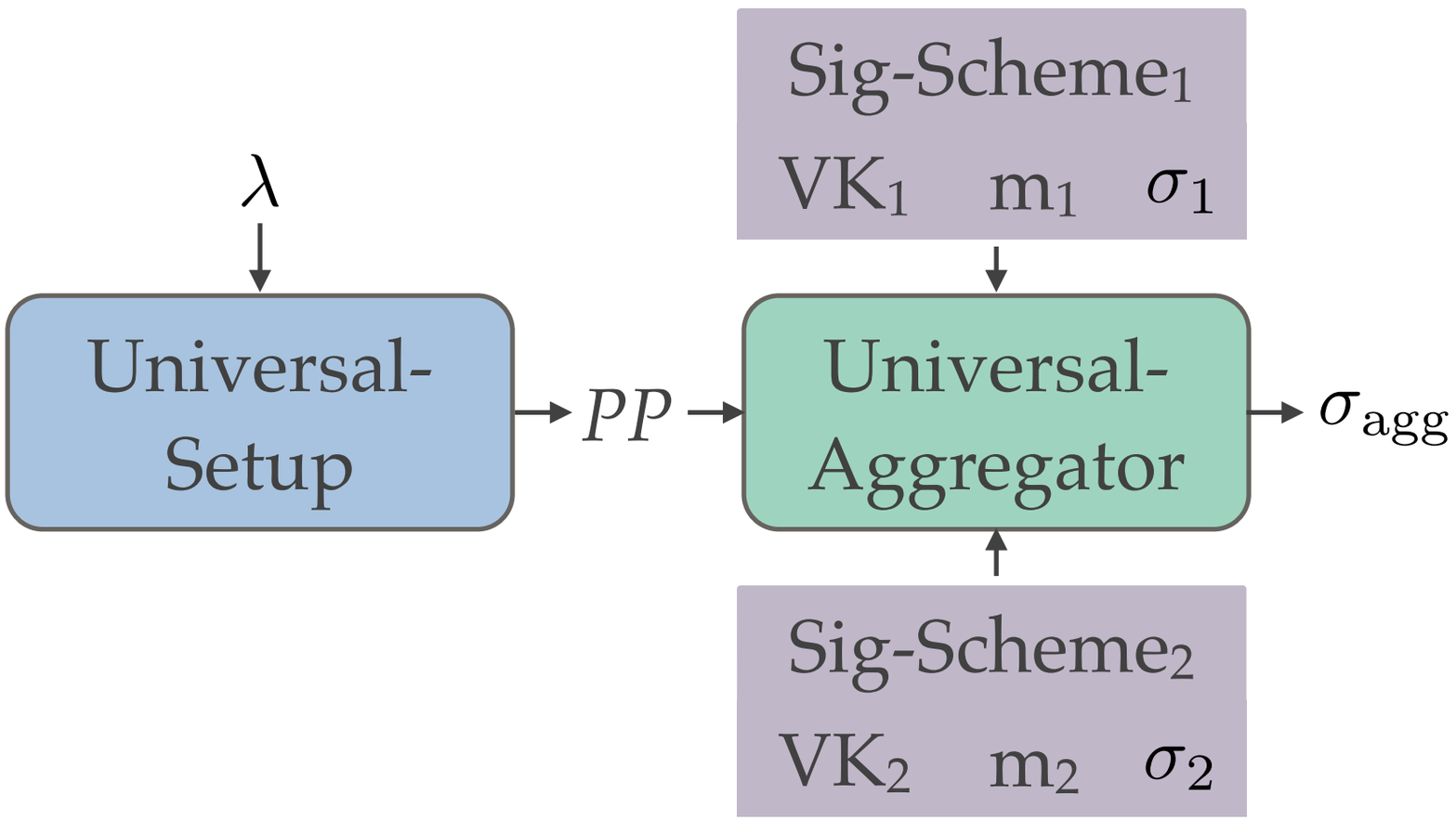

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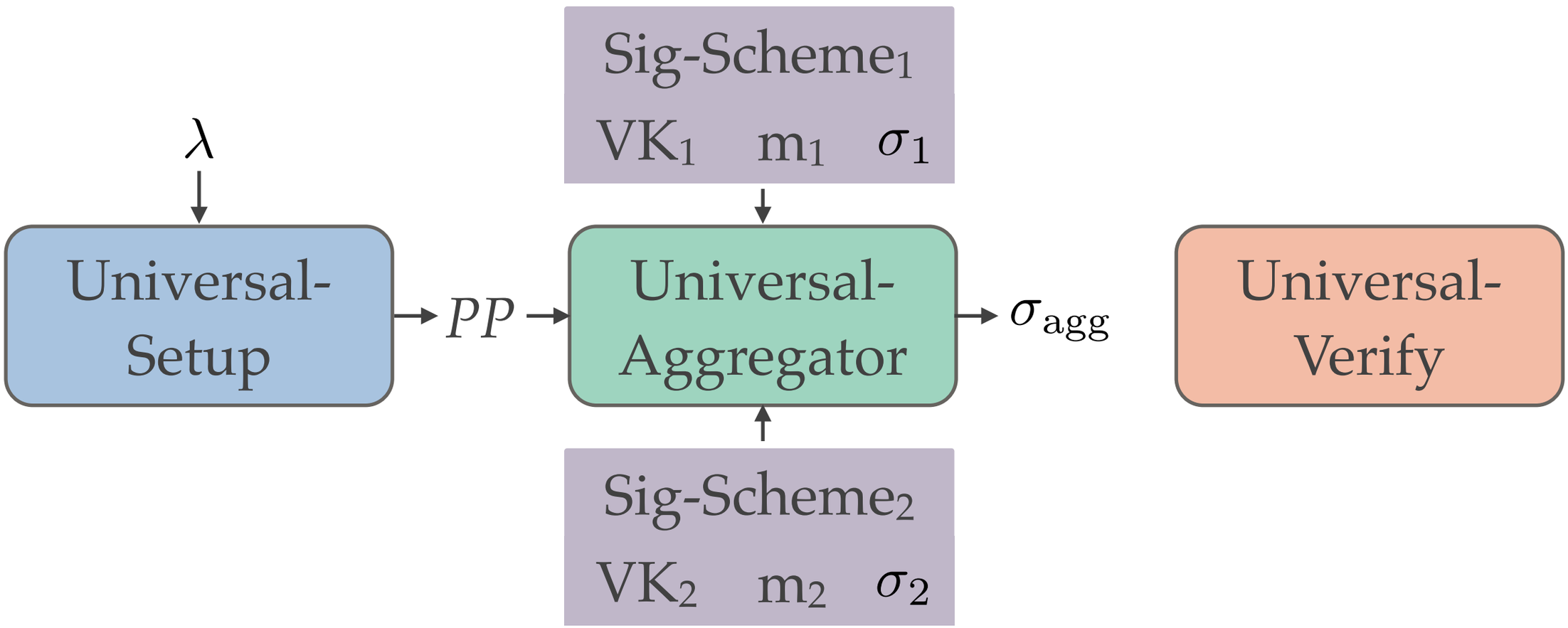

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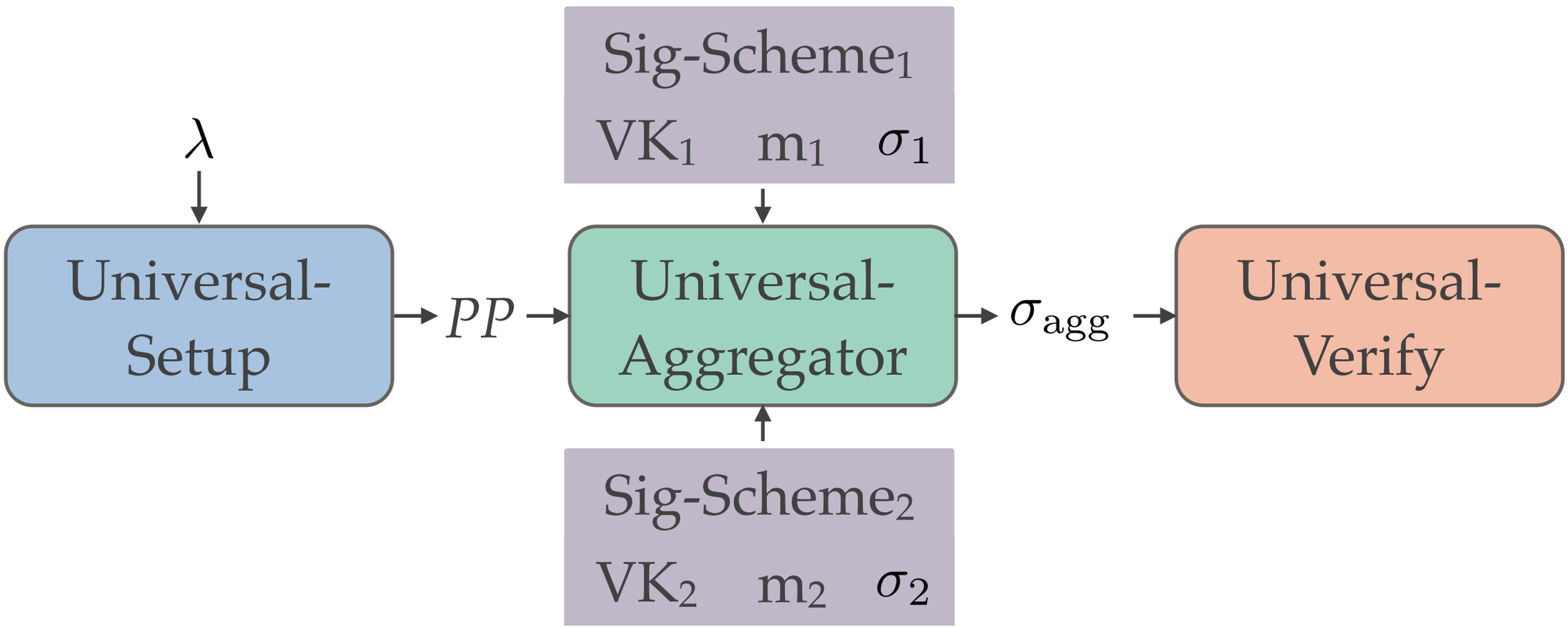

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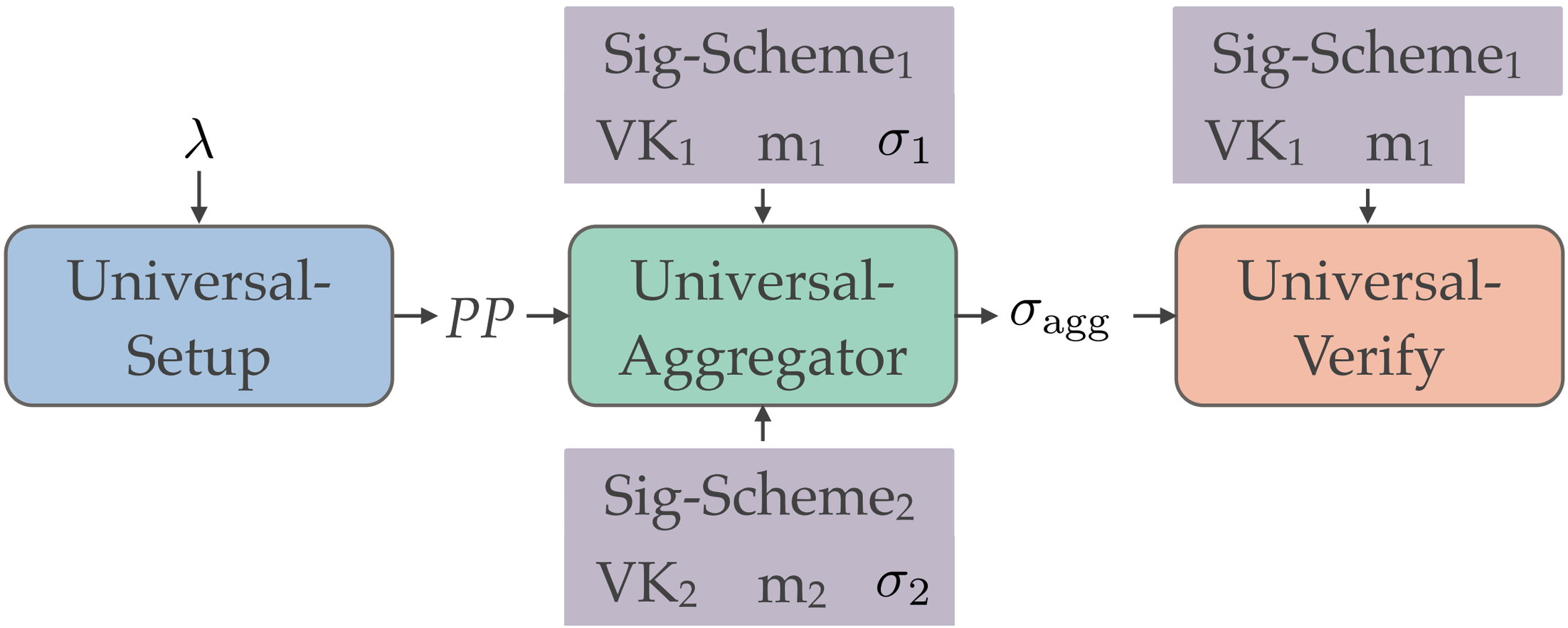

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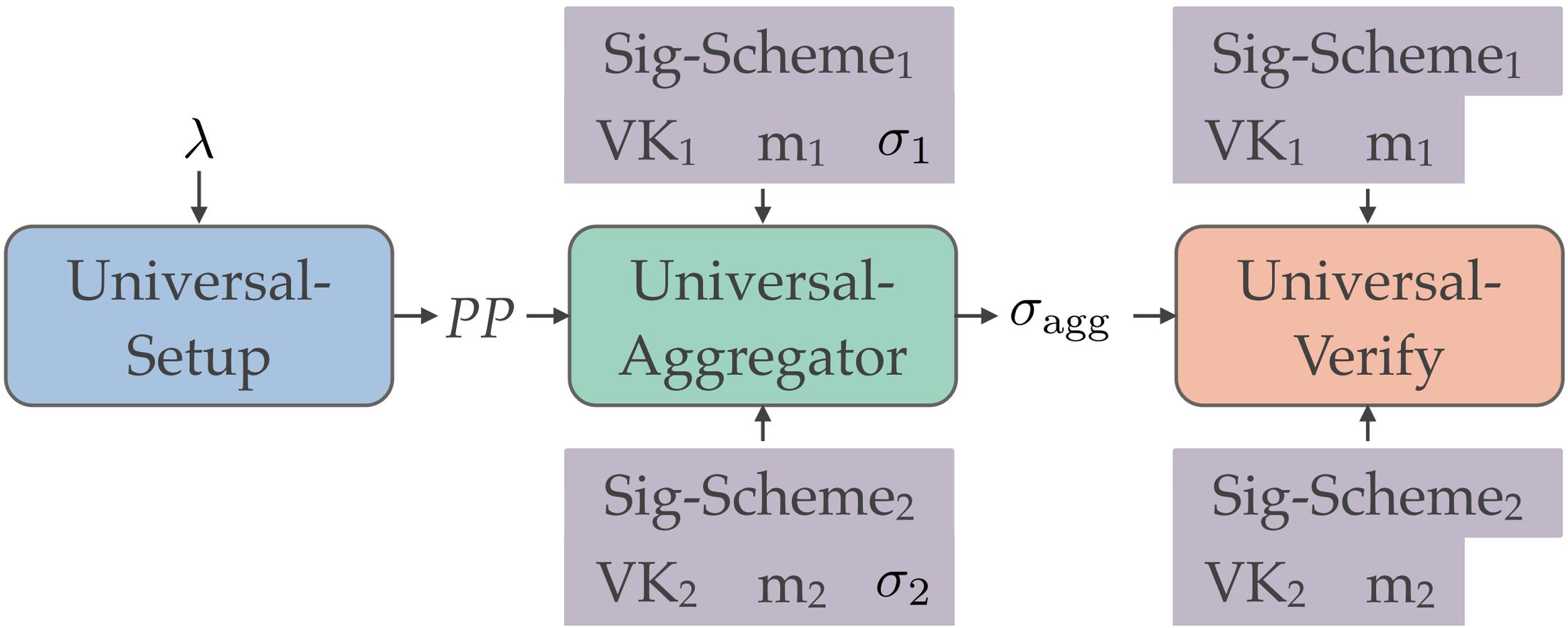

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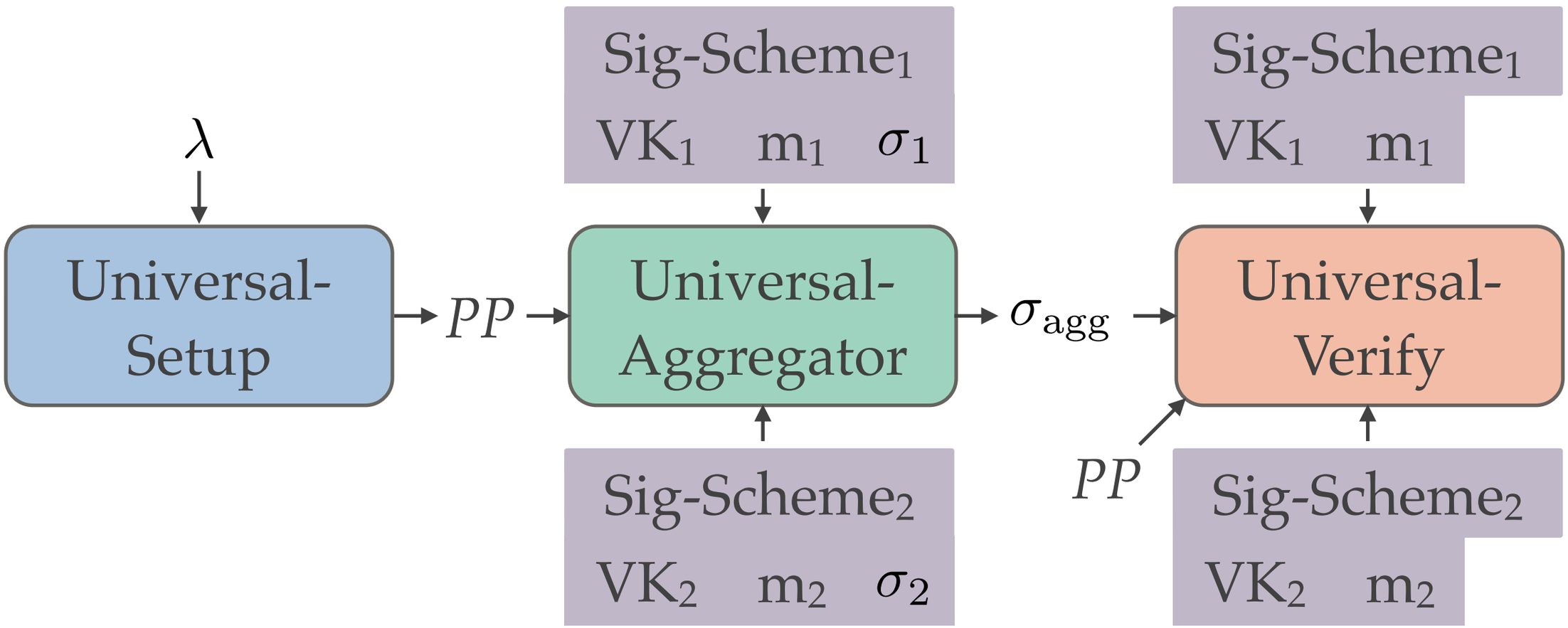

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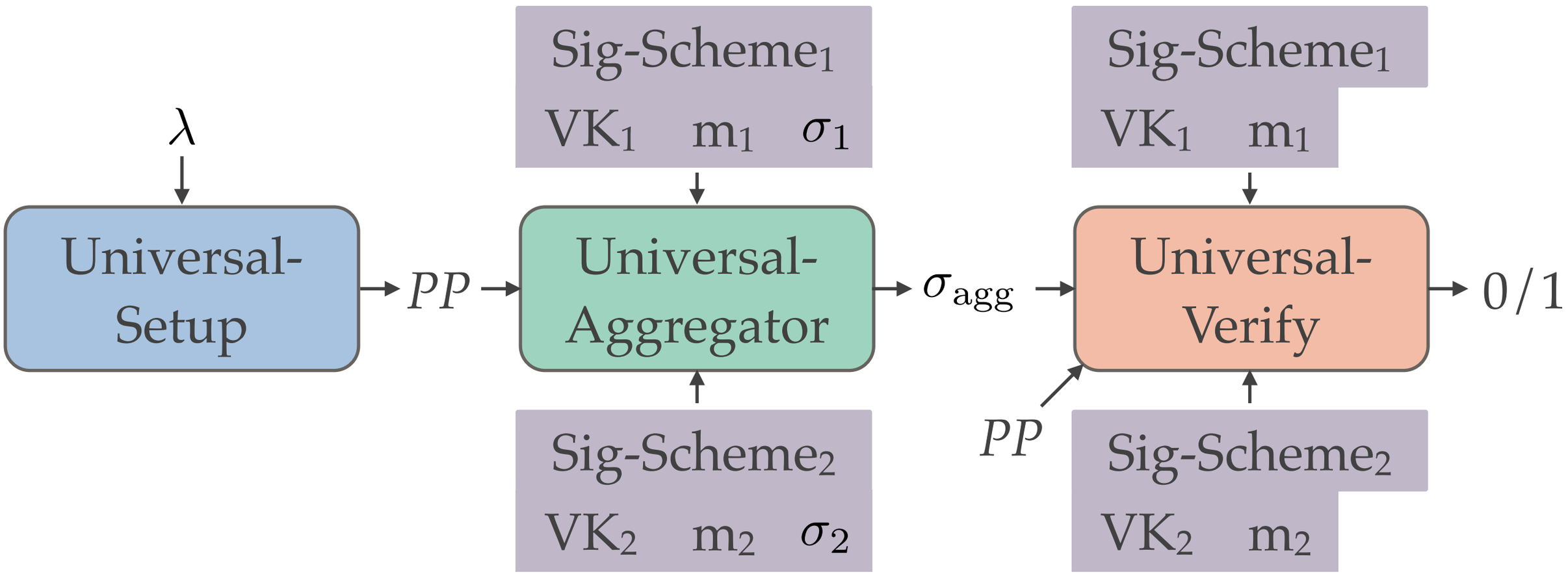

Universal Signature Aggregators

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Correctness

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σ_1, σ_2 are valid signatures for m_1, m_2,

$\Longrightarrow$ Universal-Verify accepts σ_{agg}.

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Size of σ_{agg} depends only on λ
(not on number of signatures aggregated)

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Security

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σ_1, σ_2 are valid signatures for m_1, m_2,

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Succinctness

Size of σ_{agg} depends only on λ
(not on number of signatures aggregated)

Security

"If Sig-Scheme$_1$, Sig-Scheme$_2$ are secure,
then it is hard to fool Universal-Verify"

Universal Signature Aggregators: Security

Security

Universal Signature Aggregators: Security

Security

Att-Scheme = (Setup, Sign, Verify-ckt)

Universal Signature Aggregators: Security

Security

Att-Scheme = (Setup, Sign, Verify-ckt)

(SK, VK) ← Setup

Universal Signature Aggregators: Security

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PP ← Universal-Setup

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$\sigma_i = \text{Sign}(m_i, SK)$

Universal Signature Aggregators: Security

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{ Att-Scheme, m_1^*, VK}

{Scheme$_2$, m_2^*, VK_2^*} … {Scheme$_n$, m_n^*, VK_n^*}

σ_{agg}

Universal Signature Aggregators: Security

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Attacker wins if

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Universal Signature Aggregators: Security

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Att-Scheme = (Setup, Sign, Verify-ckt)

(SK, VK) ← Setup

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PP, VK

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Attacker wins if
- m_1^* not queried

{ Att-Scheme, m_1^*, VK}

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Universal Signature Aggregators: Security

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Att-Scheme = (Setup, Sign, Verify-ckt)

(SK, VK) ← Setup

PP ← Universal-Setup

PP, VK

m_i

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σ_i

Attacker wins if
- m_1^* not queried
- Universal-Verify accepts

{ Att-Scheme, m_1^*, VK}

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σ_{agg}

Universal Signature Aggregators: Security

Selective Security

Att-Scheme = (Setup, Sign, Verify-ckt)

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PP ← Universal-Setup

PP, VK

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Universal Signature Aggregators: Security

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m_1^*

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PP, VK

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σ_{agg}

Challenge in Proving Security

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Cannot assume any algebraic structure in the signatures to be aggregated!

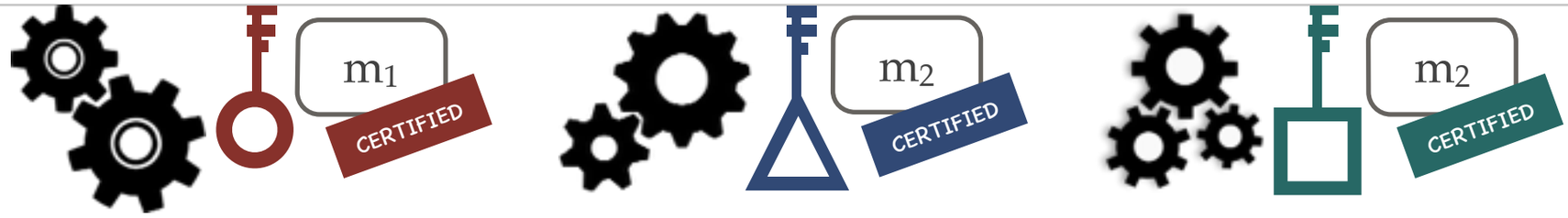
Overview of our Approach

Overview of our Approach

Overview of our Approach

Scheme$_1$ Scheme$_2$

Overview of our Approach



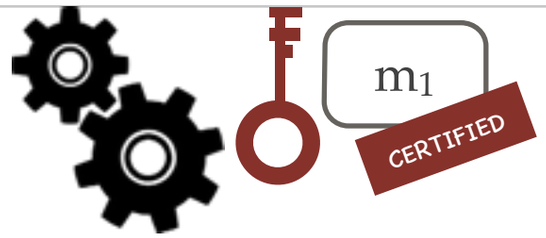
Scheme$_1$ Scheme$_2$ Scheme$_3$

Overview of our Approach

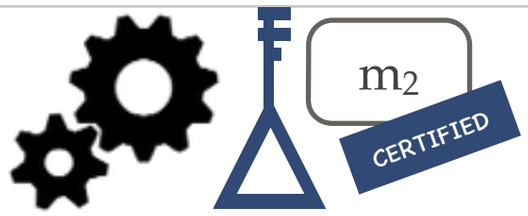
$Scheme_1$ $Scheme_2$ $Scheme_3$

Verify the signatures.

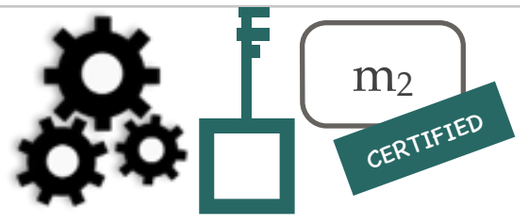
Overview of our Approach



Scheme$_1$

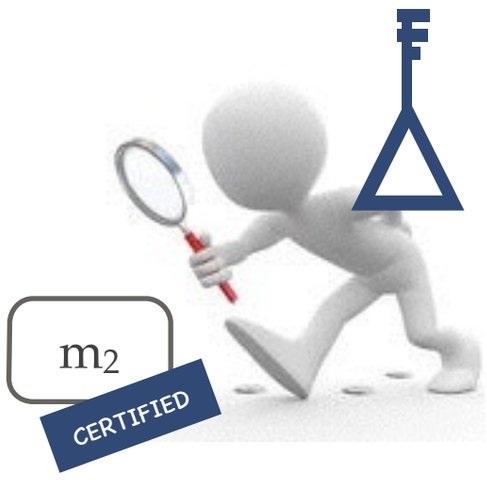


Scheme$_2$



Scheme$_3$

Verify the signatures.



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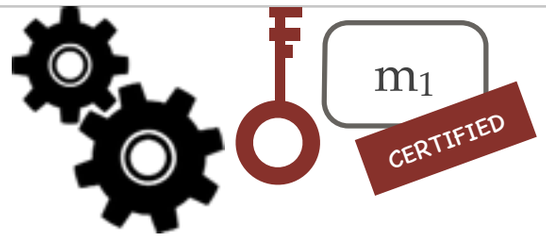

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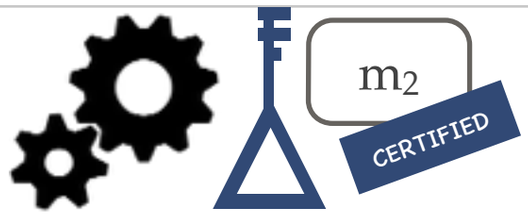

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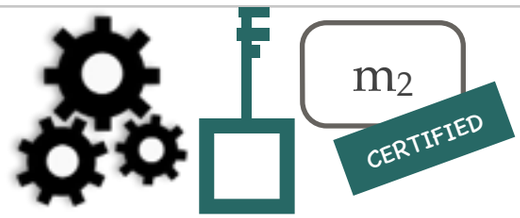

Scheme$_3$

Verify the signatures.

Transform signatures to ‘aggregation-friendly’ form.

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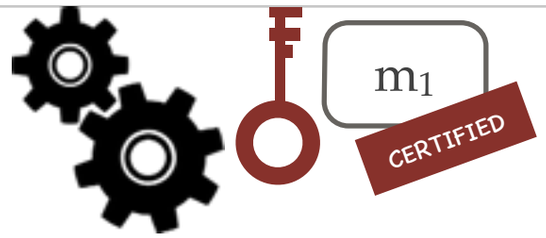

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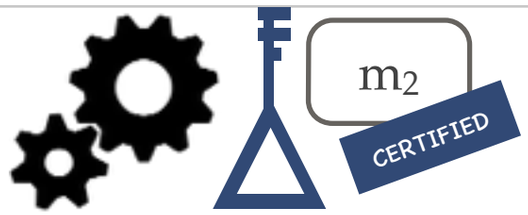
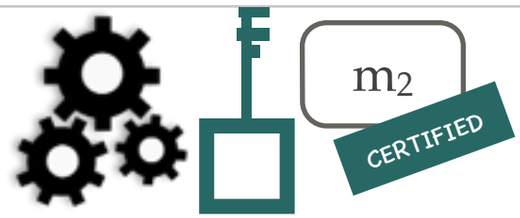
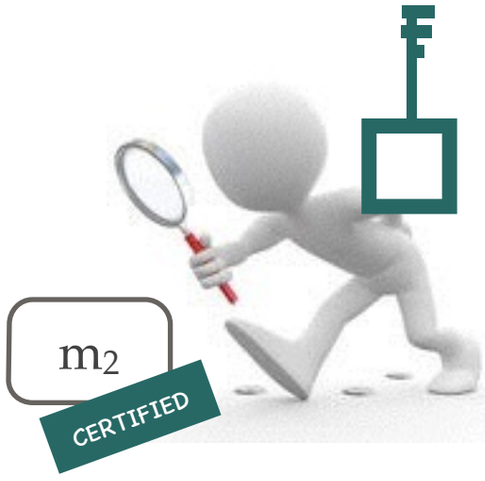


Scheme_2

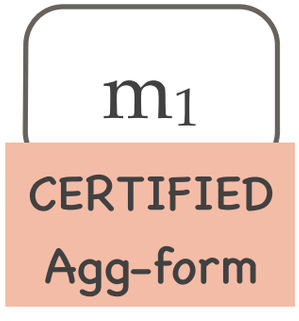


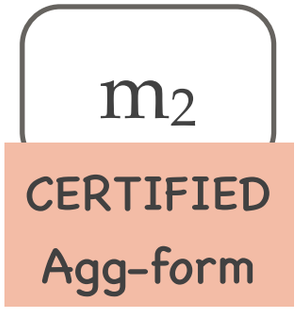
Scheme_3

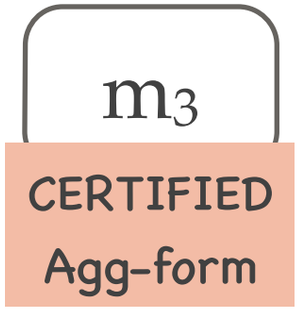
Verify the signatures.



Transform signatures to 'aggregation-friendly' form.







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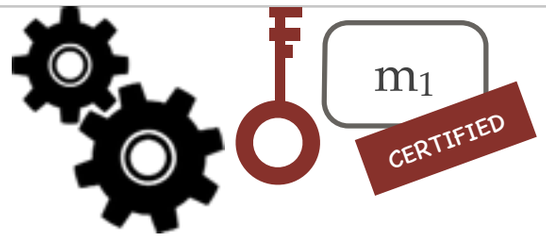

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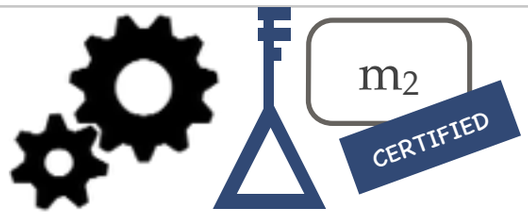
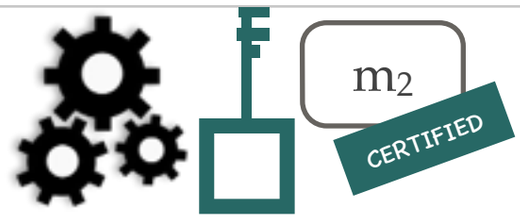


Scheme_2



Scheme_3

Verify the signatures.

Transform signatures to 'aggregation-friendly' form.

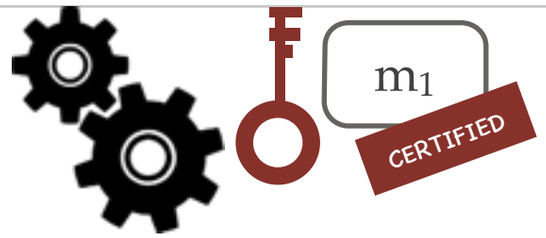
m_1 CERTIFIED Agg-form

m_2 CERTIFIED Agg-form

m_3 CERTIFIED Agg-form

Aggregate!

Overview of our Approach



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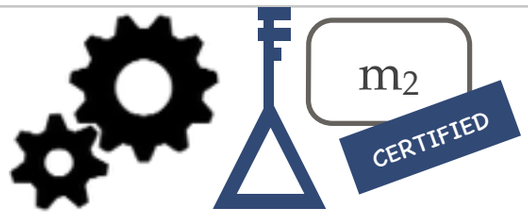
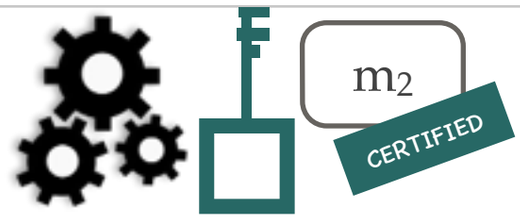


Scheme_2



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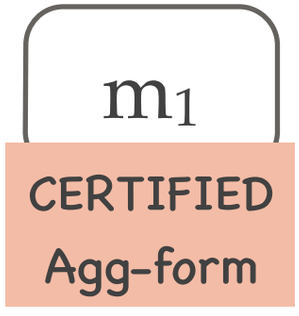

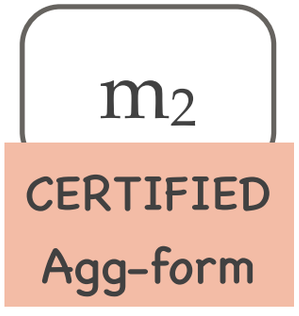

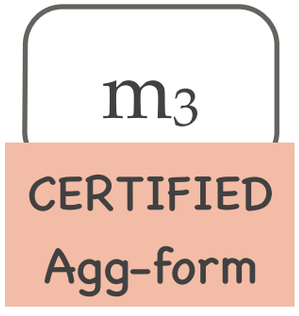

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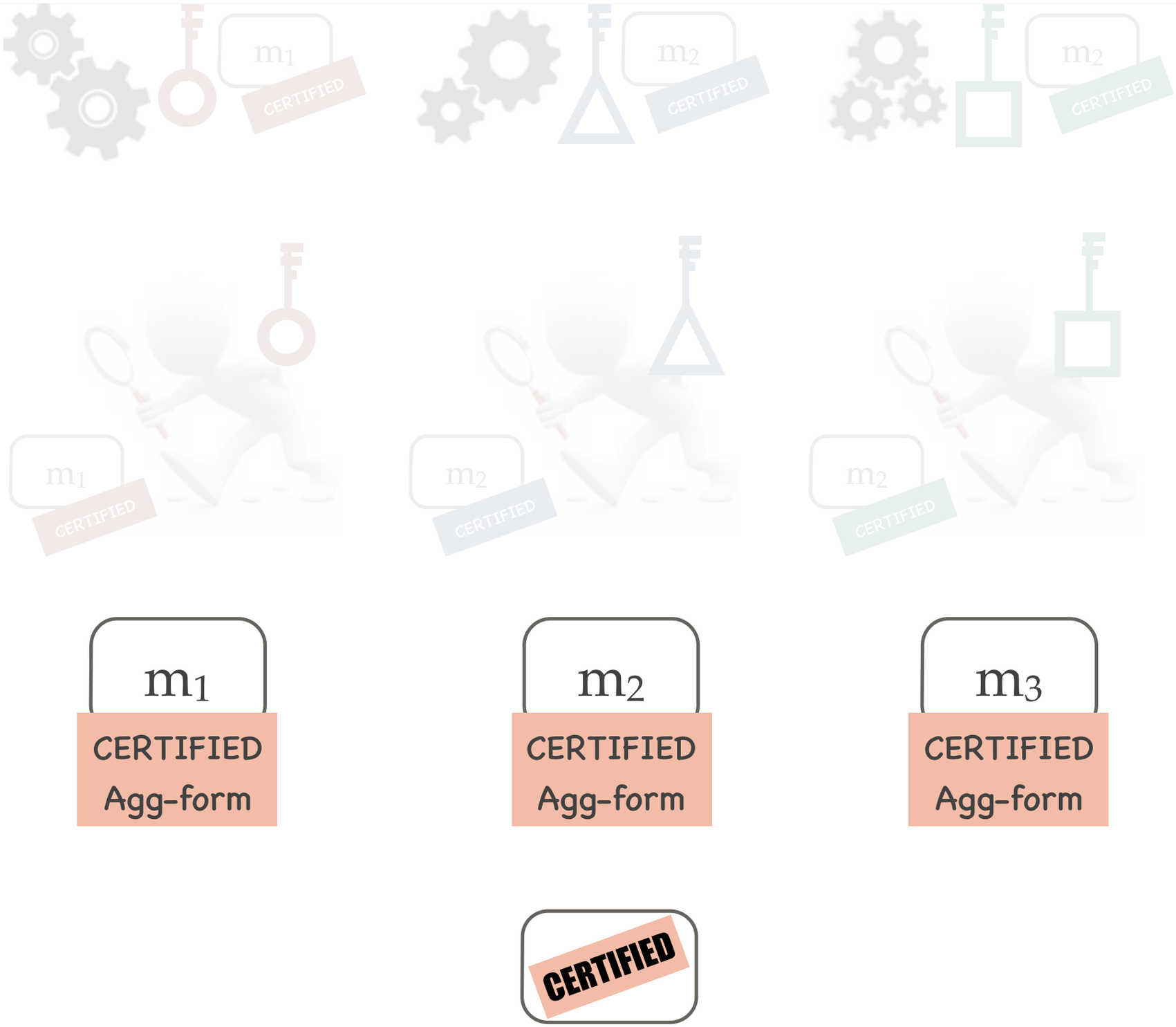

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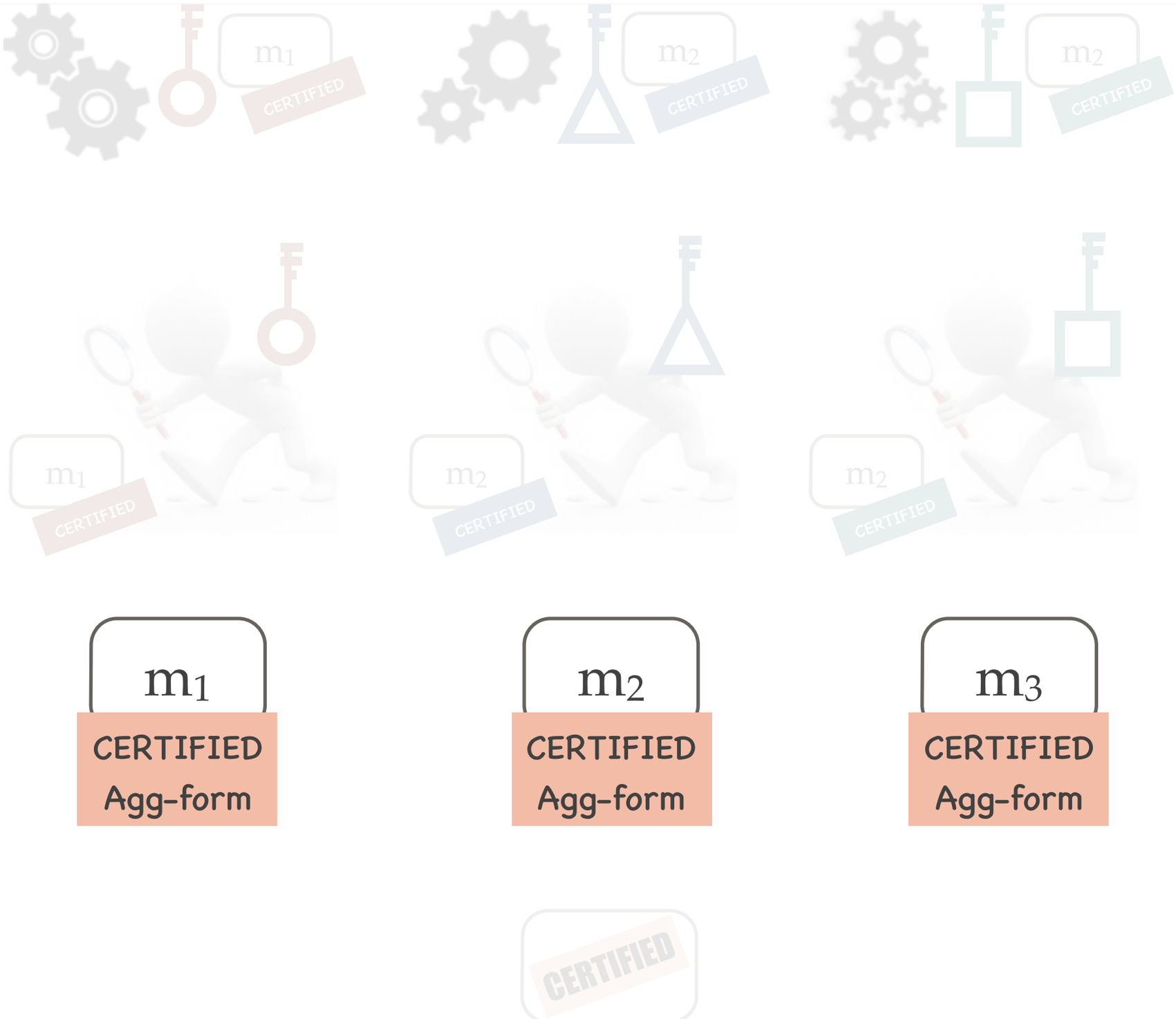

Overview of our Approach

Without SNARKs?

Verify the signatures.

Transform signatures to 'aggregation-friendly' form.

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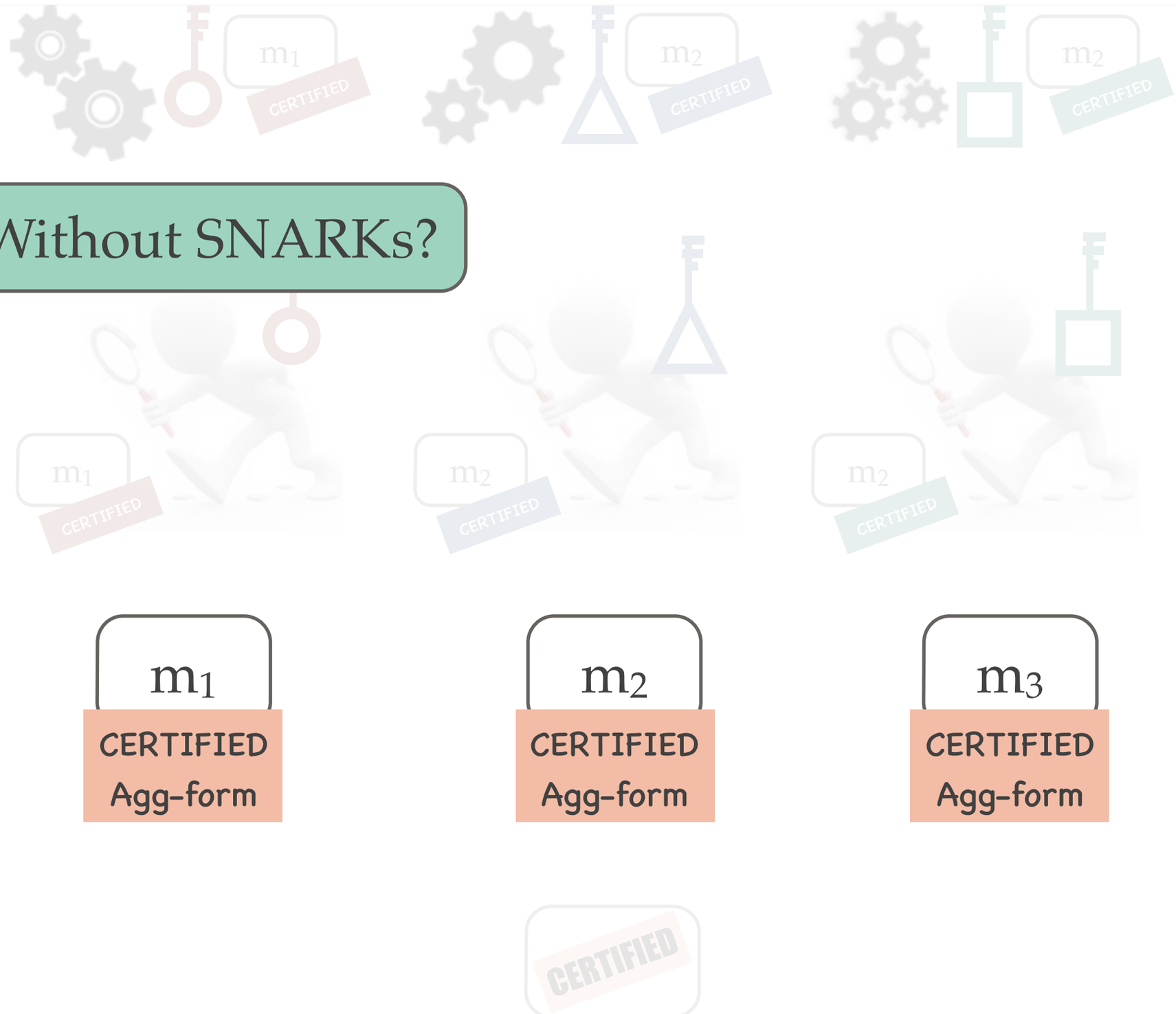

Overview of our Approach

Without SNARKs?

Without knowledge assumptions?

Verify the signatures.

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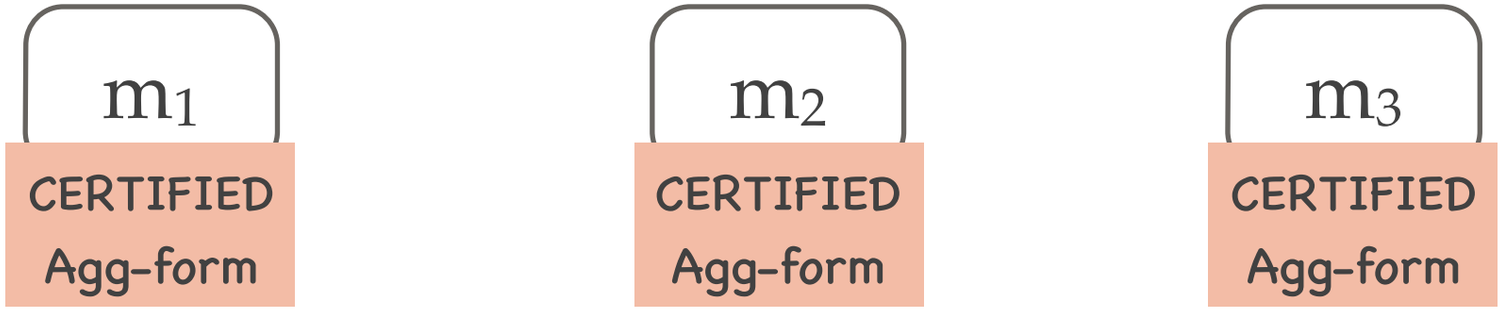

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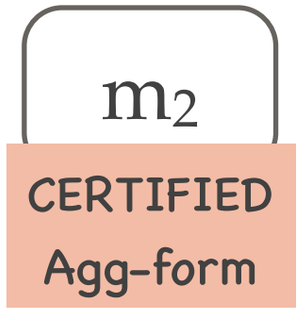

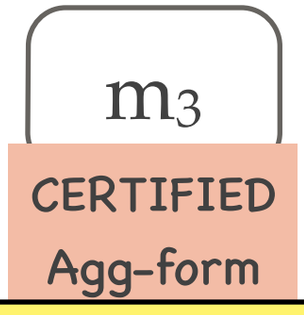

Code Obfuscation!

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Goal: Make programs maximally unintelligible.

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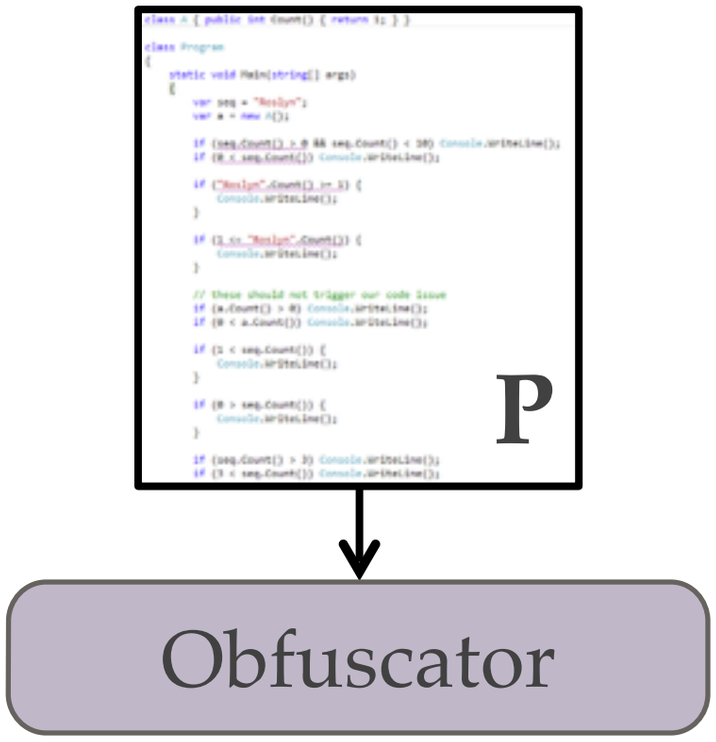

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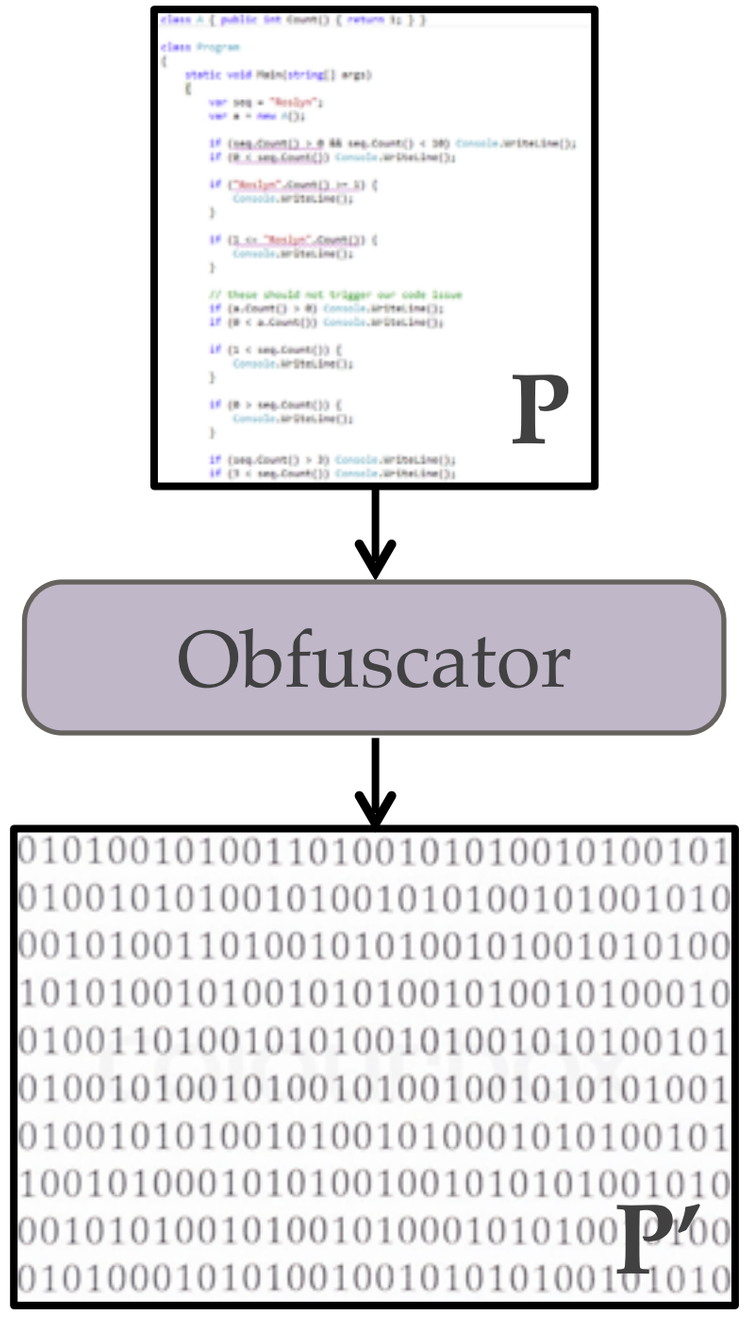

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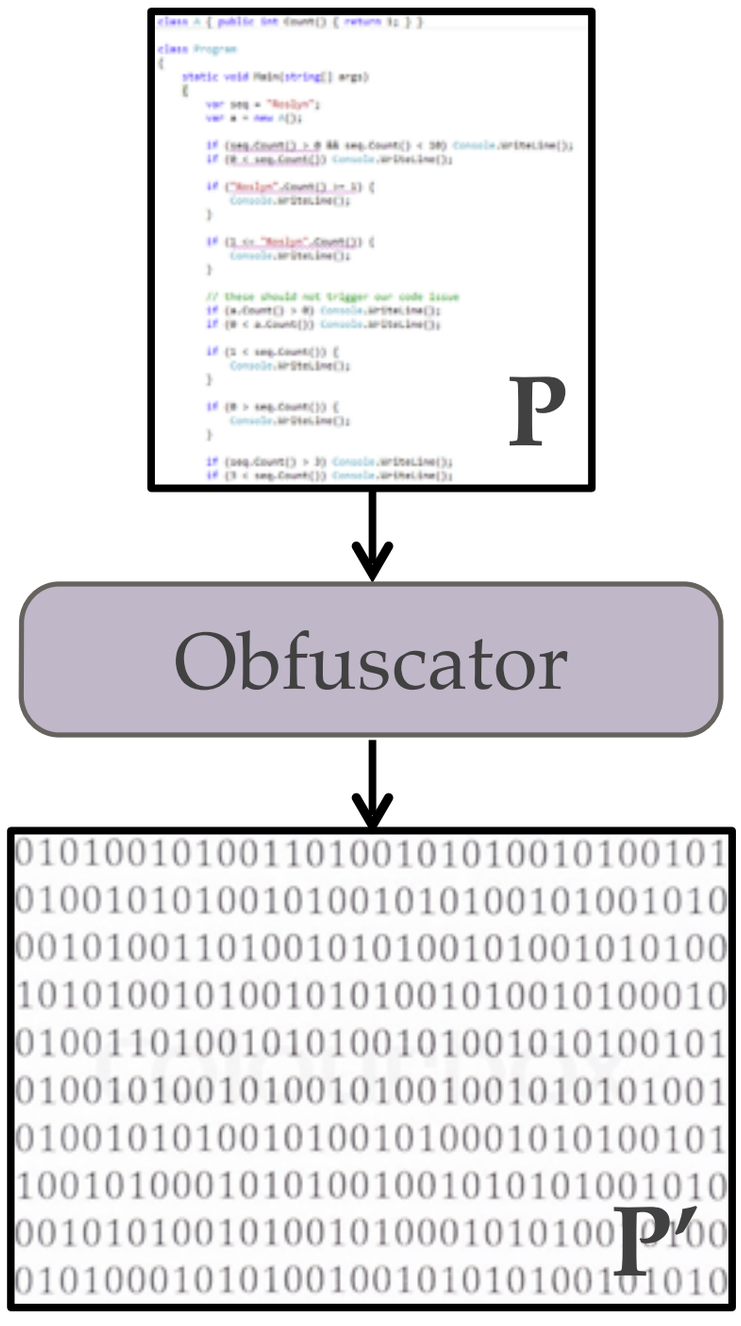

Code Obfuscation

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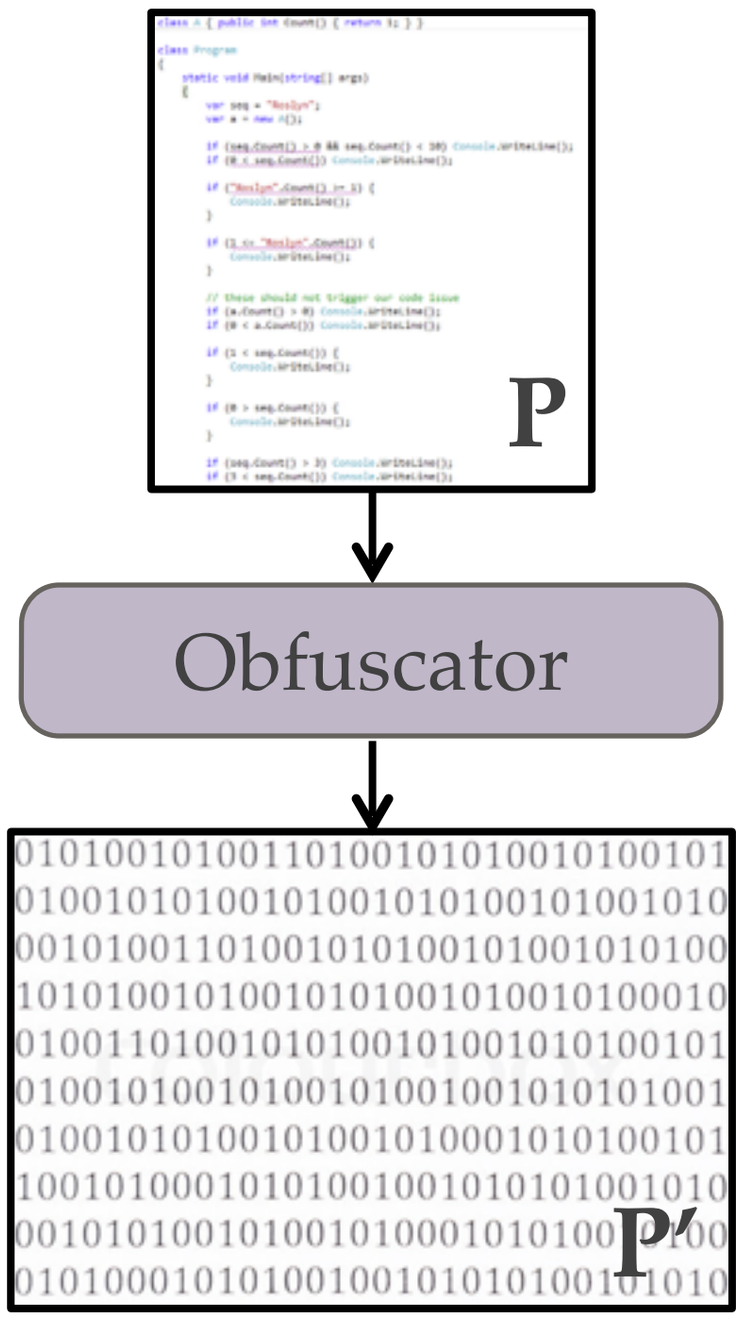
Virtual Black Box Obfuscator

Having obfuscated code

≈

Having black box access to code



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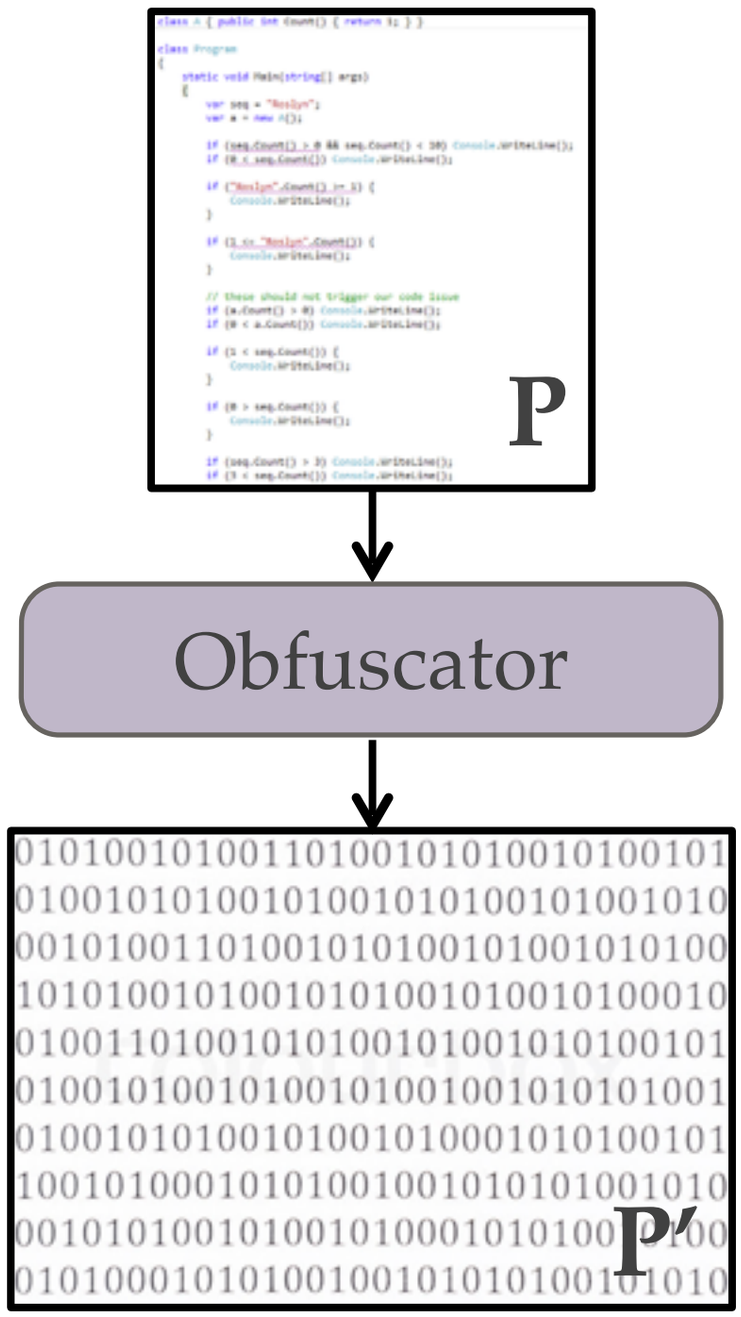

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✘ [BGIRSVY01]

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C_0, C_1 functionally identical circuits.

$iO(C_0) \approx iO(C_1)$

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[BGIRSVY01] negative result does not apply for *iO*.

[GGHRSW13] gave a candidate construction for *iO*.

Our Constructions

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iO + RSA + OWFs

$\Longrightarrow$ Universal Aggregator for unique signature schemes

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Unique Signature Scheme: For every m, VK, there exists exactly one signature that verifies.

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eg. RSA based Full Domain Hash signatures (BR-93)

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RSA: modulus N

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iO

RSA: modulus N

(puncturable) PRF F : {0,1}*$\rightarrow \mathbb{Z}_N^*$

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Universal-Setup

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1.Choose RSA modulus N, exponent e, PRF key K.

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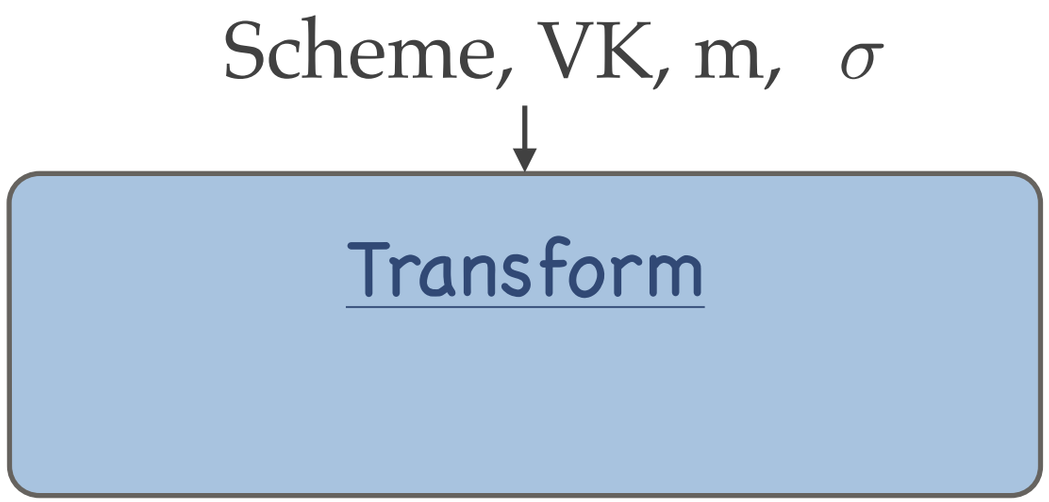

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Scheme, VK, m, σ

↓

Transform

1.Check Verify-ckt(VK, m, σ) = 1

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Scheme, VK, m

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1. Output $F(K, (\text{Scheme}, VK, m))^e$

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Scheme, VK, m

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Inputs: PP = (P_1, P_2, N, e), {($Scheme_i$, VK_i, m_i, σ_i)}

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Universal-Verify

Inputs: $PP = (P_1, P_2, N, e)$, $\{Scheme_i, VK_i, m_i\}$, σ_{agg}

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Scheme, VK, m

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Transform-Verify

1.Output F(K, (Scheme, VK, m))^e

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Inputs: $PP = (P_1, P_2, N, e)$, $\{Scheme_i, VK_i, m_i\}$, σ_{agg}

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1. Compute $s_i = P_2(Scheme_i, VK_i, m_i)$ $\in \mathbb{Z}_N^*$

Scheme, VK, m

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1. Compute $s_i = P_2(Scheme_i, VK_i, m_i)$ ← $\in \mathbb{Z}_N^*$
2. Check $\prod s_i = \sigma_{agg}^e$

Scheme, VK, m

↓

Transform-Verify

1.Output $F(K, (Scheme, VK, m))^e$

Security Proof Idea

Selective proof of security

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1. Check Verify-ckt(VK, m, σ) = 1
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Challenge-tuple fixes unique σ^*.

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Differ on (challenge tuple, σ^*)

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Differ on (challenge tuple, σ^*)

Use  to extract σ^*

Construction 2

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VBB obfuscation + RSA + OWFs

$\Longrightarrow$ Universal Aggregator for **all** signature schemes

Adaptive

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"Oracle Assimilation"

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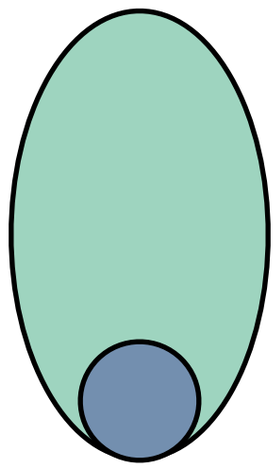

"Oracle Assimilation"

"Partitioning Strategy"

Construction 3

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subexp.

Homomorphic Enc. + iO + OWFs

$\Longrightarrow$ Universal Aggregator* for **all** signature schemes

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* : Can aggregate only a bounded number of signatures

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(puncturable) PRFs : $\{0,1\}^* \rightarrow \{0,1\}^*$

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Thank you!

Questions?

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Transform-Intermediate

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Identical if $\sigma^*[1] = 1$

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~30% win
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~10% win
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