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BETTER.

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Secure Computation -Context Hiding Multi-Key Homomorphic Authenticators

Lucas Schabhüser
Research Assistant
TU Darmstadt

Joint work with Denis Butin, Johannes Buchmann

Organization

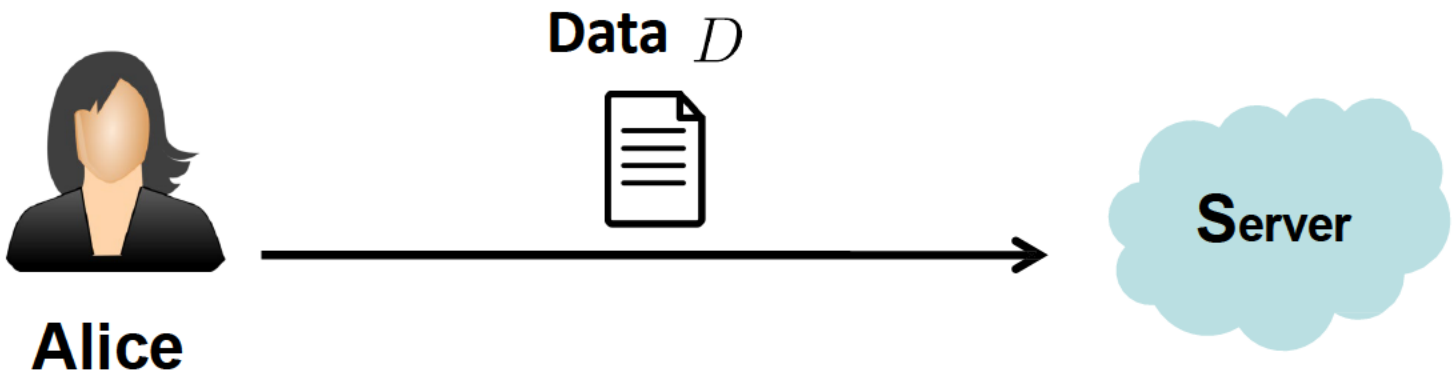
- Motivation
- Homomorphic Authenticators
- Input Privacy with respect to the Verifier
- Our Scheme
- Conclusion

Motivation

Alice

Server

Motivation



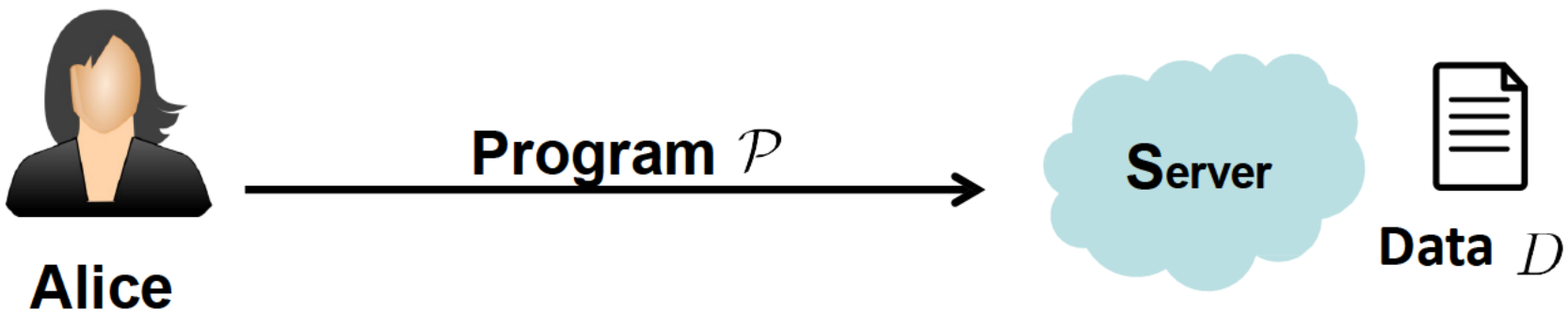
Motivation

Alice

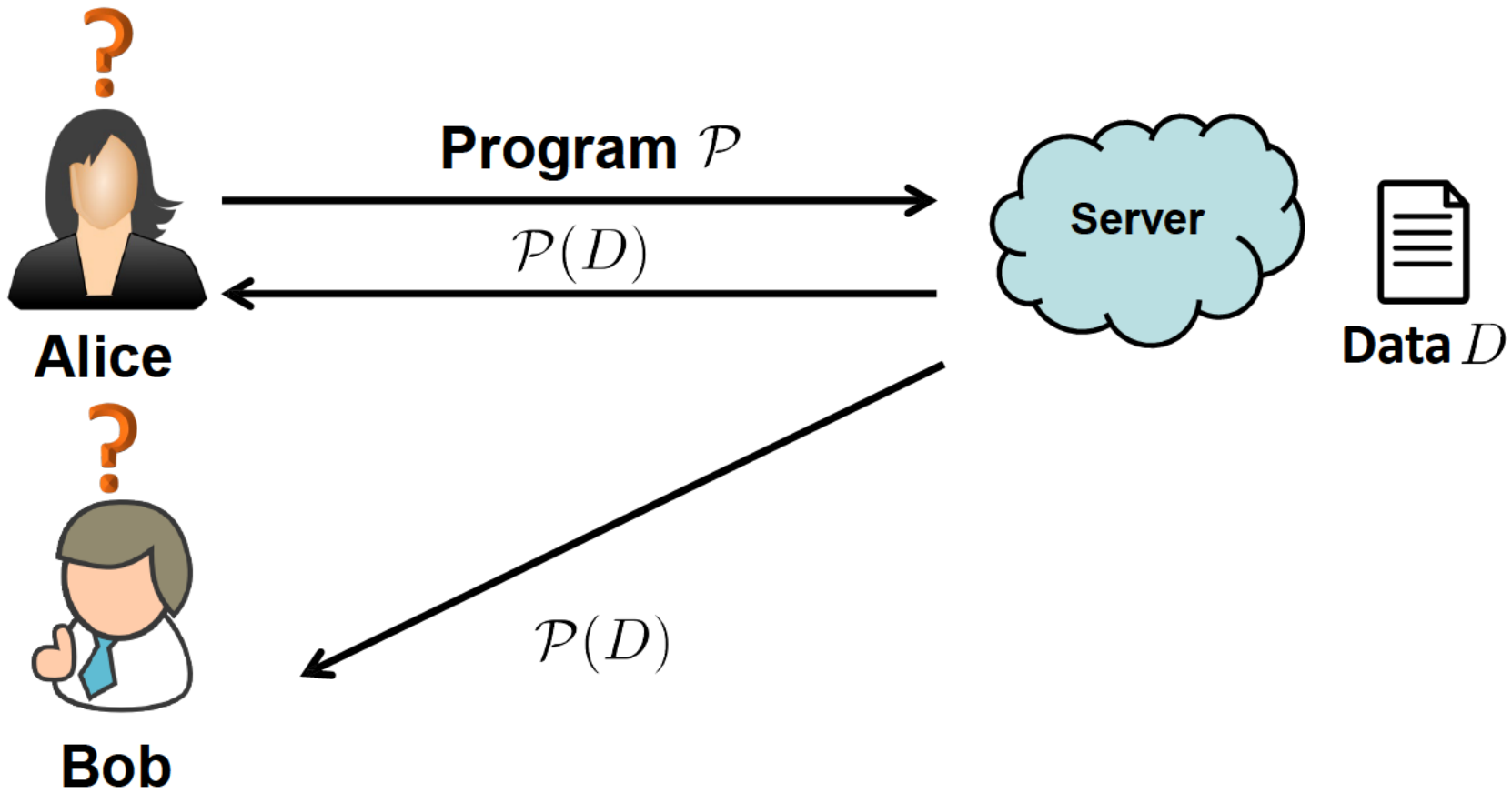
Server

Data D

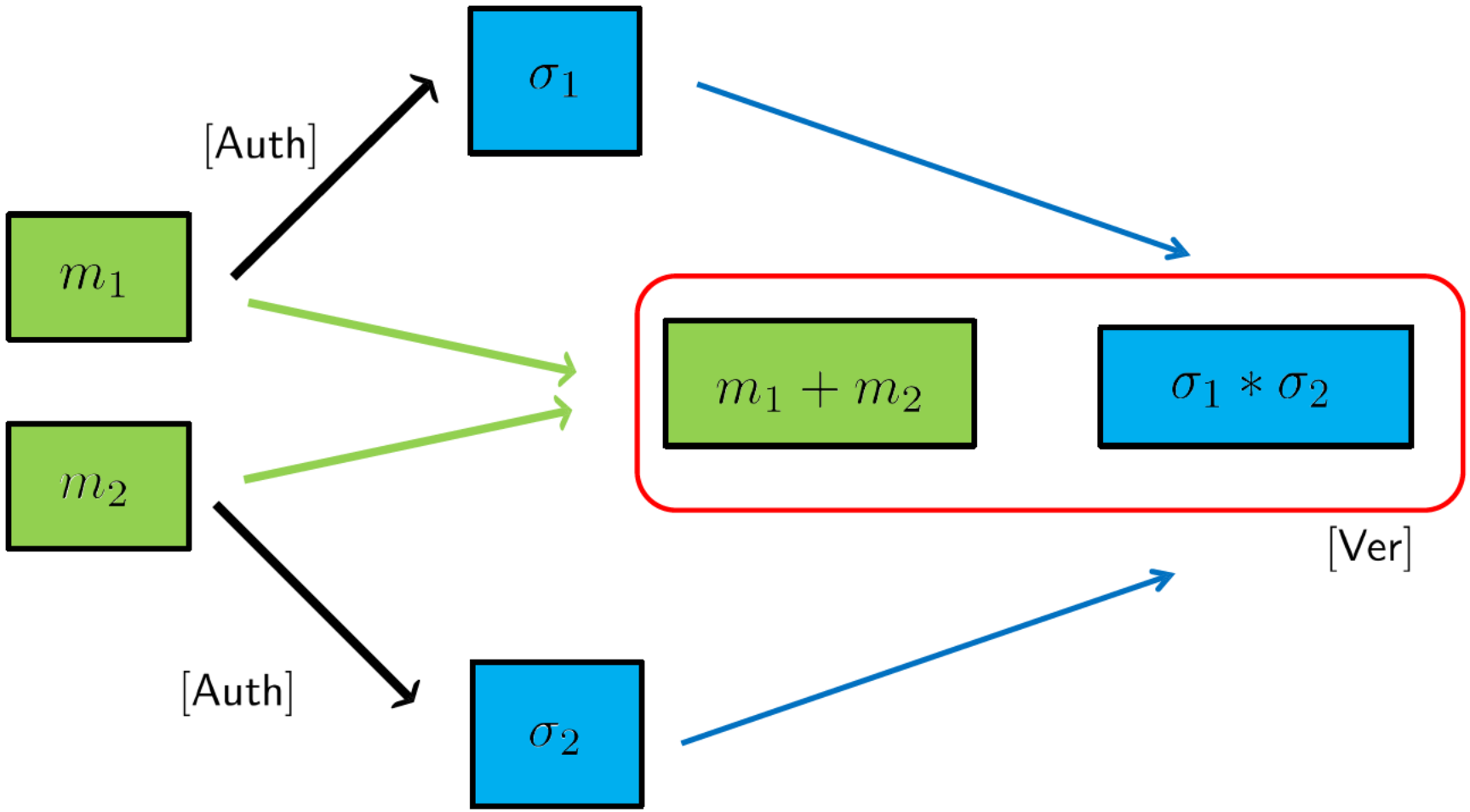
Motivation



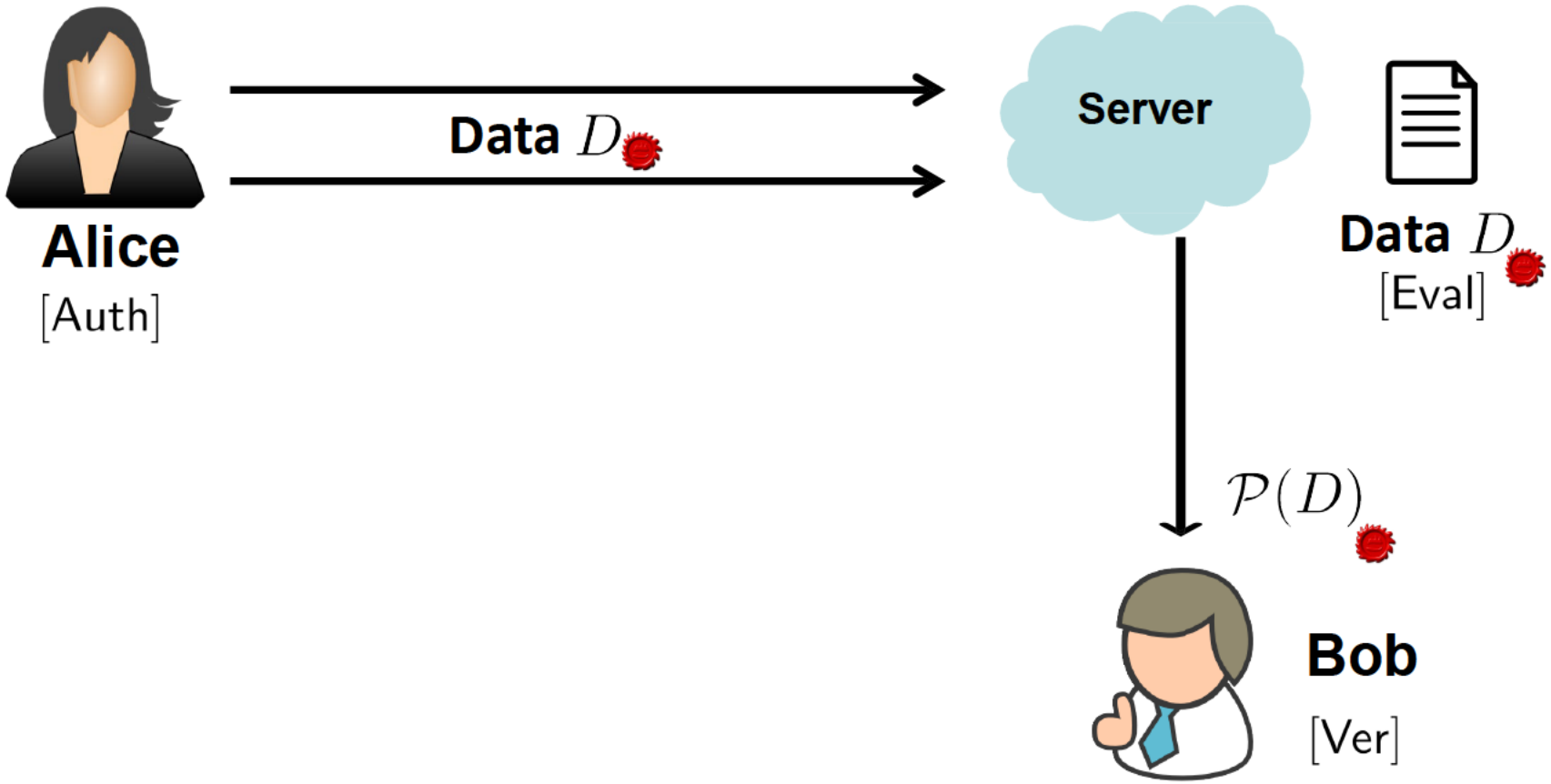
Motivation


Program $\mathcal{P}$
$\mathcal{P}(D)$
Server
Data D
Alice
$\mathcal{P}(D)$
Bob

Homomorphic Authenticators - Intuition



Homomorphic Authenticators



Labeled programs

- Messages are stored in datasets identified by an identifier Δ
- Typically, the dataset size is fixed by a value n
- Functions can only be evaluated over messages in the same dataset

	Δ_1	Δ_2	Δ_3
l_1	m_1	m_1^*	m'_1
l_2	m_2	m_2^*	m'_2
l_3	m_3	m_3^*	m'_3
$\dots$	$\dots$	$\dots$	$\dots$
$\dots$	$\dots$	$\dots$	$\dots$
$\dots$	$\dots$	$\dots$	$\dots$
l_n	m_n	m_n^*	m'_n

Homomorphic Authenticators

$$\text{Setup}: \quad \text{security parameter} \mapsto \text{public parameters}$$

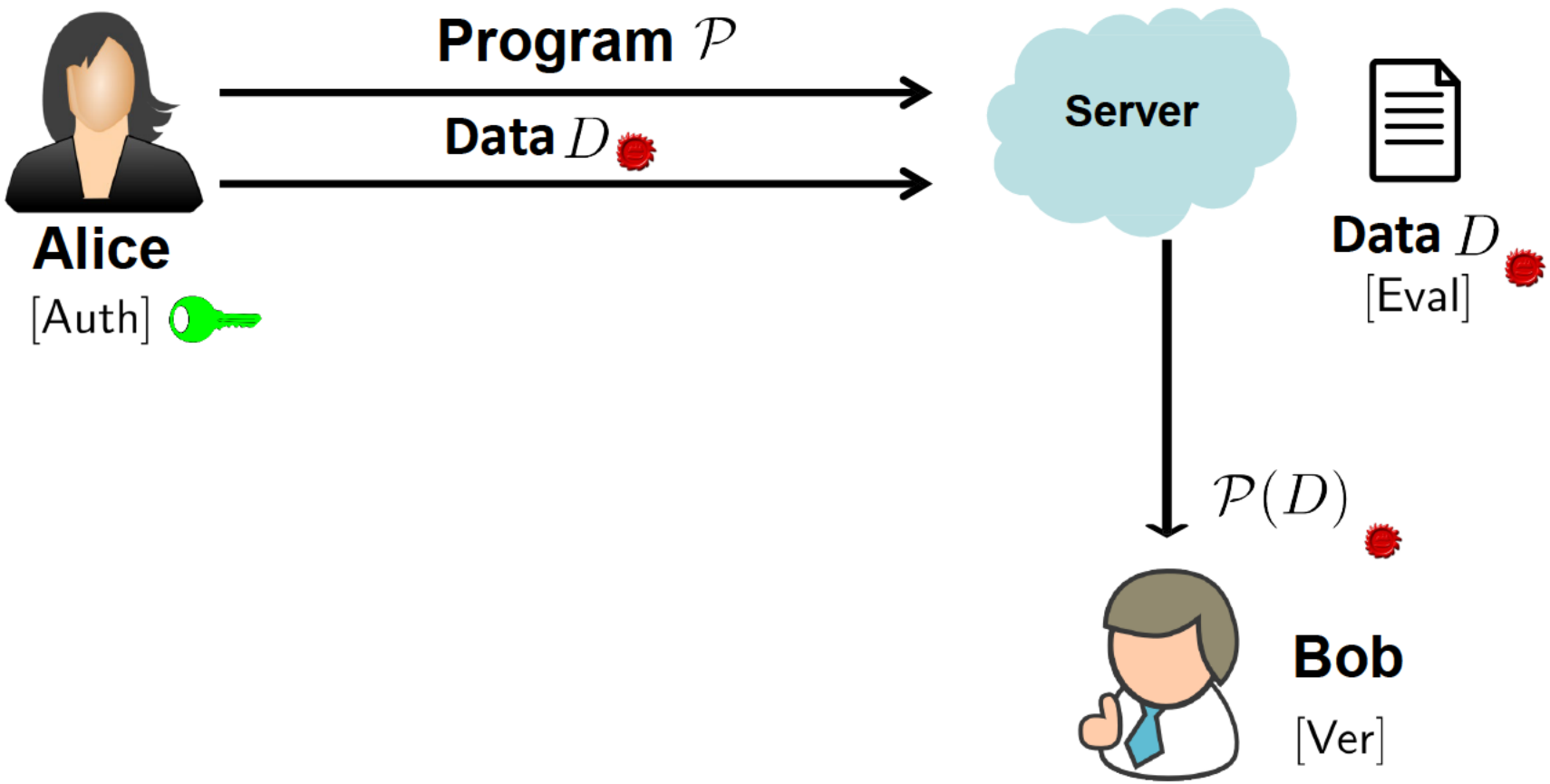
$$\text{KeyGen}: \quad \text{public parameters} \mapsto \text{key triple } (\mathsf{sk}, \mathsf{ek}, \mathsf{vk})$$

$$\text{Auth}: \quad \begin{pmatrix} \text{secret key } \mathsf{sk}, \text{message } m, \\ \text{metadata } l = (\tau, \mathsf{ID}), \Delta) \end{pmatrix} \mapsto \text{authenticator } \sigma$$

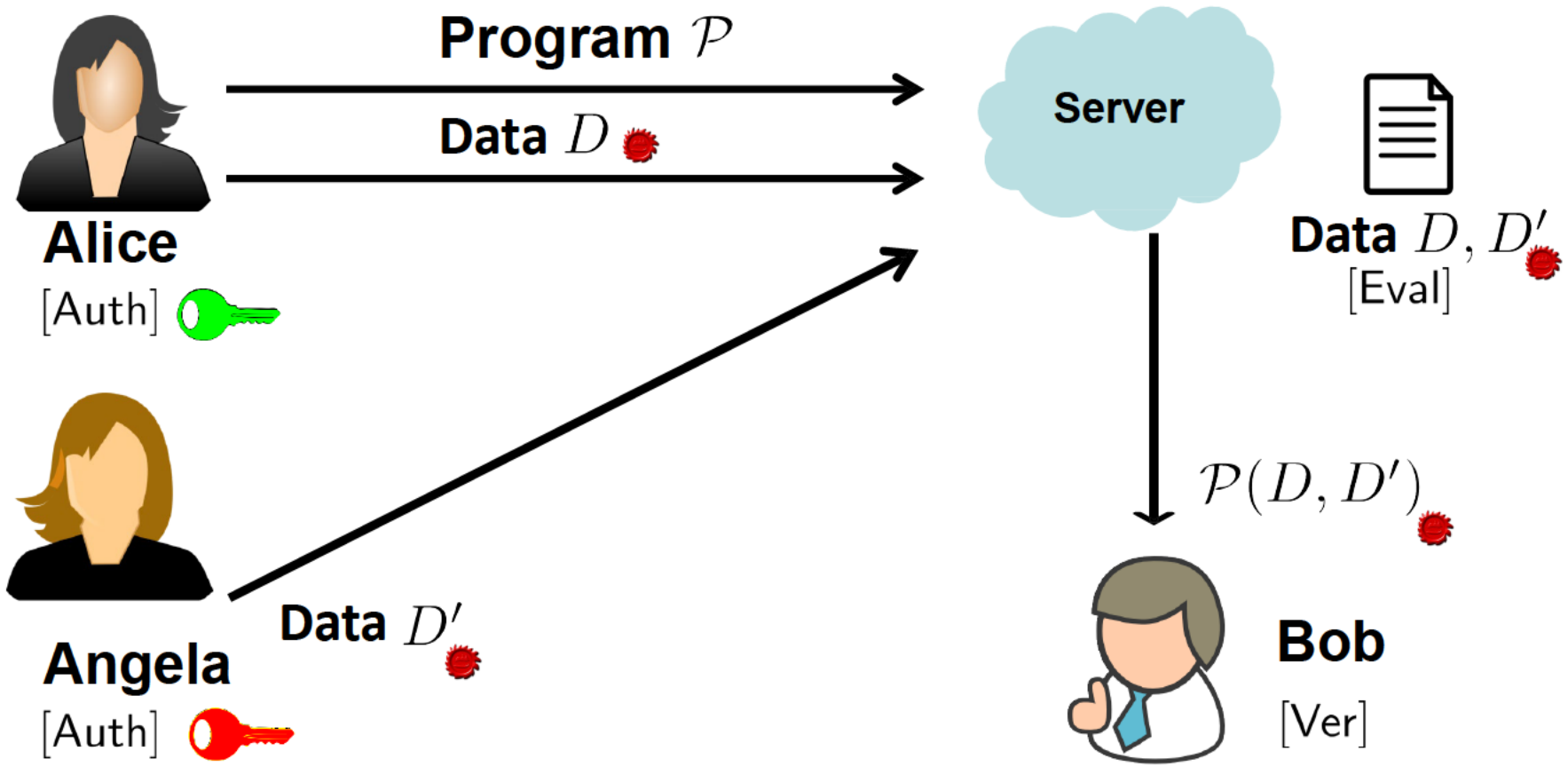
$$\text{Eval}: \quad \begin{pmatrix} \text{public evaluation key } \mathsf{ek}, \text{program } \mathcal{P}_\Delta, \\ \text{authenticators } \sigma_1, \ldots, \sigma_n \end{pmatrix} \mapsto \text{authenticator } \sigma^*$$

$$\text{Ver}: \quad \begin{pmatrix} \text{verification key } \mathsf{vk}, \text{program } \mathcal{P}_\Delta, \\ \text{message } m, \text{authenticator } \sigma \end{pmatrix} \mapsto \text{accept/reject}$$

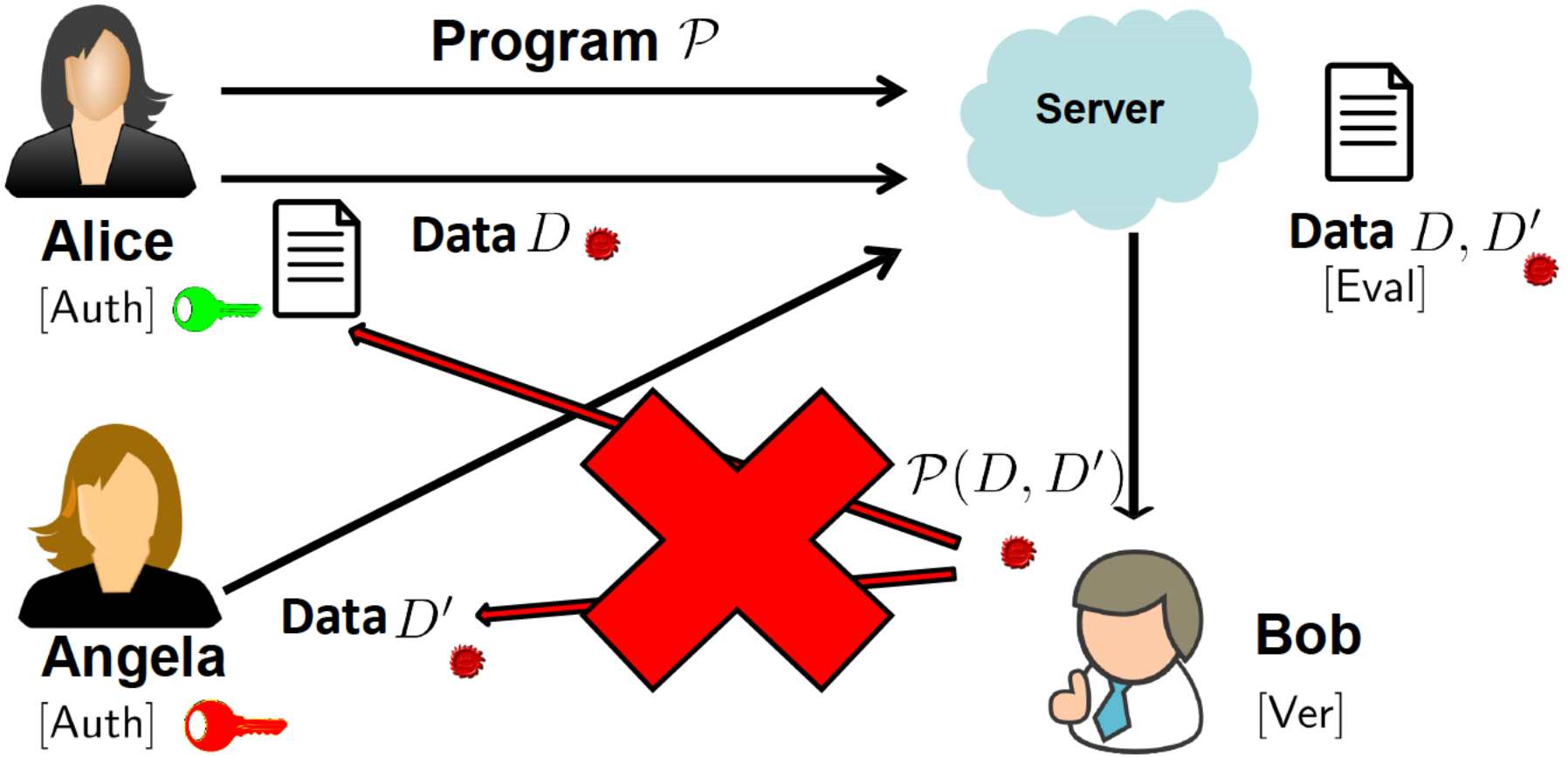
Homomorphic Authenticators



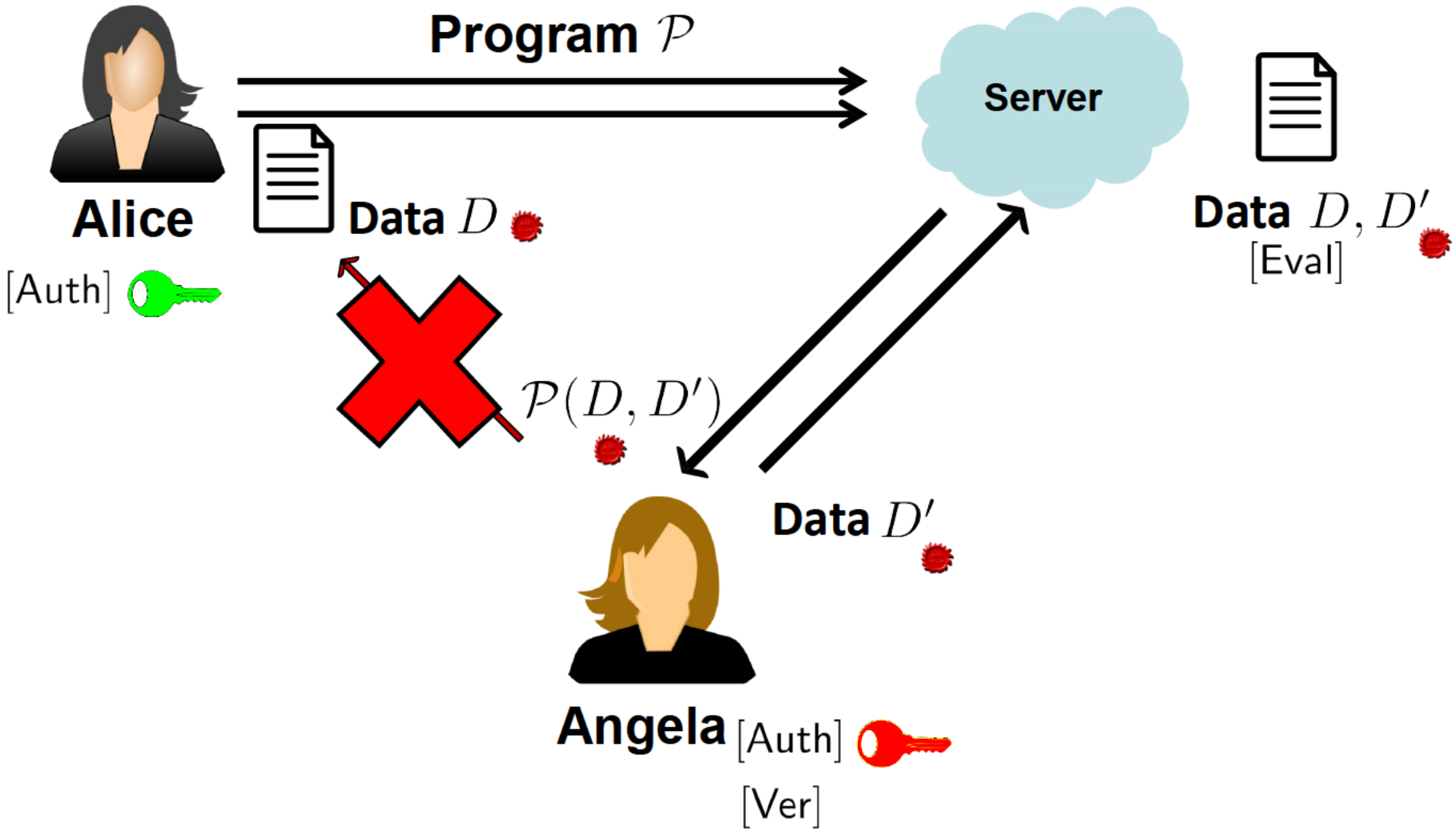
Multi- Key Homomorphic Authenticators



Input Privacy with Respect to the Verifier (external)



Input Privacy with Respect to the Verifier (internal)



Input Privacy with Respect to the Verifier (internal) - Intuition

Not always possible:

Example : $\mathsf{ID}_1 : m$
$\mathsf{ID}_2 : m'$
$m^* = m + m'$

Example: $\mathsf{ID}_1 : m_1, \ldots, m_{365}$
$\mathsf{ID}_2 : m'_1, \ldots, m'_{365}$
$\mathsf{ID}_3 : \hat{m}_1, \ldots, \hat{m}_{365}$
$m^* = m_1 + \ldots + m_{365} + m'_1 + \ldots + m'_{365} + \hat{m}_1 + \ldots + \hat{m}_{365}$

ID_2 can learn $m_1 + \ldots + m_{365} + \hat{m}_1 + \ldots + \hat{m}_{365}$

but not about individual $m_i, \hat{m}_i$

Our Solution

- A new multi-key linearly homomorphic signature scheme:
  - Supports linear functions
  - Unforgeable under DL, DDH and FDHI [CFN15] assumption
  - First multi-key homomorphic authenticator scheme to provide input privacy w.r.t. the verifier
    - both external and internal
    - even information theoretic input privacy

Our Solution – Comparison with State of the Art

	Functions	Privacy	Signature Size	Verification	Security
[ABBF10]	Linear	×	O(#ID)	O(#Inputs)	Pairings
[FMNP16]	Boolean Circuits	×	O(#ID)	O(#ID)	Lattices
[LTWC18]	Depends	Depends	Depends ≥O(#ID)	Depends ≥O(#Inputs)	SNARKs
This scheme	Linear	✓	O(#ID)	O(#ID)	Pairings

Our Solution - Efficiency

- Succinctness:
  - Authenticators size independent of number of inputs
  - Authenticators of size O(#ID)
- Efficient Verification
  - After a function-dependent preprocessing
    - Verification time independent of number of inputs
    - Verification in time O(#ID)

Our Solution – Signature Size

$$e : \mathbb{G}_1 \times \mathbb{G}_2 \to \mathbb{G}_t$$

$\mathsf{Auth}(\mathsf{sk}, \Delta, l_i, m_i) \mapsto \sigma_i$ (regular signature: 1, $\mathbb{G}_2$: 2, $\mathbb{G}_1$: 3)

$\mathsf{Eval}(\mathsf{ek}, \mathcal{P}_\Delta, \sigma_1, \ldots, \sigma_n) \mapsto \sigma^*$ (regular signature: #ID, $\mathbb{G}_2$: #ID+1, $\mathbb{G}_1$: 2#ID+1)

Our Solution – High Level Intuition

$\mathcal{P}$ = Aggregation: $m^* = m_1 + \ldots + m_{365} + m'_1 + \ldots + m'_{365} + \hat{m}_1 + \ldots + \hat{m}_{365}$

σ^* : 3 regular signatures and 3 $\mathbb{G}_2$ elements

2 $\mathbb{G}_1$ elements associated to ID_1

$m_1 + \ldots + m_{365}$ metadata

r_{ID_1}, s_{ID_1}

2 $\mathbb{G}_1$ elements associated to ID_2

$m'_1 + \ldots + m'_{365}$ metadata

r_{ID_2}, s_{ID_2}

2 $\mathbb{G}_1$ elements associated to ID_3

$\hat{m}_1 + \ldots + \hat{m}_{365}$ metadata

r_{ID_3}, s_{ID_3}

Global $\mathbb{G}_1$ element

$r_{\mathsf{ID}_1} + r_{\mathsf{ID}_2} + r_{\mathsf{ID}_3}$

Global $\mathbb{G}_2$ element

$s_{\mathsf{ID}_1} + s_{\mathsf{ID}_2} + s_{\mathsf{ID}_3}$

Summary

- Introduced new notion of input privacy in the multi-key setting
- New scheme
  - First multi-key homomorphic authenticator scheme to achieve any type of input privacy w.r.t. the verifier
  - Input privacy even in an information theoretic sense
  - Amortized efficiency + succinctness

Open Problems

- Achieving a stronger form of succinctness
  - Size independent of **both** number of inputs and number of identities
- Achieving a stronger form of efficient verification
  - Verification time independent of **both** number of inputs and number of identities
- Multi-key homomorphic authenticators with input privacy beyond the linear case

Conclusion

Thank you for your attention!

Questions?