Anonymous Credentials on Legacy Phones

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Based on joint works with Andrea Flamini, Christian Mouchet, Anja Lehmann, Andrey Sidorenko

EUropean Digital Identity Wallet

(Aspiring to be) *privacy centric:*

- selective disclosure
- unlinkability
- pseudonyms

EU regulation eIDAS 2.0

securely [..] ***authenticate*** to relying parties [..] while ensuring ***selective disclosure*** of data [..] enable privacy-preserving techniques which ensure ***unlinkability*** [..] possibility of users to access services through the ***use of pseudonyms*** [..] providers should ensure ***unobservability*** by not collecting data and not having insight into the transactions of the users [..]

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The good,

- We know how!
- Anonymous Credentials
- Zero Knowledge Proofs

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... and the ugly

- *Standardization* and the *Standards Zoo*
- Existing *hardware limitations*

A Practical Barrier: Credential Cloning

- Digital nature $\Rightarrow$ credential cloning / transferability
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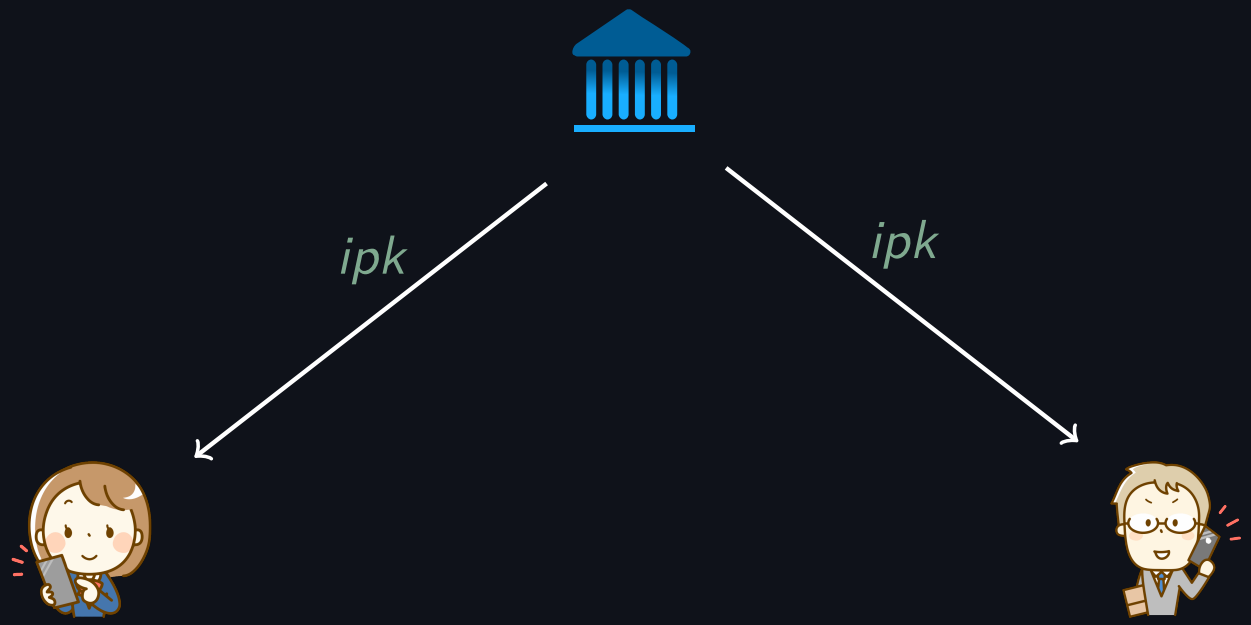
- *Idea*: credential "bound" to a device $\Rightarrow$ *Proof-of-Possession*
  - *Secure Element*: (inaccessible) dsk
  - dpk in the credential
  - User: *oracle access* to $\mathsf{Sign}(\mathsf{dsk}, \cdot)$
  - During presentation: σ_{PoP} on a challenge *nonce*

A (basic) AC Blueprint: Signature Scheme + ZKP



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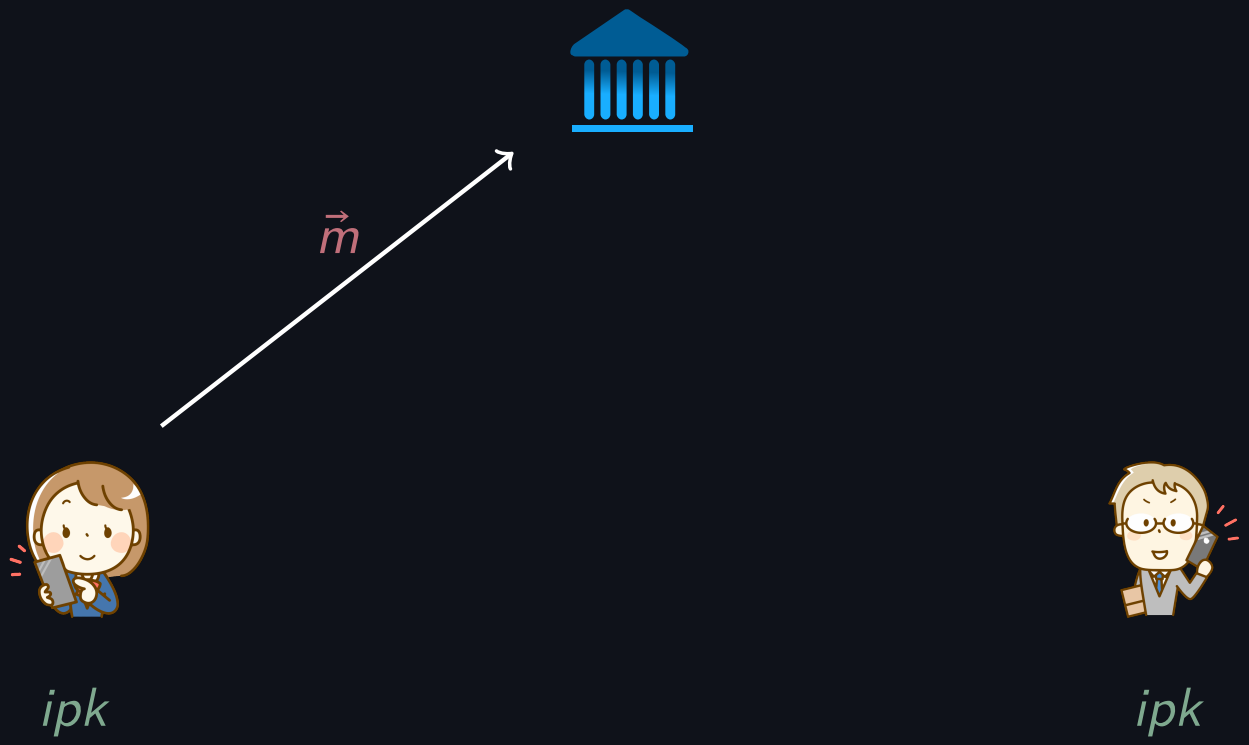

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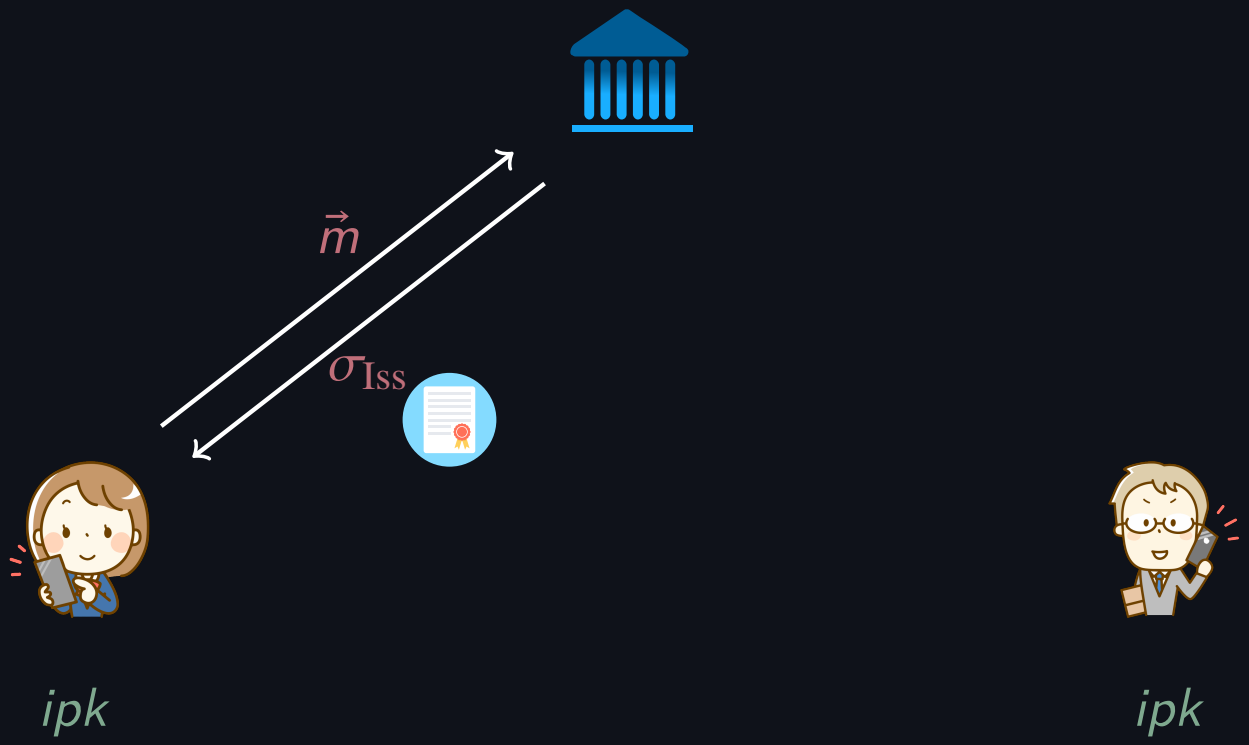

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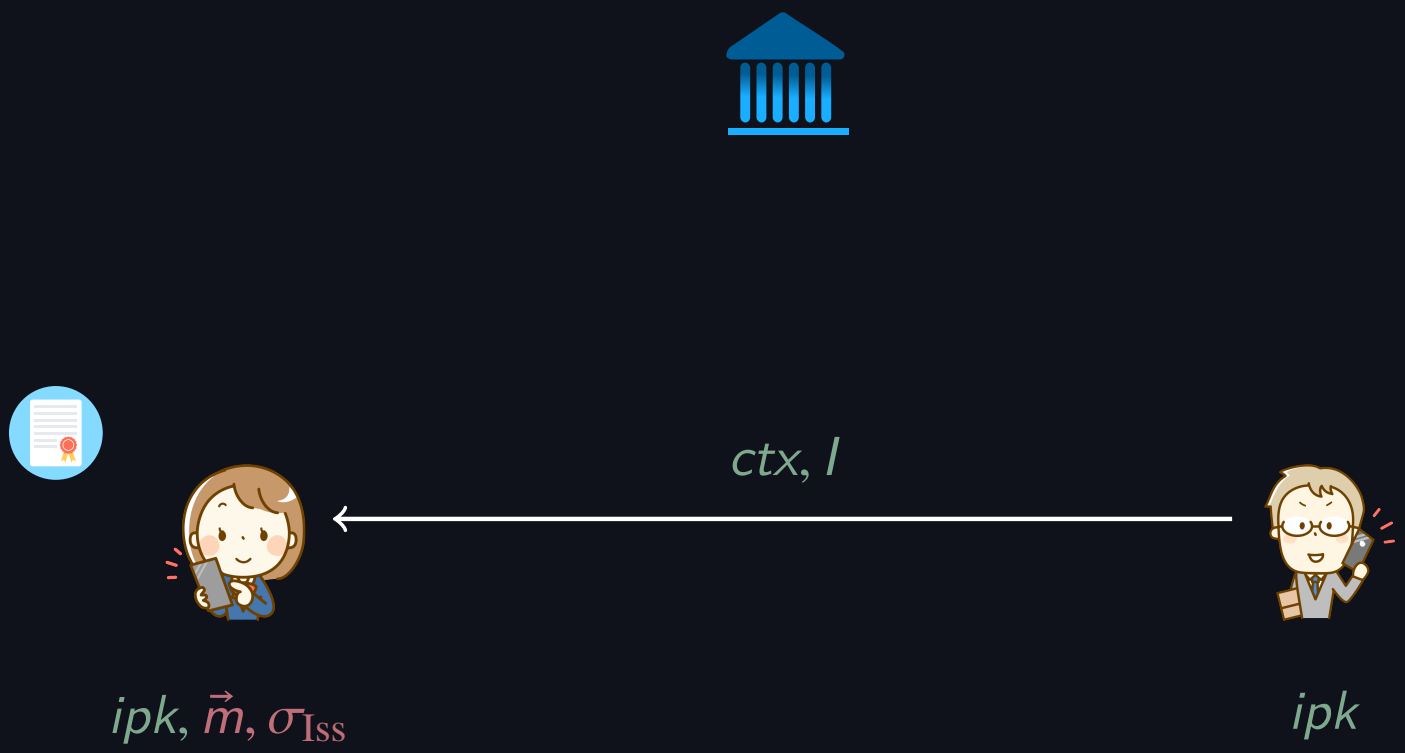

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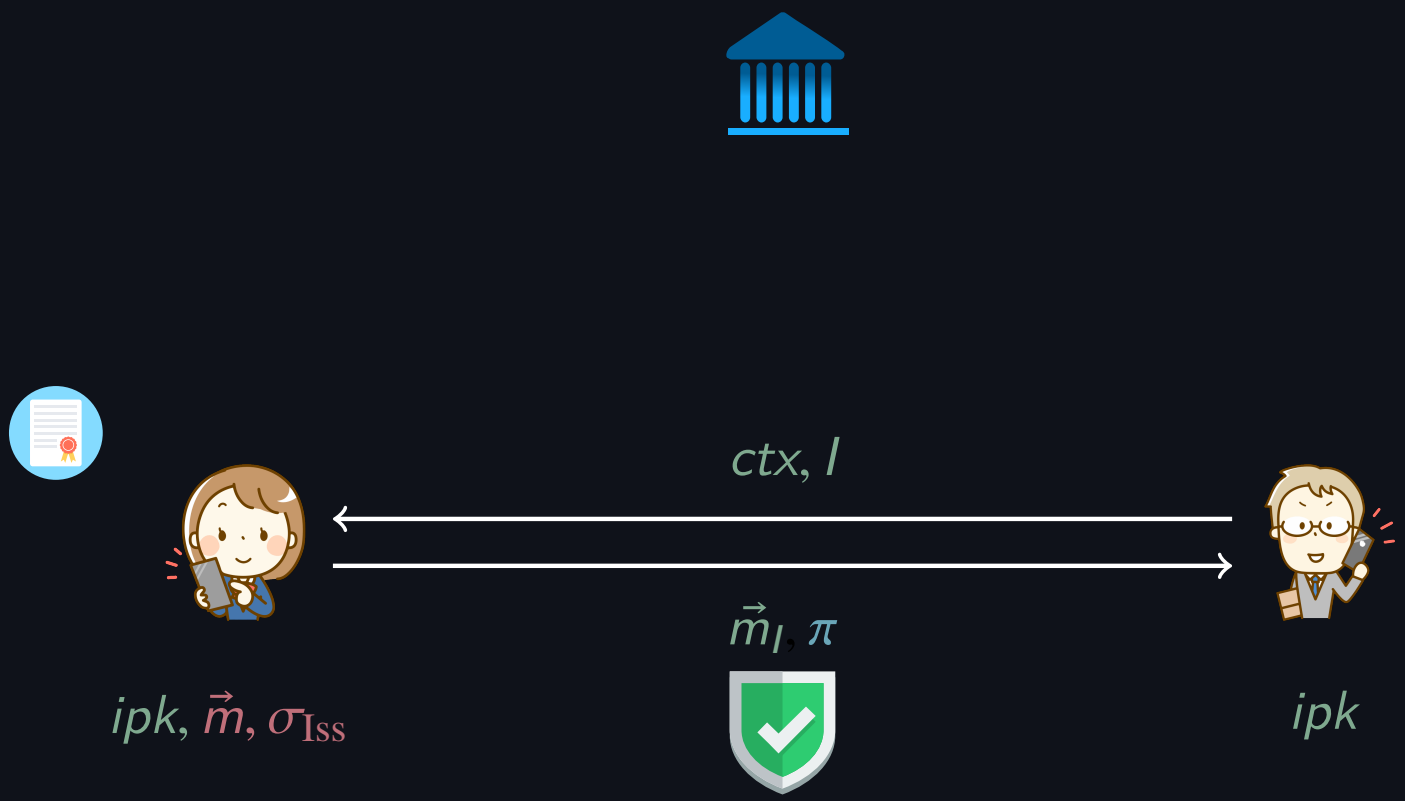

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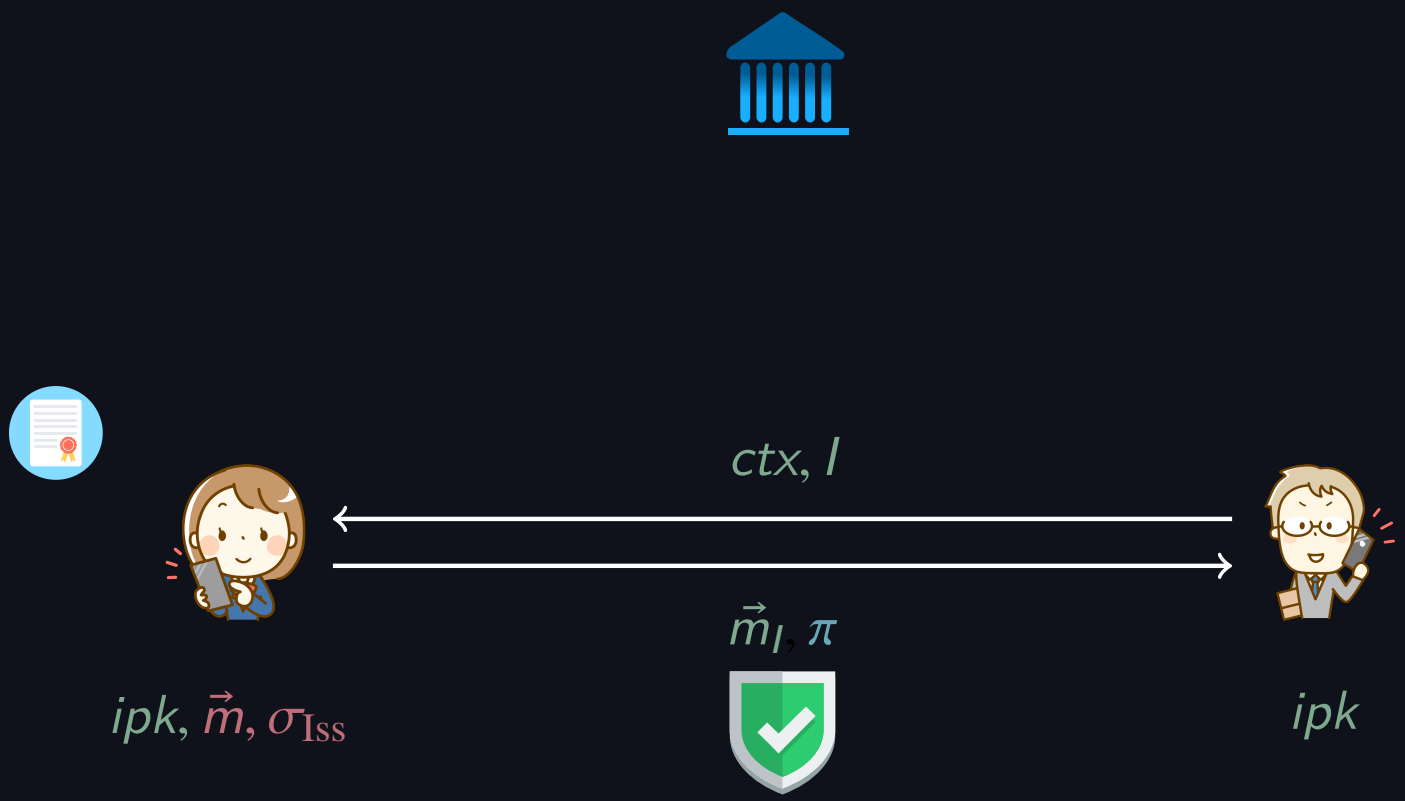

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A More Realistic Scenario...

More functionality:

- Predicate Proofs
- Non-Revocation
- Pseudonyms
- ***Device Binding***
- …

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Issue!

The ZKP becomes *too complex*!

AC + Device Binding

$ipk, \vec{m}, \sigma_{\text{Iss}}$

ipk

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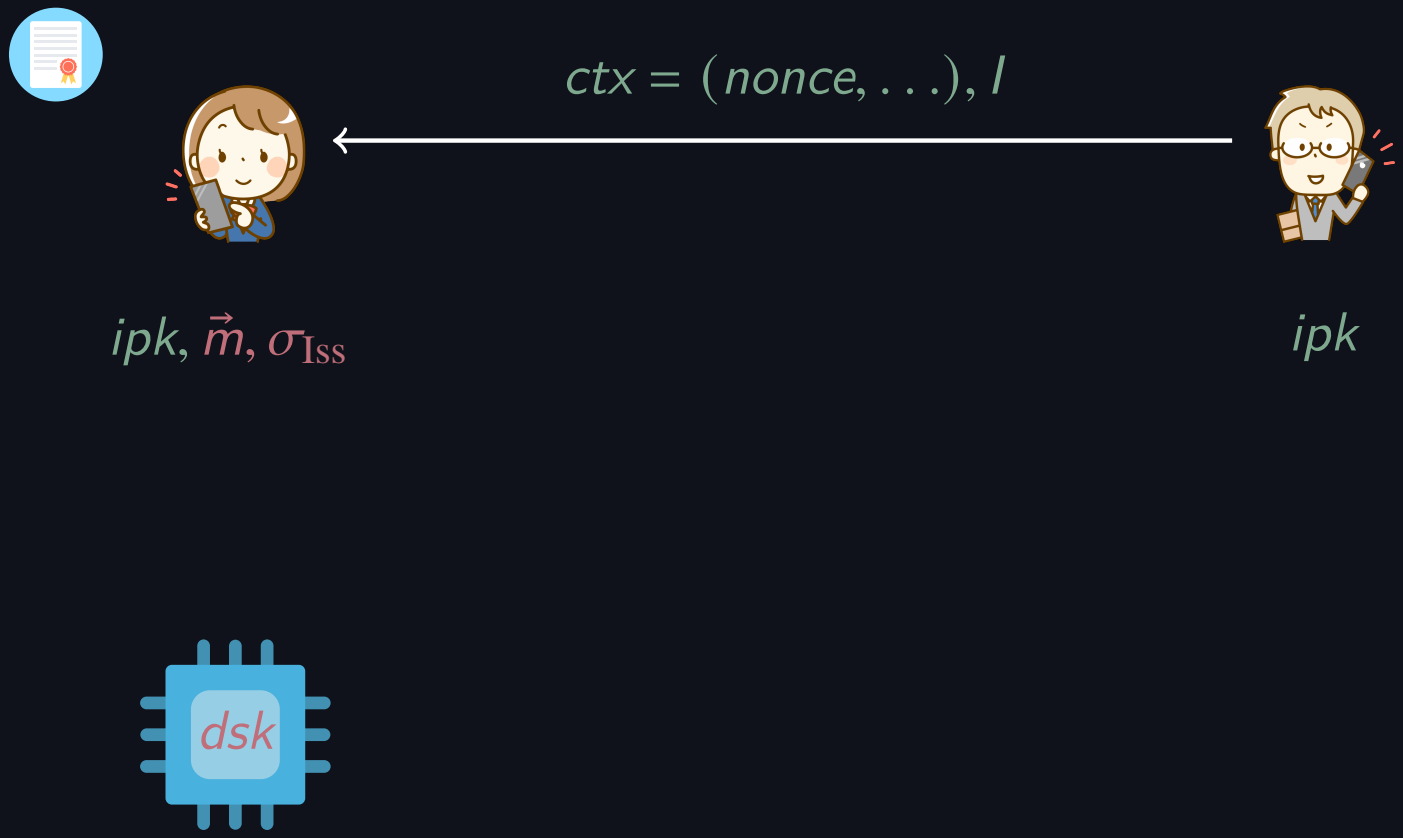

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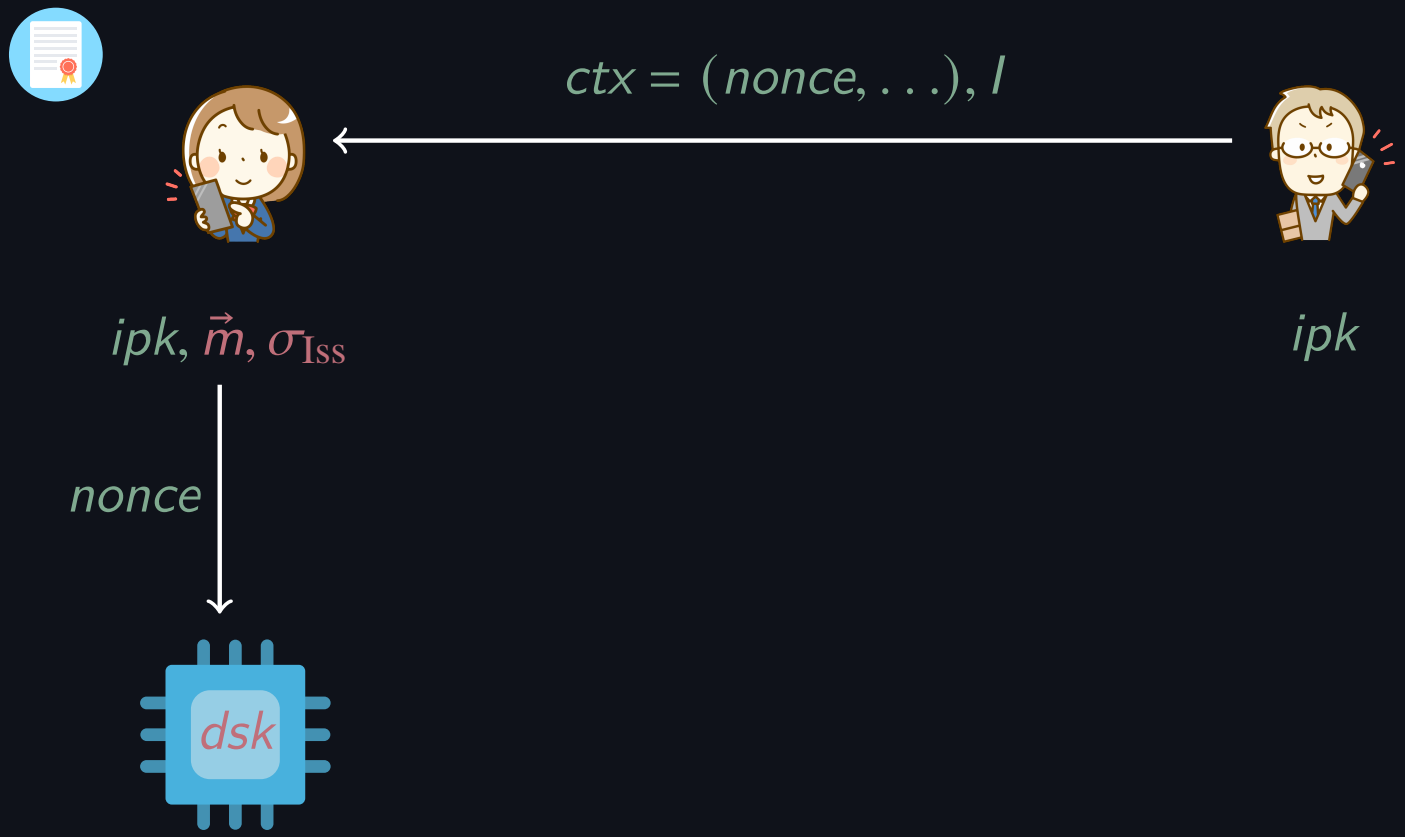

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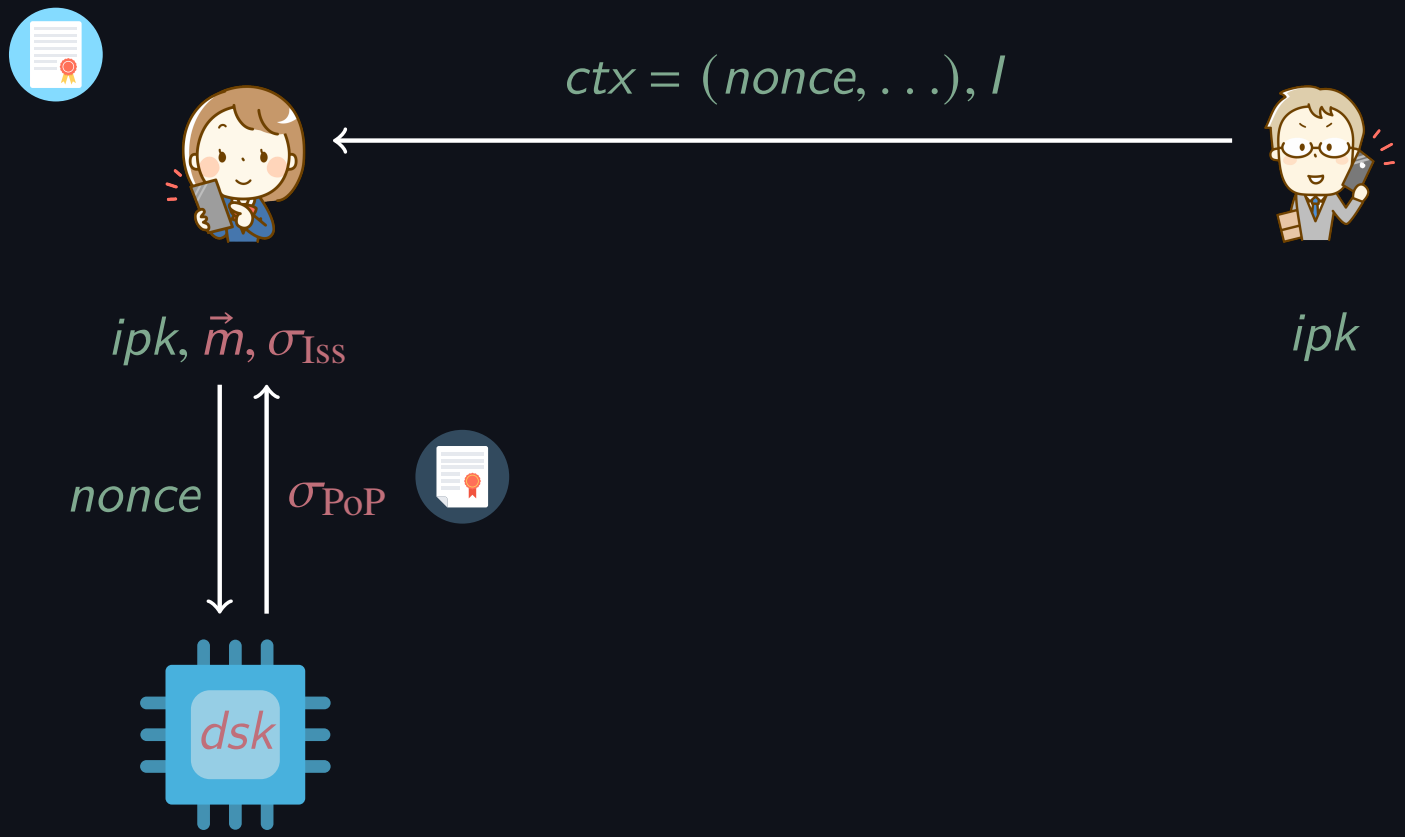

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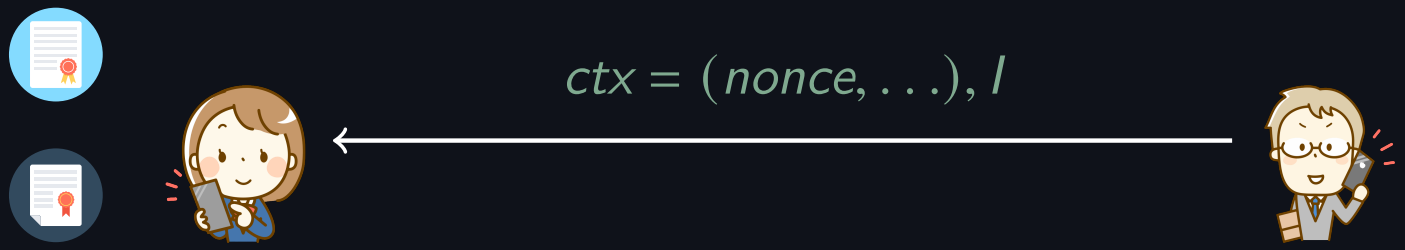

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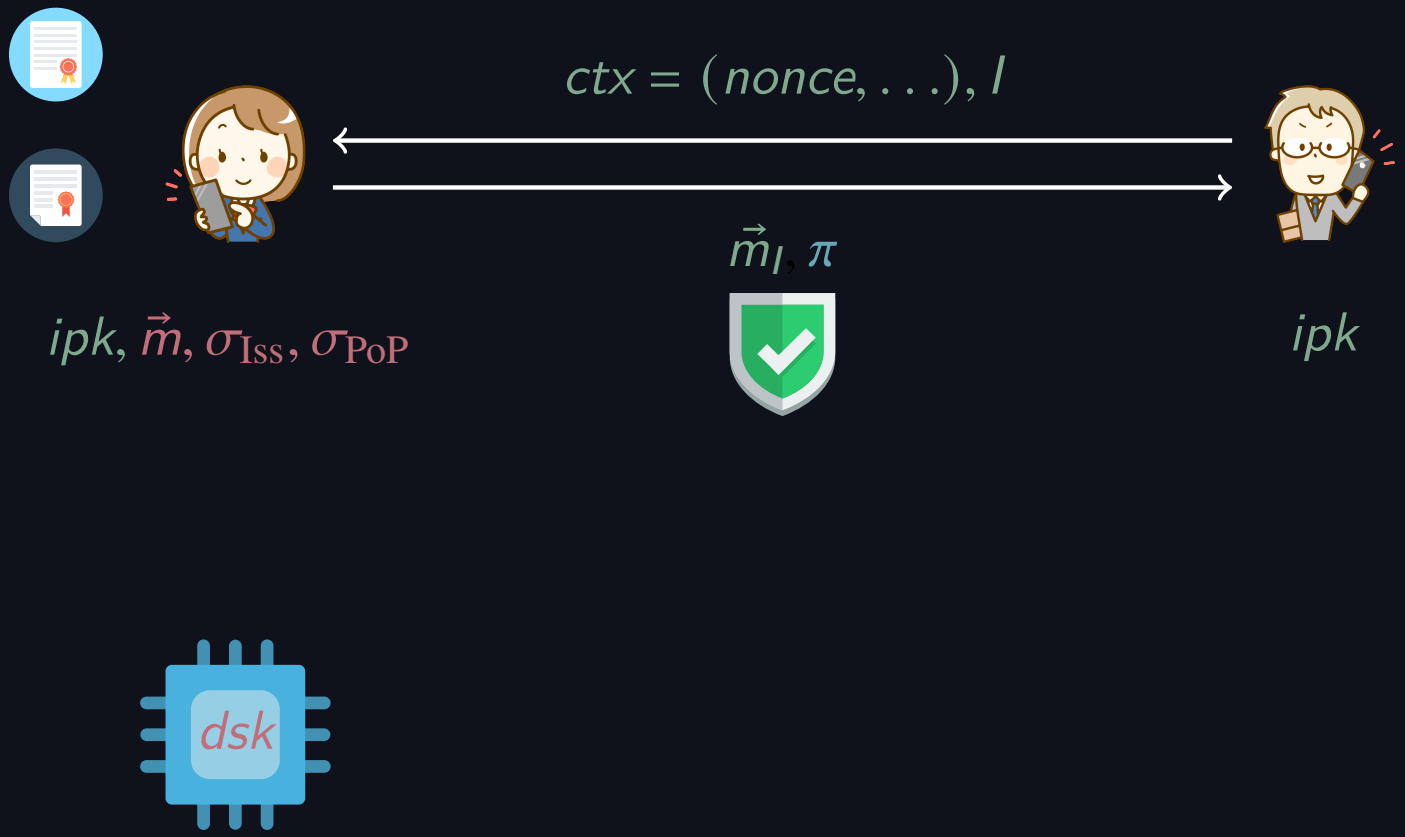

Device Binding: An *Ugly* Reality

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What signature scheme to use?

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Let's use an:

- Efficient ✔
- Super Secure / Post quantum guarantees ✔
- Native ZKPs for knowledge of a signature ✔
- Fancy niche features X, Y, Z ✔

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or . . . let's use ECDSA (?!)

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  - Building SEs is *hard*, *timely* and *costly*
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ECDSA PoPs

ECDSA was *not* designed with PoPs in mind. Must use *generic, non-native ZKP techniques* which:

1. Add *complexity*
2. Incur *efficiency costs*

Monolithic Approach

Issuer	SE	ZKP	$t_{\mathcal{P}}$	$\lvert\pi\rvert$
ECDSA	ECDSA	$\mathcal{C}$	90ms - 500ms	90KB - 300KB

Table 1: Adapted from **[Vega]** and **[OpenAC]**. Run on 16vCPUs with 64GB RAM

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Idea

Let's ***minimize ECDSA use*** to the absolutely necessary!

A Modular Framework [LSZ 25]

Core idea:

- Divide & Conquer apporach
- *Small, flexible* building blocks vs of *monolithic, complex* construction
- signature scheme + ZKP modules + commitment linking

A Modular Framework [LSZ 25]

$ipk, \vec{m}, \sigma_{\text{Iss}}$

ipk

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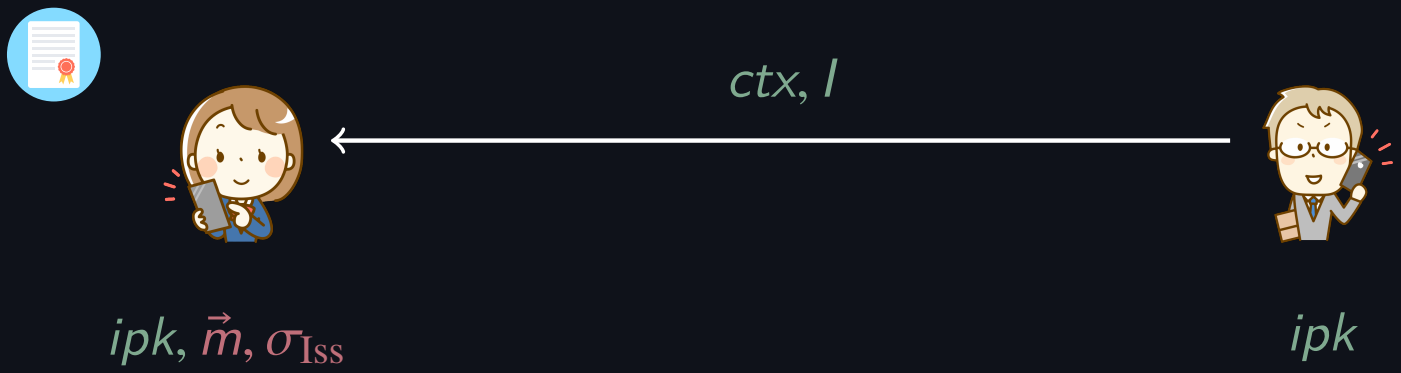

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m_4 C_4

m_5 C_5

m_8 C_8

ipk

π_{core}

$\pi_{\text{core}} : \sigma_{\text{Iss}}$ is valid signature of $\vec{m}$ under ipk, "consistent" with $\vec{m}_I$ ***and*** C_4, C_5, C_8

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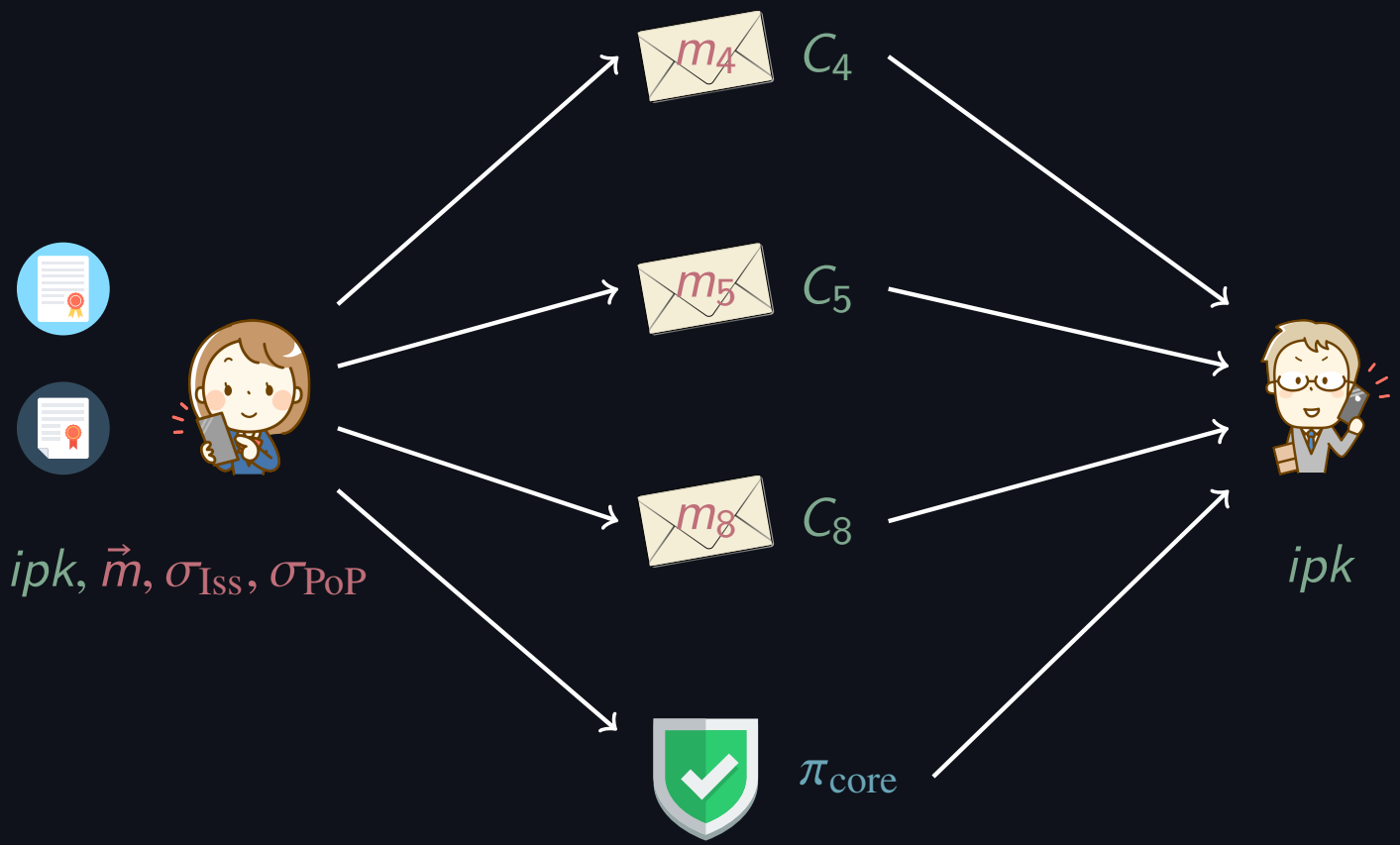

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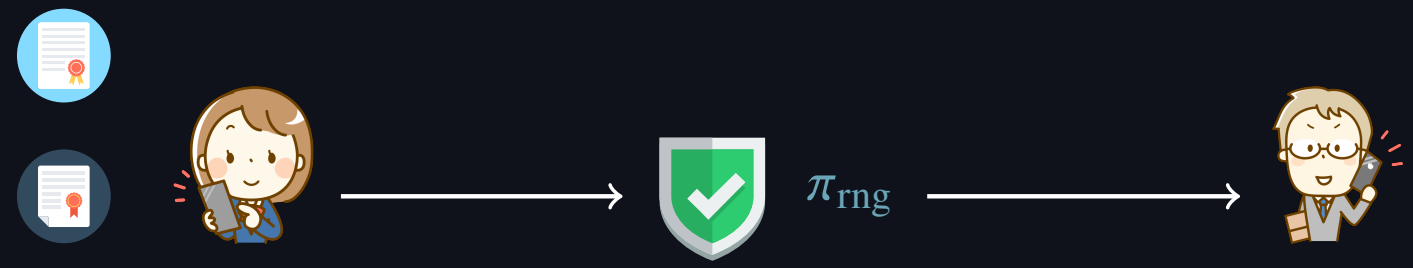

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A Modular Framework [LSZ 25]

- Simple
- Different ZKP for each task:
  - MMS and *native* ZKP for *Core* $\Rightarrow$ *Ultra efficient!*
  - Speialized proofs/different tradeoffs for other "modules"
- Crypto Agility $\Rightarrow$ Easier *PQ transition*
- Trade-offs
- "Incremental" Standardization

Choosing the building blocks

- **Issuer:** Pairing-based + *Native* ZKP (e.g. BBS) ✔
- **Linking:** Pedersen Commitments ✔
- **SE:** ECDSA ✗
- π_{PoP}: ???

ECDSA Based PoPs [LZ 26]

Various ZKPs with *different trade-offs:*

- Efficiency
- System complexity
- Assumptions

Modularity:

- Compatible with **[LSZ 25]**
- ZKPs themselves are modular, **[KP 23]** framework

ECDSA Based PoPs [LZ 26]

π_{PoP}: *"I know* σ_{PoP} *on* nonce *under committed* dpk

Simplified statement

- Only signing one-time (short lived) messages
- Part of the signature can be revealed[1]

The problem essentially reduces to $zK = Q$ over P256 with Q committed.

[1] Terms and conditions apply: EC paper **[KHLL 26]**.

Core Challenge

$C_x = xG + r_1 H$

$C_y = yG + r_2 H$

in BLS12

$zK = Q$

$Q = (x, y)$

in P256

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3. PoP-Σ: Σ-based + commitment linking
   - (Very) Simple
   - Relying on “not-standard” curve
   - Large Proofs

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PoP-PLONK	BBS	ECDSA	$\Sigma + C$	2.6s	~ 4KB
PoP-BP	BBS	ECDSA	$\Sigma + C$	350ms	1.5KB
PoP-Σ	BBS	ECDSA	Σ	350ms	172KB

Table 2: Run on commodity laptop (i5-1345U, 16GB RAM). Only considers π_{PoP}.

PoP-BP

Concluding Remarks

Modularity:

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Societal impact

We discussed from the "cryptographers" lens. Digital identity will *rearrange power* and will have a deep societal impact.

Bringing AC and ZKP to EUDI

- Contributions to Standarization
  - TS 14
  - ETSI
  - IETF
- [LSZ 25]
  - reduce complexity
  - simplify standarization
- [LZ 26]
  - reduce complexity
  - address hardware limitaions
  - simplify standarization
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