Short Identity-Based Signatures with Tight Security from Lattices

Jiaxin Pan NTNU

Benedikt Wagner KIT Karlsruhe Institute of Technology

Digital Signatures in Practice

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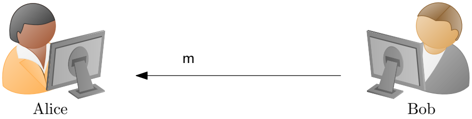

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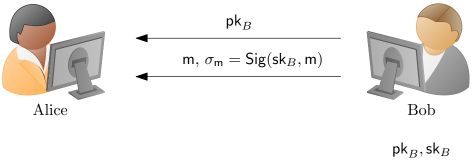

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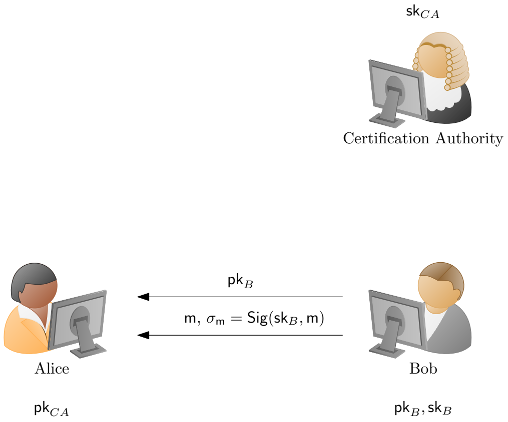

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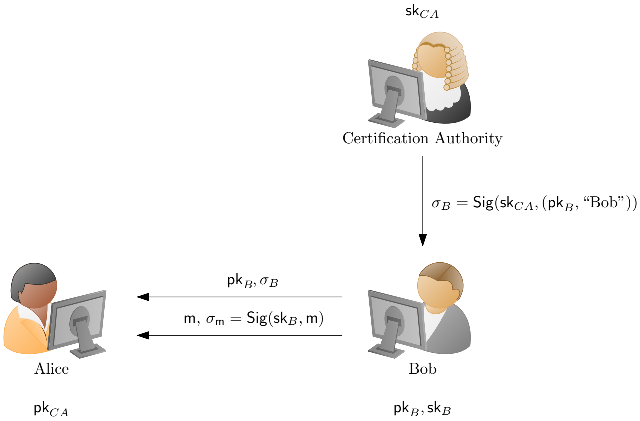

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$$\underline{\mathcal{C}} \qquad \qquad \underline{\mathcal{A}}$$

$$\xrightarrow{\quad\quad\mathsf{mpk}\quad\quad}$$

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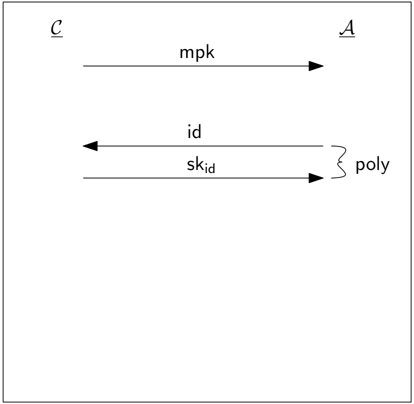

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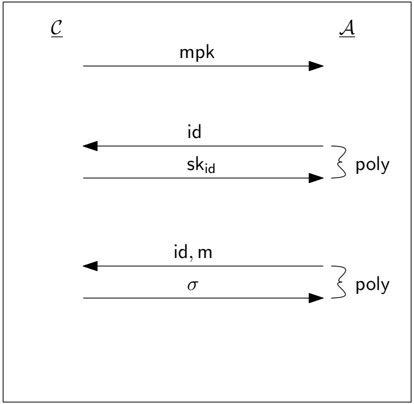

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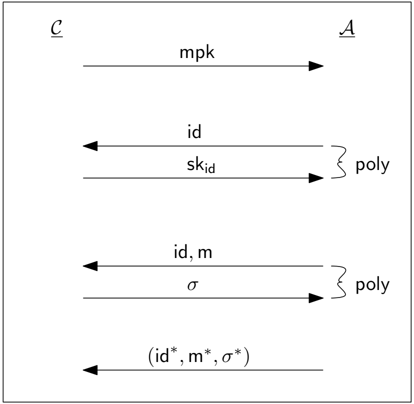

$\mathcal{A}$ wins iff id^* fresh $\wedge(\mathsf{id}^*, \mathsf{m}^*)$ fresh $\wedge \mathsf{Ver}(\mathsf{mpk}, \mathsf{id}^*, \mathsf{m}^*, \sigma^*)$

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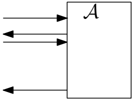

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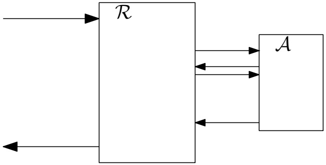

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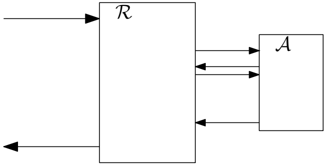

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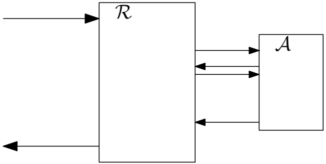

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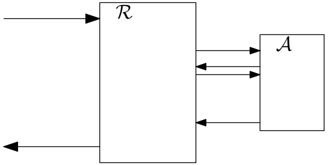

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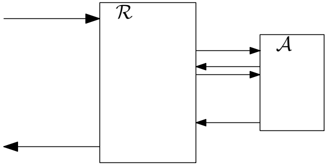

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Tightness

We say the reduction is tight, iff the loss L is a small constant.

Our Goal: IBS in the lattice setting

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$\Longrightarrow$ **avoid certification approach**

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- Construction from 2-level HIBE [GS02, AC]
  - tight
  - we do not know tight 2-level HIBE from lattices

Overview

SIS

Given: $\mathbf{A} \in \mathbb{Z}_q^{n \times m}$

Find: short $\mathbf{x} \in \mathbb{Z}_q^m \setminus \{\mathbf{0}\}$

such that $\mathbf{A}\mathbf{x} = \mathbf{0}$

Overview

$$\mathsf{SIS} \xrightarrow{\text{ROM}} \underset{\text{}}{\overset{\text{non-adaptively secure}}{\mathsf{IBS}}}$$

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  - allows to solve SIS with respect to $\mathbf{A}$
  - allows to derive trapdoor for any extension $[\mathbf{A} \mid \mathbf{B}]$

Non-adaptive Security from SIS - Construction

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Non-adaptive Security from SIS - Construction

$\mathsf{mpk} = \mathbf{A} \in \mathbb{Z}_q^{n \times m}$ $\longrightarrow$ $\mathbf{F}_{\mathsf{id}} = [\mathbf{A} \mid H_1(\mathsf{mpk}, \mathsf{id})]$

$\mathsf{msk} = \mathbf{T}$: trapdoor for $\mathbf{A}$ $\longrightarrow$ $\mathsf{sk}_{\mathsf{id}} = \mathbf{T}_{\mathsf{id}}$: trapdoor for $\mathbf{F}_{\mathsf{id}}$

Non-adaptive Security from SIS - Construction

$$\begin{array}{ccc}
\mathsf{mpk} = \mathbf{A} \in \mathbb{Z}_q^{n\times m} & & \mathsf{msk} = \mathbf{T}\text{: trapdoor for } \mathbf{A} \\
\downarrow & & \downarrow \\
\mathbf{F}_{\mathsf{id}} = [\mathbf{A} \mid H_1(\mathsf{mpk}, \mathsf{id})] & & \mathsf{sk}_{\mathsf{id}} = \mathbf{T}_{\mathsf{id}}\text{: trapdoor for } \mathbf{F}_{\mathsf{id}} \\
\downarrow & & \downarrow \\
\mathbf{F}_{\mathsf{id},\mathsf{m}} = [\mathbf{A} \mid H_1(\mathsf{mpk}, \mathsf{id}) \mid H_2(\mathsf{mpk}, \mathsf{id}, \mathsf{m})] & & \sigma = \mathbf{z} \text{ short s. t. } \mathbf{F}_{\mathsf{id},\mathsf{m}}\mathbf{z} = \mathbf{0}
\end{array}$$

Non-adaptive Security from SIS - Proof

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$\underline{\mathcal{C}}$ $\underline{\mathcal{R}}$ $\underline{\mathcal{A}}$

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$\mathcal{C} \xrightarrow{\mathbf{A} \in \mathbb{Z}_q^{n \times m}} \mathcal{R}$

$\mathcal{R} \xleftarrow{(\mathsf{id}_1, \mathsf{m}_1), \ldots, (\mathsf{id}_Q, \mathsf{m}_Q)} \mathcal{A}$

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$$H_1(\mathsf{mpk}, \mathsf{id}) = \begin{cases} \mathbf{A}\mathbf{R}_{\mathsf{id}} + \mathbf{G}, & \text{if } \mathsf{id} = \bar{\mathsf{id}}_i \\ \mathbf{A}\mathbf{R}_{\mathsf{id}}, & \text{otherwise} \end{cases}$$

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$$\Longrightarrow \mathbf{F}_{\bar{\mathsf{id}}_i} = [\mathbf{A} \mid \mathbf{A}\mathbf{R}_{\bar{\mathsf{id}}_i} + \mathbf{G}]$$

$$\Longrightarrow \mathsf{sk}_i := \mathbf{R}_{\bar{\mathsf{id}}_i} \text{ is a trapdoor for } \mathbf{F}_{\bar{\mathsf{id}}_i}$$

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$\mathcal{C} \to \mathcal{R}$: $\mathbf{A} \in \mathbb{Z}_q^{n \times m}$

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$\implies$ use $\mathbf{R}_{\mathsf{id}_i,\mathsf{m}_i}$ to compute σ_i

$\mathcal{R} \xrightarrow{\sigma_1, \dots, \sigma_Q} \mathcal{A}$

$\mathcal{R} \xrightarrow{\mathsf{sk}_1, \dots, \mathsf{sk}_L} \mathcal{A}$

$\mathcal{R} \xleftarrow{(\mathsf{id}^*, \mathsf{m}^*, \mathbf{z}^*)} \mathcal{A}$

Non-adaptive Security from SIS - Proof

$\mathcal{C}$ $\qquad$ $\mathcal{R}$ $\qquad$ $\mathcal{A}$

$\mathcal{C} \xrightarrow{\mathbf{A} \in \mathbb{Z}_q^{n \times m}} \mathcal{R}$

$\mathcal{R} \xleftarrow{(\mathsf{id}_1, \mathsf{m}_1), \ldots, (\mathsf{id}_Q, \mathsf{m}_Q)} \mathcal{A}$

$\mathcal{R} \xleftarrow{\bar{\mathsf{id}}_1, \ldots, \bar{\mathsf{id}}_L} \mathcal{A}$

$\mathcal{R} \xrightarrow{\mathsf{mpk} := \mathbf{A}} \mathcal{A}$

$$H_1(\mathsf{mpk}, \mathsf{id}) = \begin{cases} \mathbf{A}\mathbf{R}_{\mathsf{id}} + \mathbf{G}, & \text{if } \mathsf{id} = \bar{\mathsf{id}}_i \\ \mathbf{A}\mathbf{R}_{\mathsf{id}}, & \text{otherwise} \end{cases}$$

$$\implies \mathbf{F}_{\bar{\mathsf{id}}_i} = [\mathbf{A} \mid \mathbf{A}\mathbf{R}_{\bar{\mathsf{id}}_i} + \mathbf{G}]$$

$$\implies \mathsf{sk}_i := \mathbf{R}_{\bar{\mathsf{id}}_i} \text{ is a trapdoor for } \mathbf{F}_{\bar{\mathsf{id}}_i}$$

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$$\mathbf{F}_{\mathsf{id}^*,\mathsf{m}^*}\mathbf{z}^* = \mathbf{0}$$

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$$\mathbf{F}_{\mathsf{id}^*,\mathsf{m}^*}\mathbf{z}^* = \mathbf{0}$$

$$\implies [\mathbf{A} \mid \mathbf{A}\mathbf{R}_{\mathsf{id}^*} \mid \mathbf{A}\mathbf{R}_{\mathsf{id}^*,\mathsf{m}^*}]\mathbf{z}^* = \mathbf{0}$$

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$$H_2(\mathsf{mpk}, \mathsf{id}, \mathsf{m}) = \begin{cases} \mathbf{A}\mathbf{R}_{\mathsf{id},\mathsf{m}} + \mathbf{G}, & \text{if } (\mathsf{id}, \mathsf{m}) = (\mathsf{id}_i, \mathsf{m}_i) \\ \mathbf{A}\mathbf{R}_{\mathsf{id},\mathsf{m}}, & \text{otherwise} \end{cases}$$

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$\mathbf{F}_{\mathsf{id}^*,\mathsf{m}^*}\mathbf{z}^* = \mathbf{0}$

$\Longrightarrow [\mathbf{A} \mid \mathbf{A}\mathbf{R}_{\mathsf{id}^*} \mid \mathbf{A}\mathbf{R}_{\mathsf{id}^*,\mathsf{m}^*}]\mathbf{z}^* = \mathbf{0}$

$\mathcal{C} \xleftarrow{[\mathbf{I} \mid \mathbf{R}_{\mathsf{id}^*} \mid \mathbf{R}_{\mathsf{id}^*,\mathsf{m}^*}]\mathbf{z}^*} \mathcal{R}$

Conclusion and Future Work

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- First lattice-based short IBS with tight security

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- Two step approach

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Open Problems

- Analysis in the QROM

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- Non-adaptively secure IBS in the standard model
  - based on SIS
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Thank you for your attention!