Anonymous Credentials for the EUDI Wallet: Closing the Gaps

EUDI ON – 25.6.2026

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EUDI Wallet | Privacy Requirements in eIDAS

§ 16. The technical framework of the European Digital Identity Wallet shall:

(a) **not allow providers** of electronic attestations of attributes [..], after the issuance of the attestation of attributes, **to obtain data that allows transactions or user behaviour** to be **tracked, linked or correlated**, [..]

(b) enable privacy preserving techniques which ensure ~~unlikeability~~

Corrigendum 9.4.25: unlinkability! ☺

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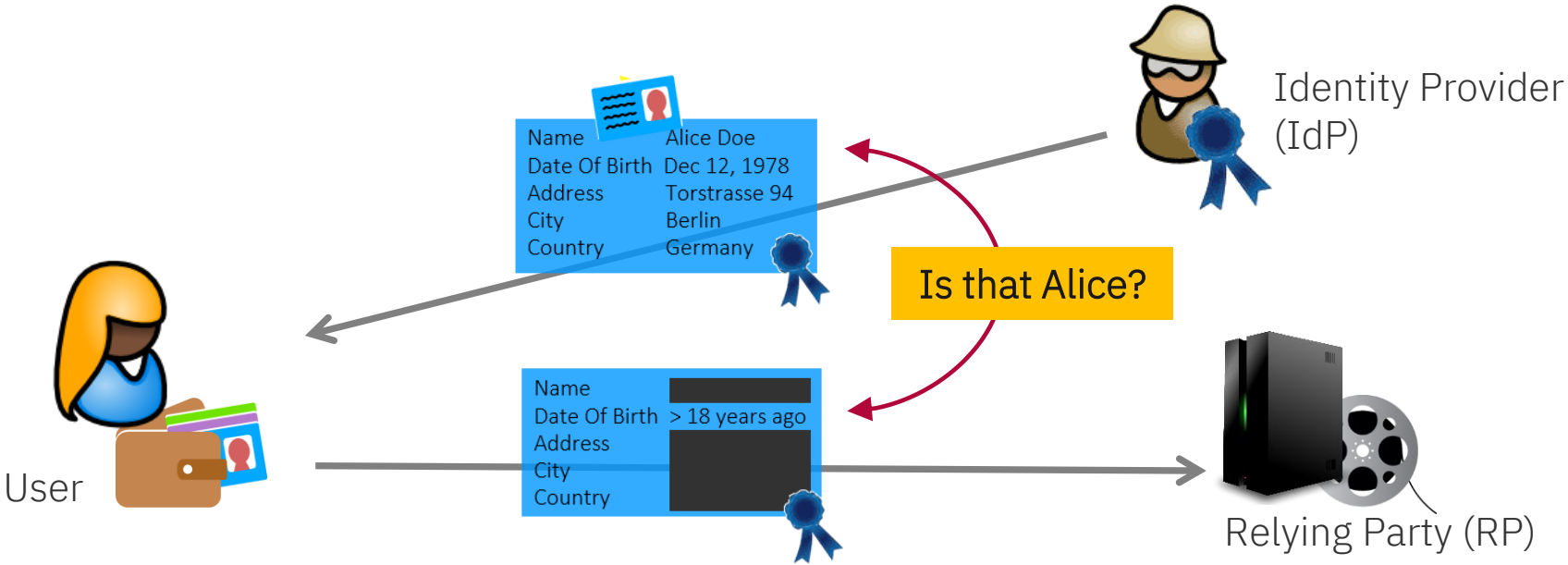
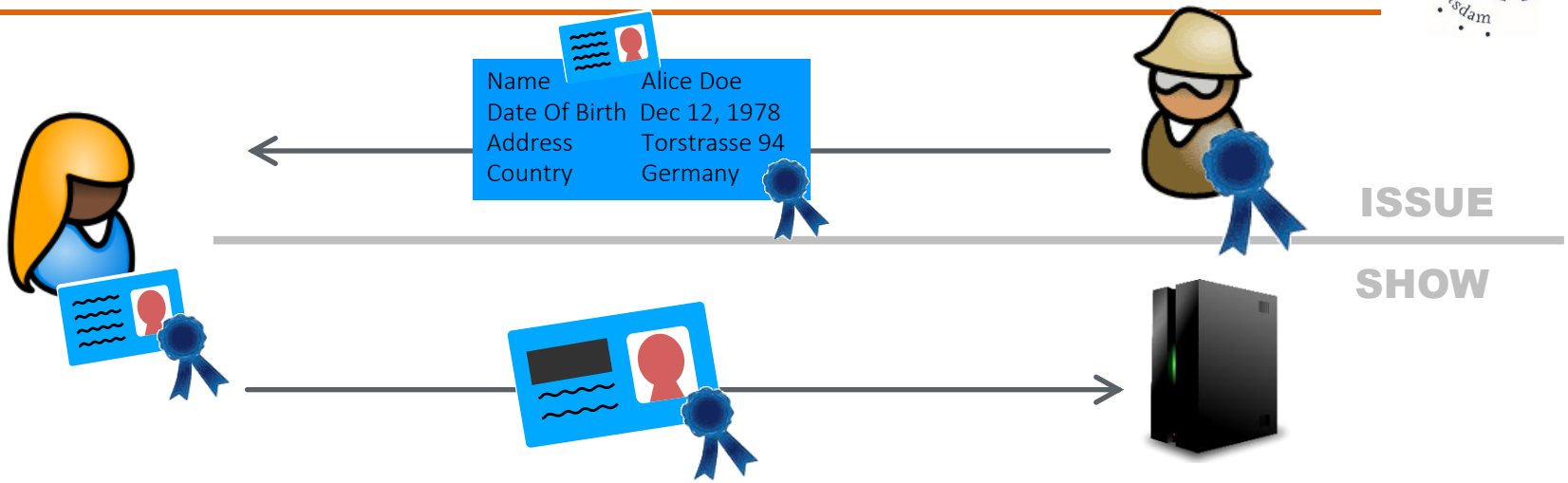


EUDI | Solution with Classical Signatures



- Digital identity credentials based on cryptographic signatures

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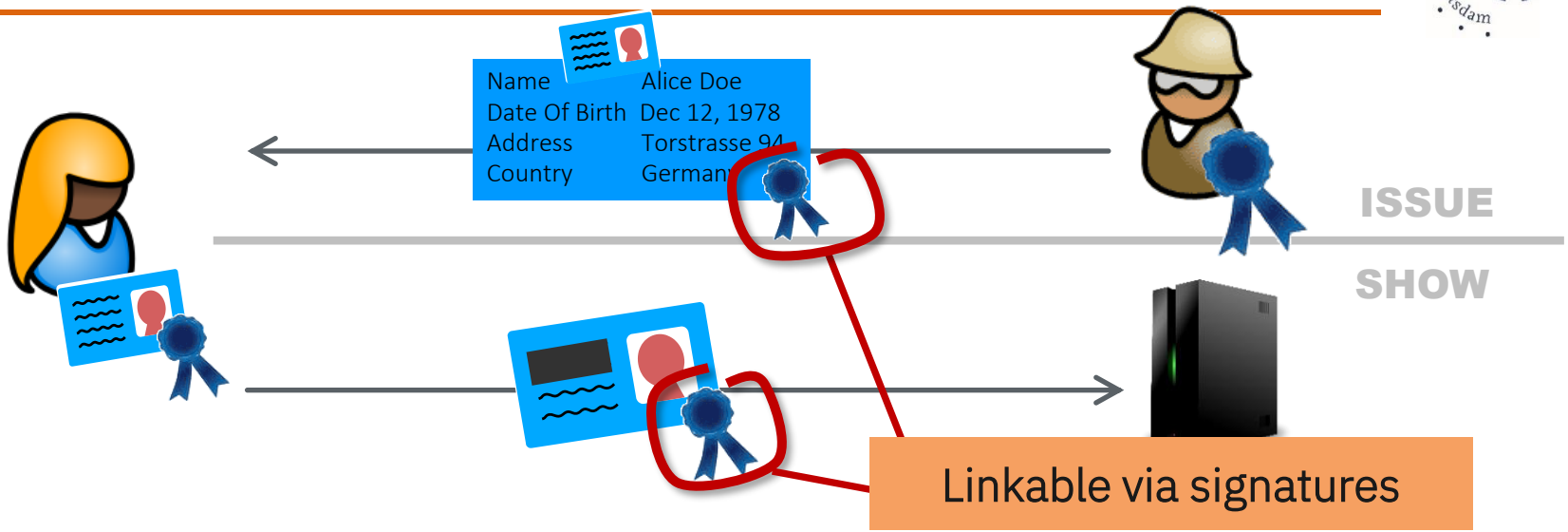
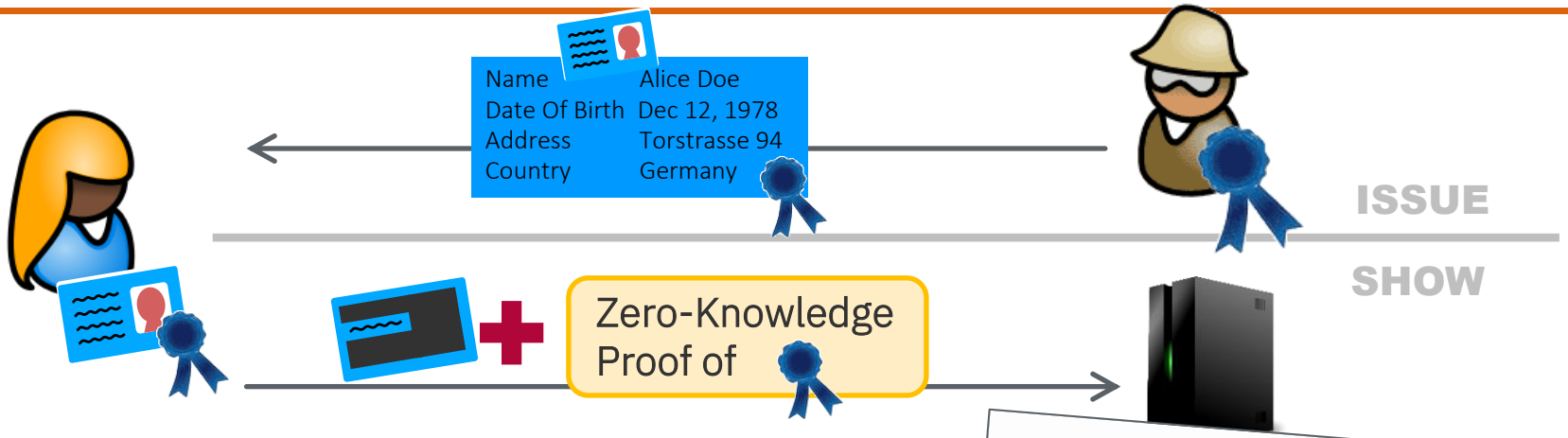
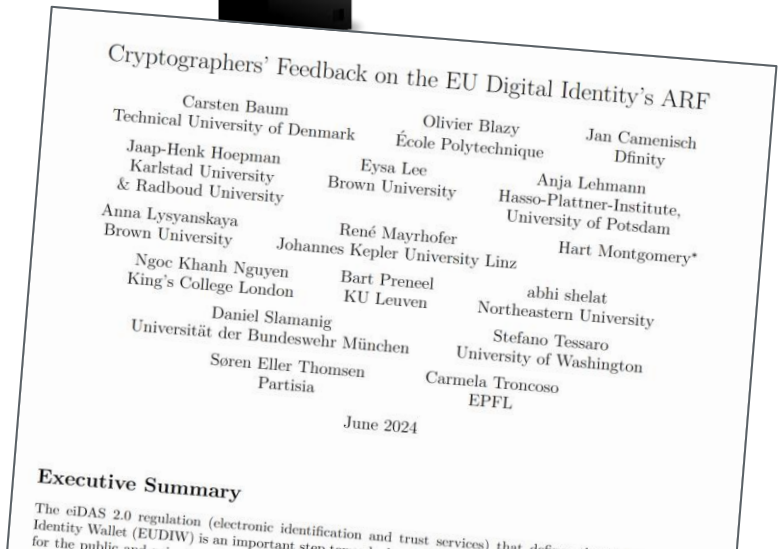


- Digital identity credentials based on cryptographic signatures
- Digital Signatures are great for security, but bad for privacy → unique identifier
- Batch issuance helps for unlinkability towards RPs (but is rather costly)

  & does **not achieve** unlinkability/untraceability if IdP and RP collude

Anonymous Credentials & Zero-Knowledge Proofs





Cryptographers' Feedback on the EU Digital Identity's ARF

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abhi shelat, Northeastern University
Daniel Slamanig, Universität der Bundeswehr München
Stefano Tessaro, University of Washington
Søren Eller Thomsen, Partisia
Carmela Troncoso, EPFL

June 2024

Executive Summary

The eIDAS 2.0 regulation (electronic identification and trust services) that defines the Identity Wallet (EUDIW) is an important step

https://github.com/eu-digital-identity-wallet/eudi-doc-architecture-and-reference-framework/issues/200

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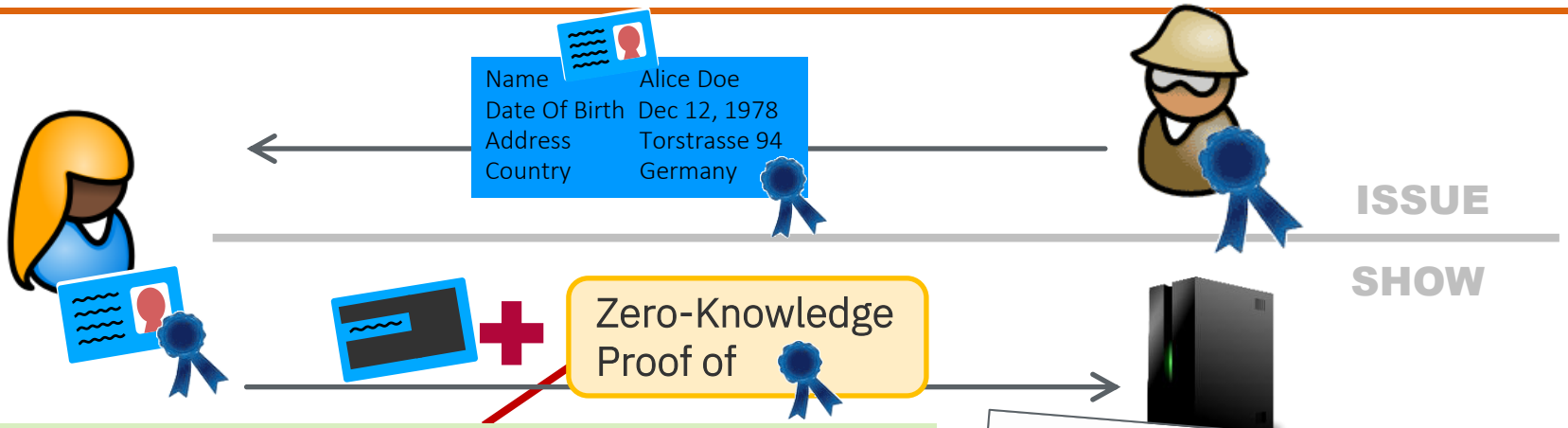
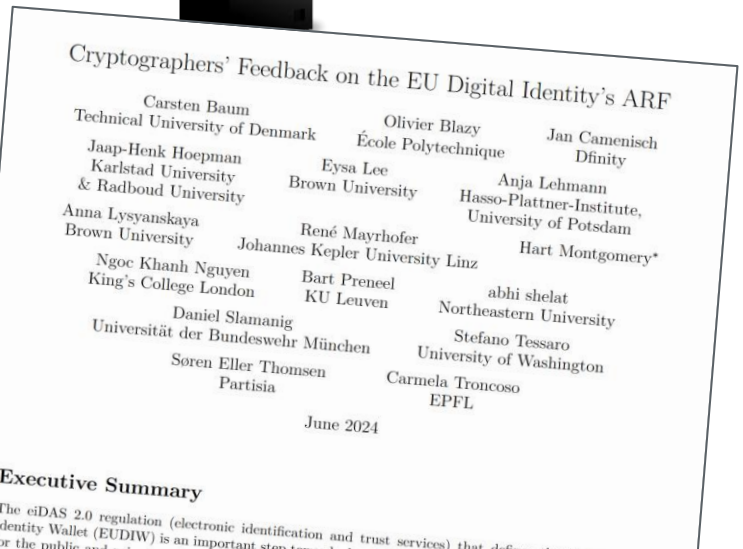


Zero-Knowledge Proof (ZKP)

Proof that reveals nothing beyond validity

→ multi-show unlinkability & no trust on IdP needed

Practical ZKP-based solutions exist since 25 years



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Why does EUDI not use Anonymous Credentials (yet) ?

- Main focus so far: PID, i.e., national identity card

This comes with strong security requirements:

1) Must only use “Agreed Cryptographic Mechanisms”
2) Security on Level of Assurance High

→ ZKP not included in ACM or supported by secure hardware

KYC e.g., opening bank account

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  Adding lightweight ZKPs would still offer better privacy and security though

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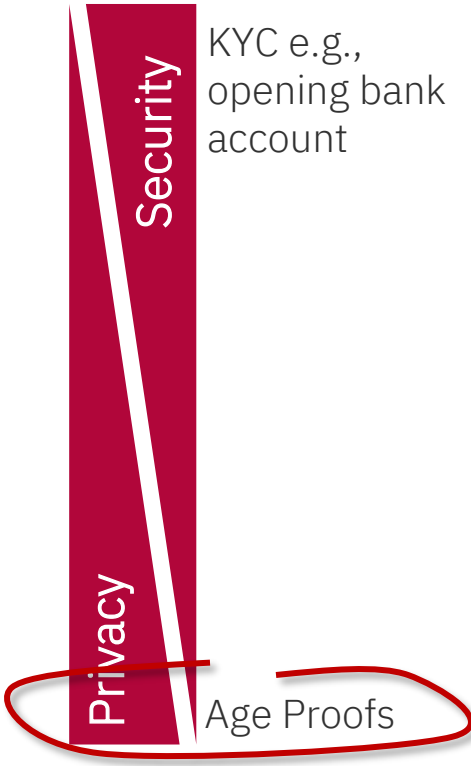
- Current attention: age verification online (from age credential ≠ PID)

  High privacy needs, but lower security requirements than KYC

  Right setting to deploy anonymous credentials

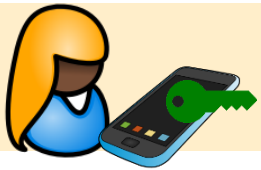


Towards Deploying Anonymous Credentials

1 | Standardisation of all required cryptographic protocols → interoperability

IETF: ongoing standards for all core crypto primitives (e.g., BBS)
ETSI: dedicated standard for ZKP-based EUDI Wallet under development

2 | Realize cloning-prevention for anonymous credentials
Usually done through device binding



→ Challenge: Secure Elements only support non-ZKP friendly signatures (ECDSA)

3 | Ensure that privacy is strong enough for real-world use case, e.g., for age proofs

→ Challenge: (Anonymous) Credentials usually reveal the issuer‘s identity

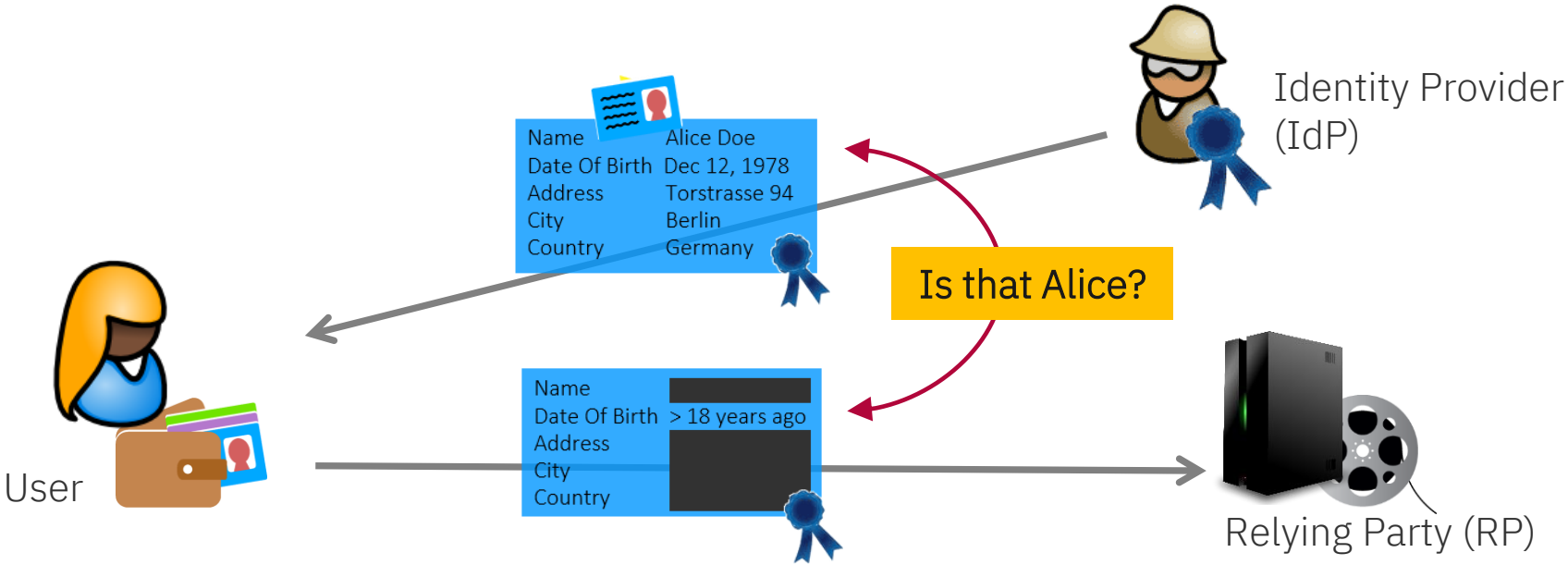
Device Binding for Anonymous Credentials

Alexandros Zacharakis

based on joint work with Sofia Celi, Anja Lehmann and Shai Levin

Recall Unlinkability

- Presentations cannot be traced back to a credential.
- Great for privacy! But...
- Makes misuse easier.



Credential Transfer/Cloning

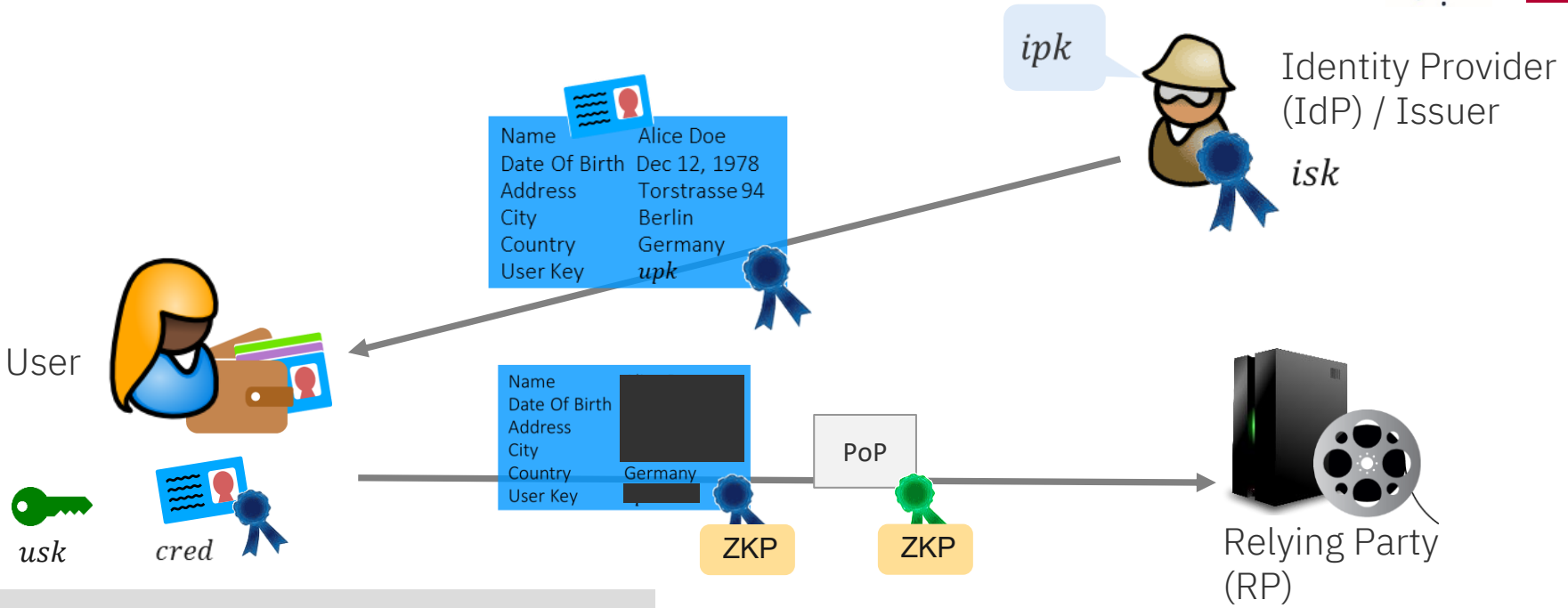
The core problem:

- Digital goods are easy to *clone*
- *Privacy vs Security:* misuse (e.g. sharing credentials) can happen *undetectably*
- Lack of security ⟶ reduced trust on the system: presentations are “vacant”

A (somewhat partial) solution

- Bind credentials to a device ⟶ harder to share “en masse”
- Valid presentation requires accessing the device
- Implemented via SE that stores an (inaccessible) secret signing key + *Proof-of-Possession*

Device Bound Anonymous Credentials



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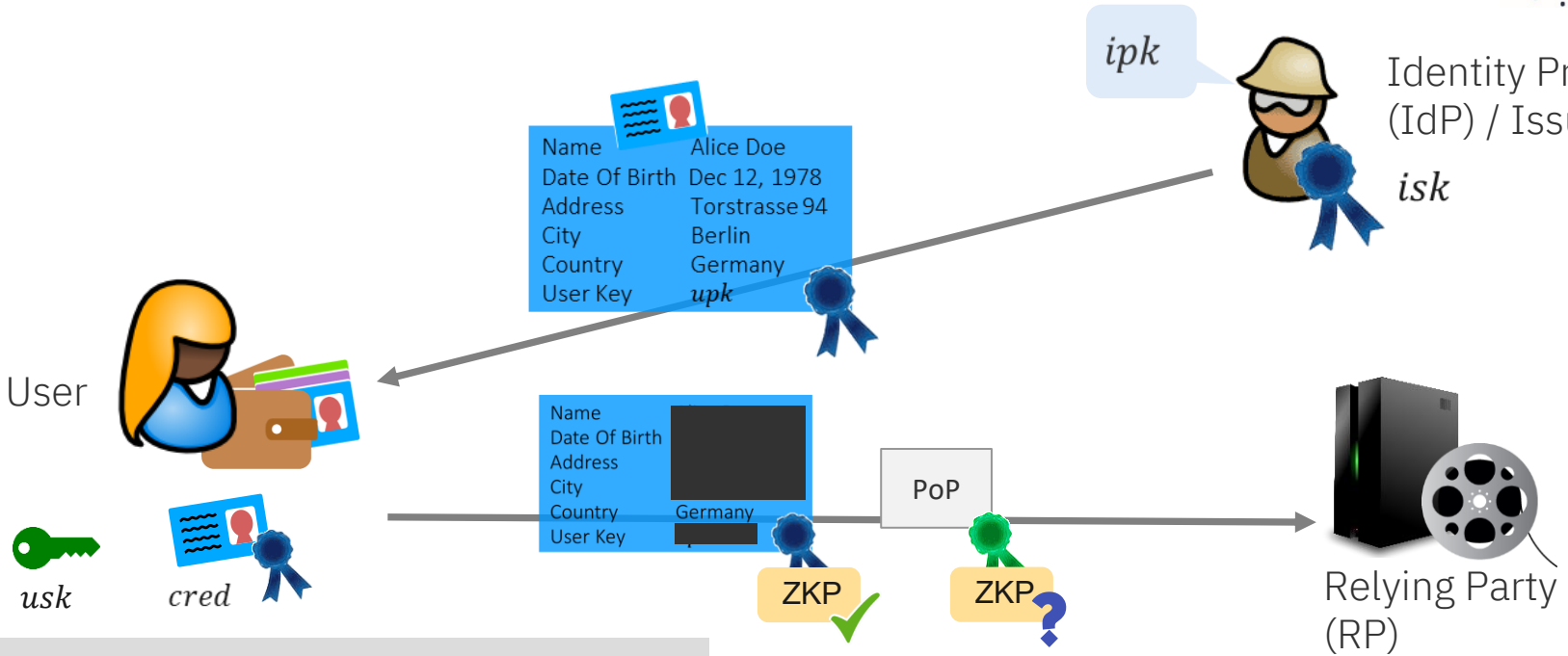

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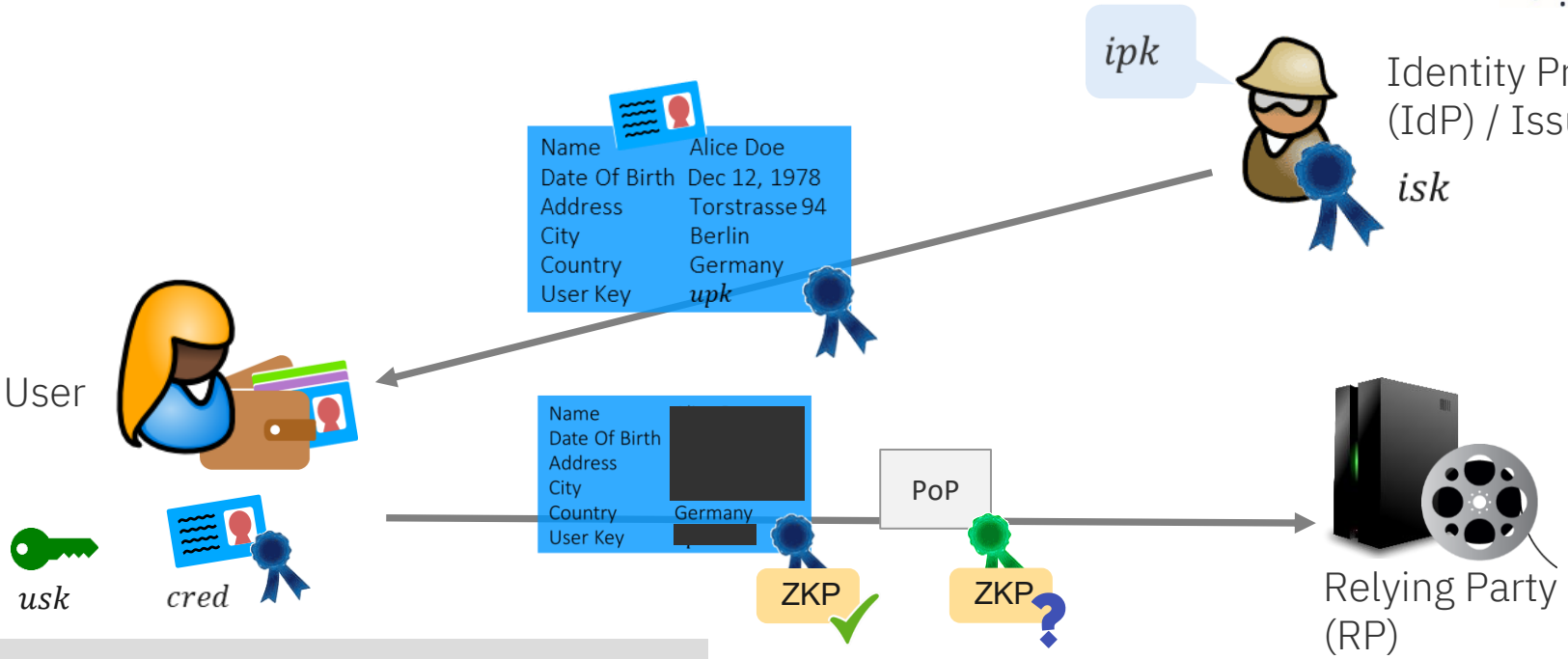

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- **Goal**: efficient ZKP for cred and PoP
- **Constraints**: ECDSA for PoP (at least for the short term)

ZKPs for ECDSA

- ECDSA was *not* designed to support ZKP
- We can use generic ZKP techniques ⟶ complex*

* This is an understatement.

ZKPs for ECDSA

How can we improve?

- PoP is an easier problem since the nonce is public
- Leverage the “structure” of ECDSA to get *specialized ZKPs* for PoP

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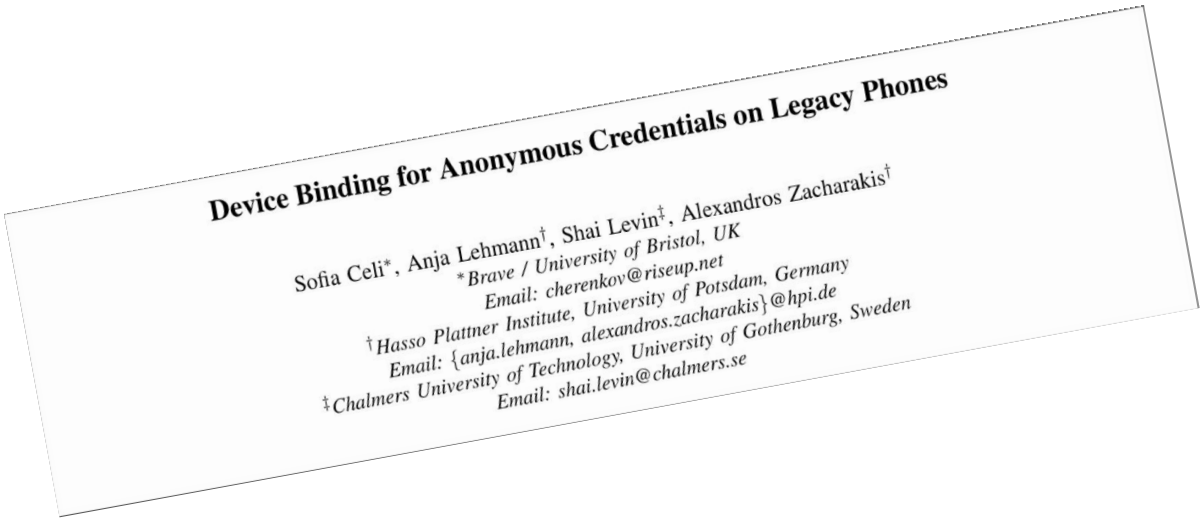

Device Binding for Anonymous Credentials on Legacy Phones

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‡Chalmers University of Technology, University of Gothenburg, Sweden
Email: shai.levin@chalmers.se

https://eprint.iacr.org/2026/965.pdf

The Current Landscape

Issuer	User	ZKP	Efficiency (rough guestimates)	Advantages

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BBS	**ECDSA** 	Circuit (simple)	~350ms, ~1.5kB	Easy to extend & standardize Short proofs
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Conclusion

Can we achieve efficient, privacy preserving device binding?

Can we do that now under the existing restrictions?

Are we done?

Conclusion

Can we achieve efficient, privacy preserving device binding? ***YES!***

Can we do that now under the existing restrictions? ***YES!***

- Various solutions for ECDSA with a *broad trade-off* spectrum

Are we done? ***YES*** *and* ***NO***

- Efficient (and simple) solutions already exist!
- The remaining challenge: *standardization*

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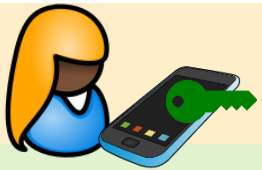

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→ Solved: Device-binding from ECDSA Secure Elements

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→ Challenge: (Anonymous) Credentials usually reveal the issuer‘s identity

Anonymous Credentials with Issuer Hiding

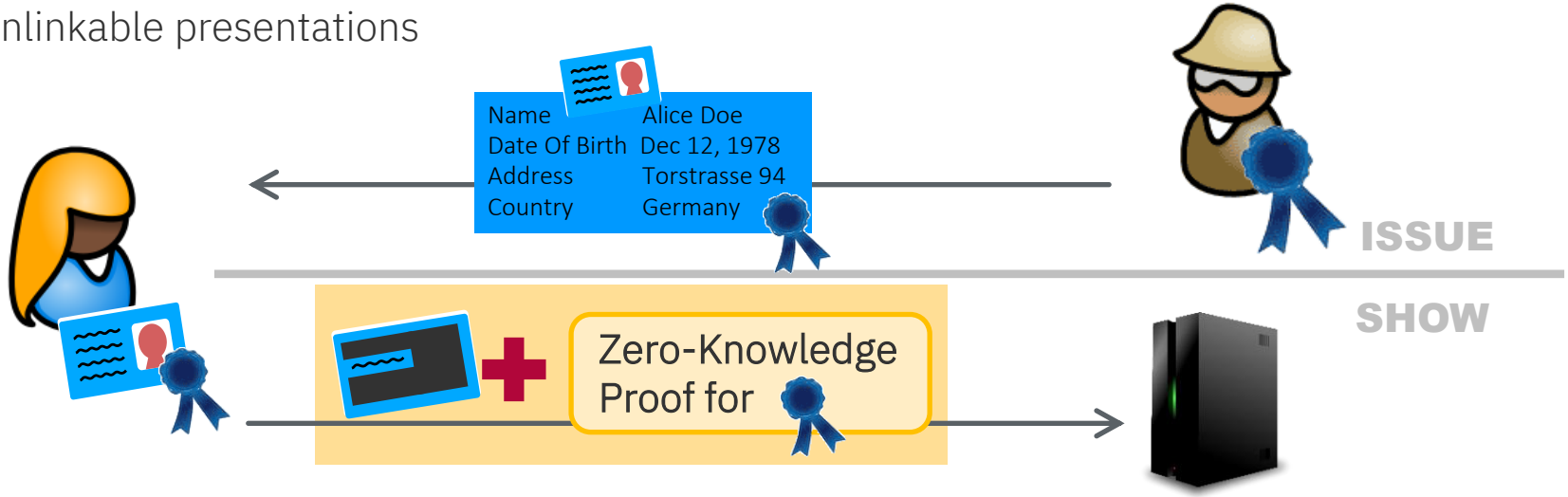
Andrea Flamini

based on joint works with Karla Friedrichs, Jonathan Katz, Watson Ladd, Anja Lehmann and Marek Sefranek

Do anonymous credentials really enable minimal disclosure?

We have verifiable credentials supporting

1. selective disclosure
2. unlinkable presentations



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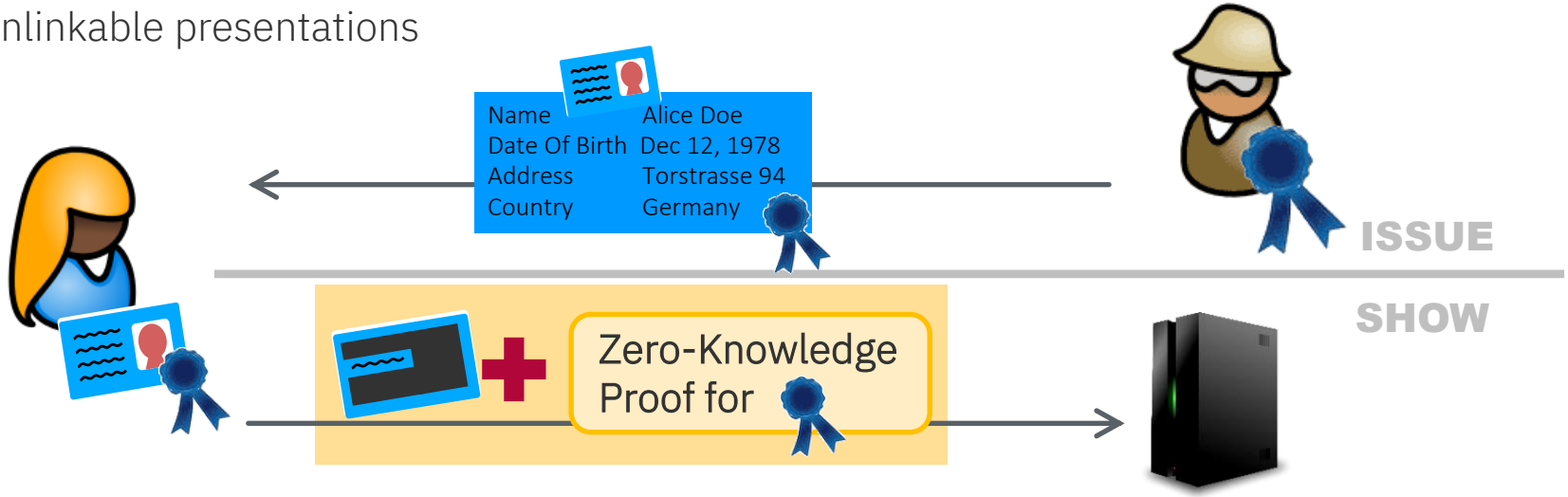
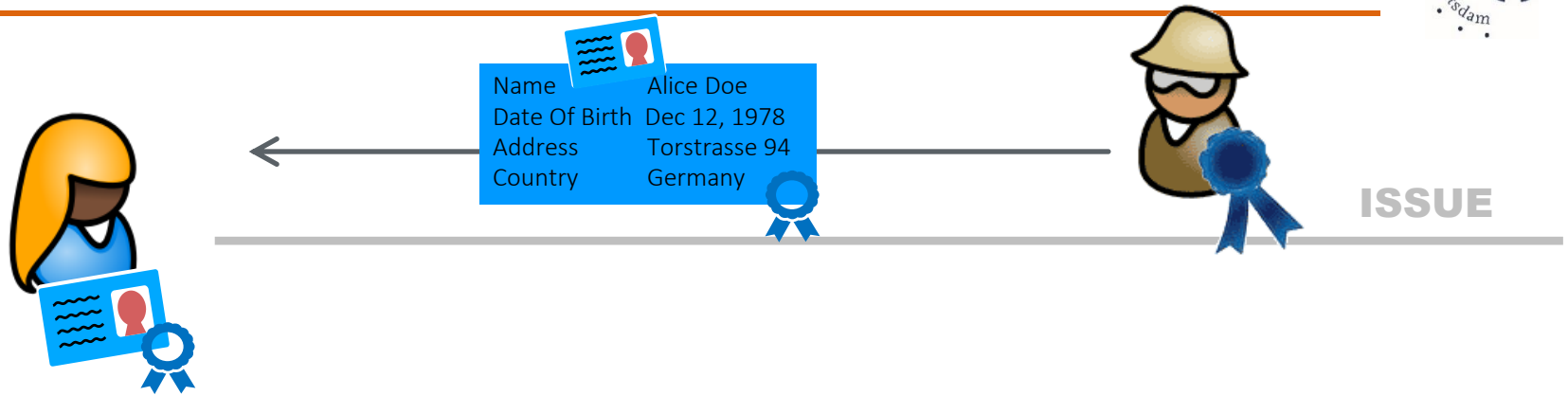


Presentations **always reveal the issuer** to enable public verifiability

This can reveal your **citizenship**, your **university**, your **device's manufacturer**...

What we want to have



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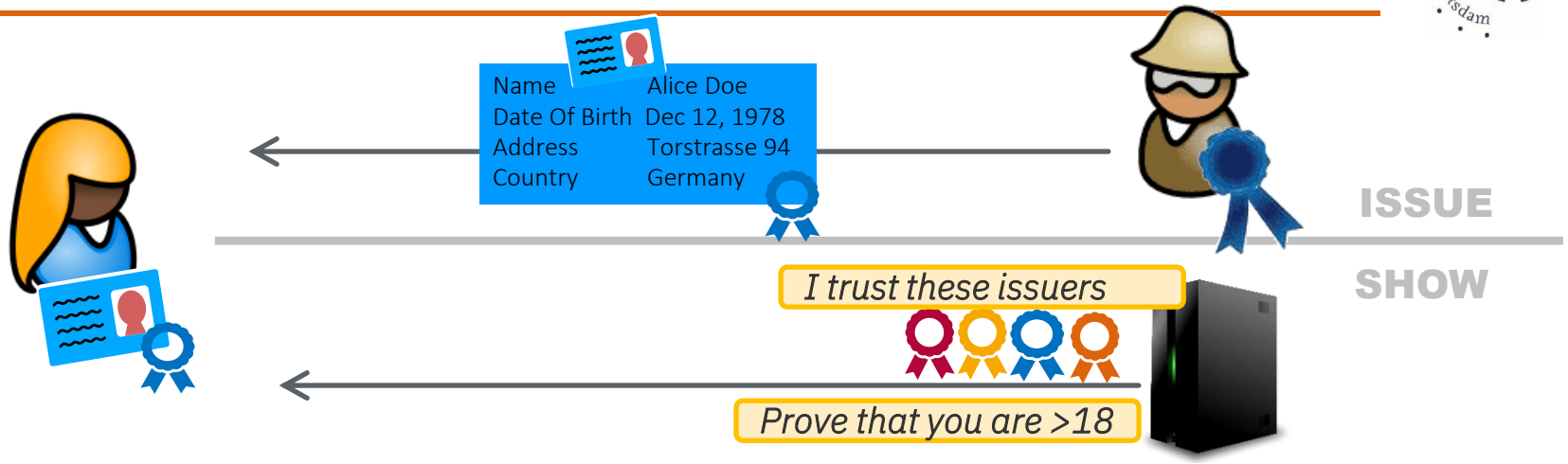

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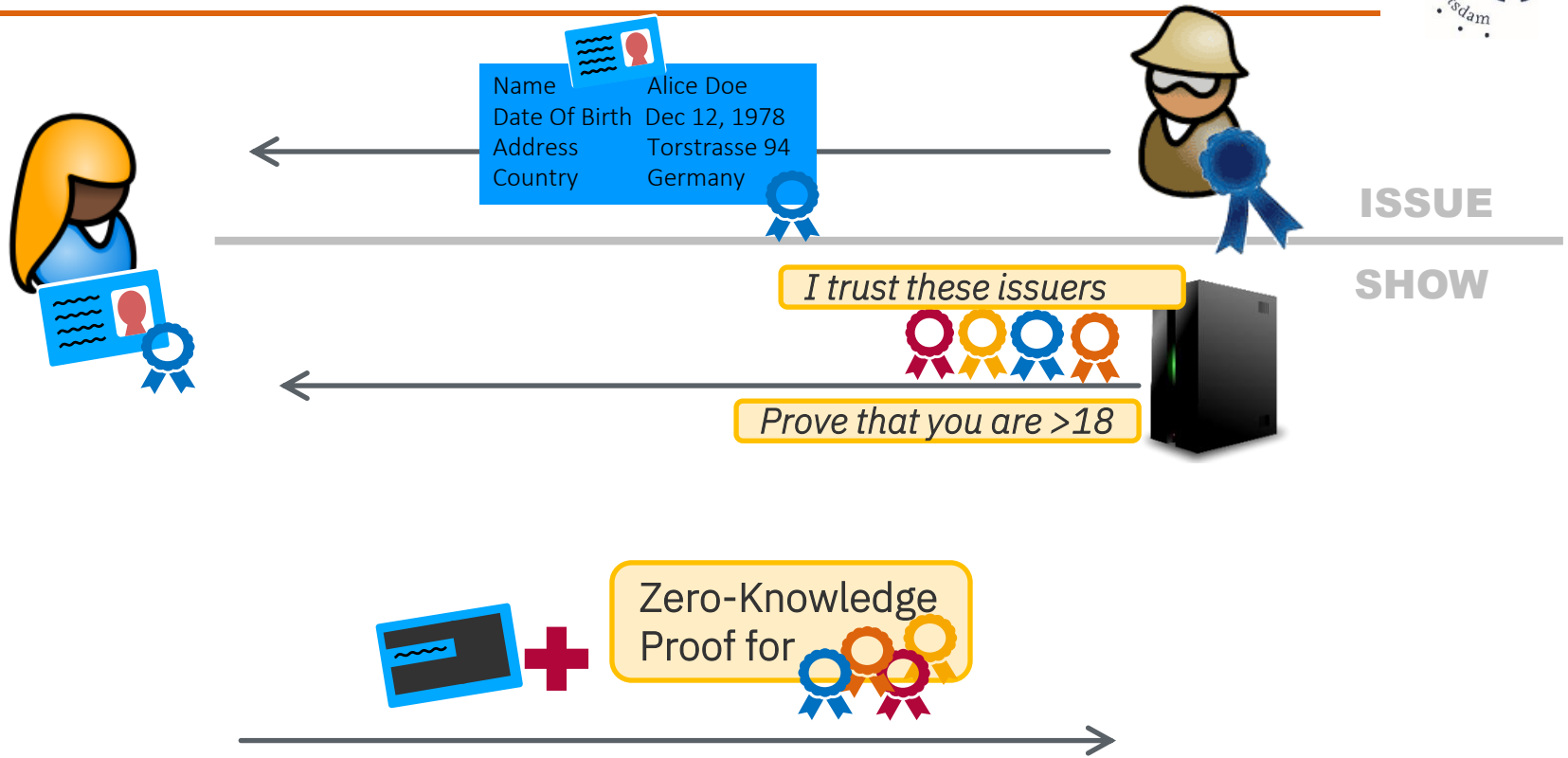

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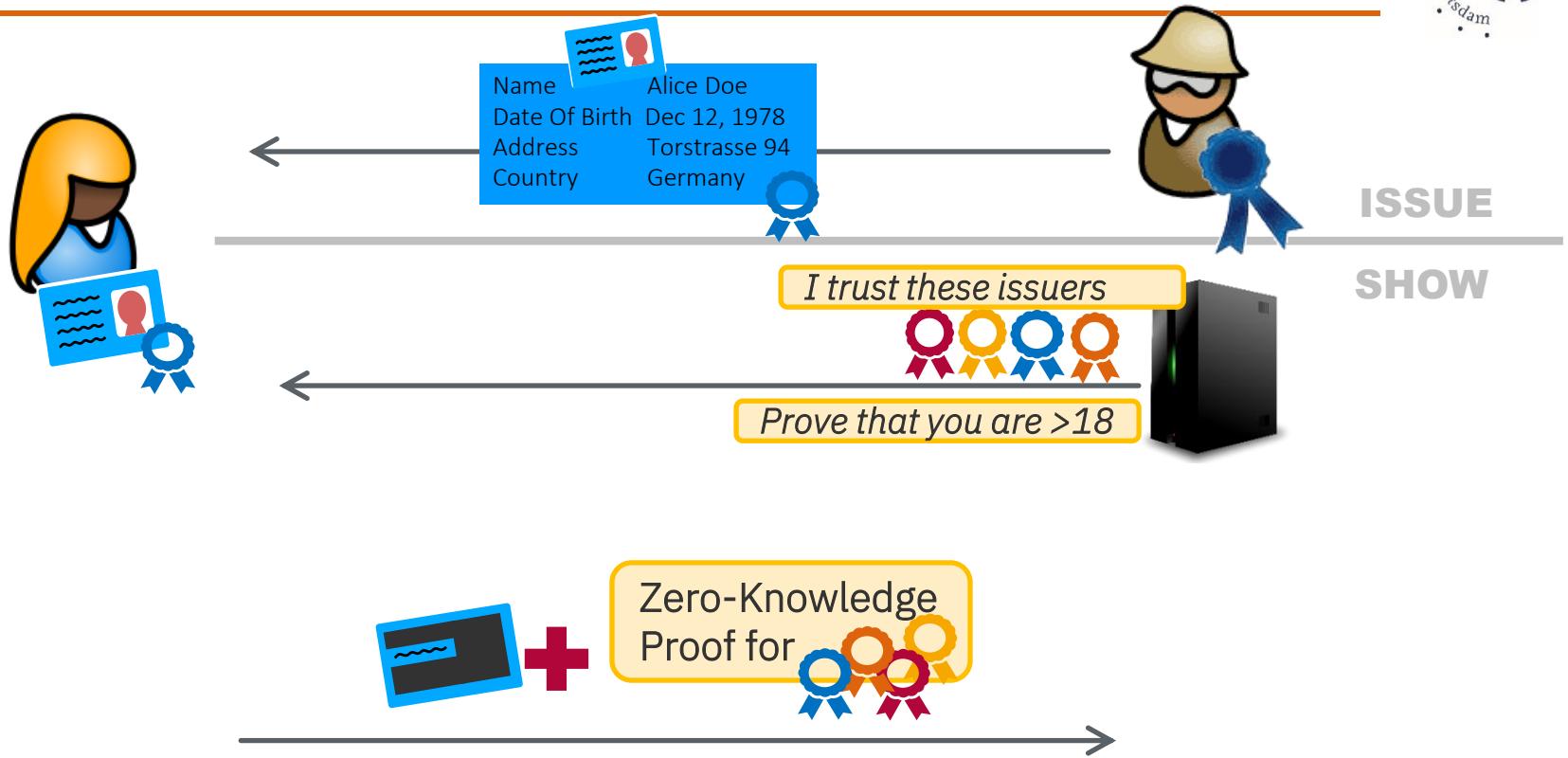

GOOD NEWS:

WE KNOW HOW TO DO IT!

A useful property of BBS signatures

Given a BBS credential issued by 

Name	Alice Doe
Date Of Birth	Dec 12, 1978
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We know how to transform it into a credential for the same attributes that verifies under a **random public key**

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This might look irrelevant, but it is actually very useful!

Our Solutions

We have designed two solutions that match two use cases:

	Small sets of issuers	Large sets of issuers
Use case	Issuers are EU member states	Issuers are EU Universities
Trust	Trust only the issuers	Trust the **issuers** and **a third party** who certifies the public keys of the issuers in a set
Presentation size	overhead logarithmic in the number of issuers	Constant presentation size
Compatibility with BBS	✓	✓

Simple construction for small policies

When the set of trusted issuers is small (e.g. <64) we have an efficient construction

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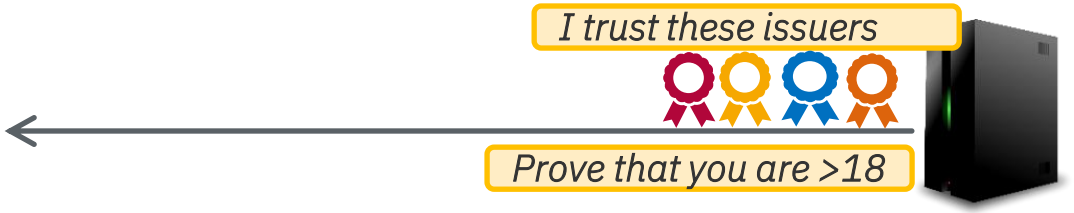

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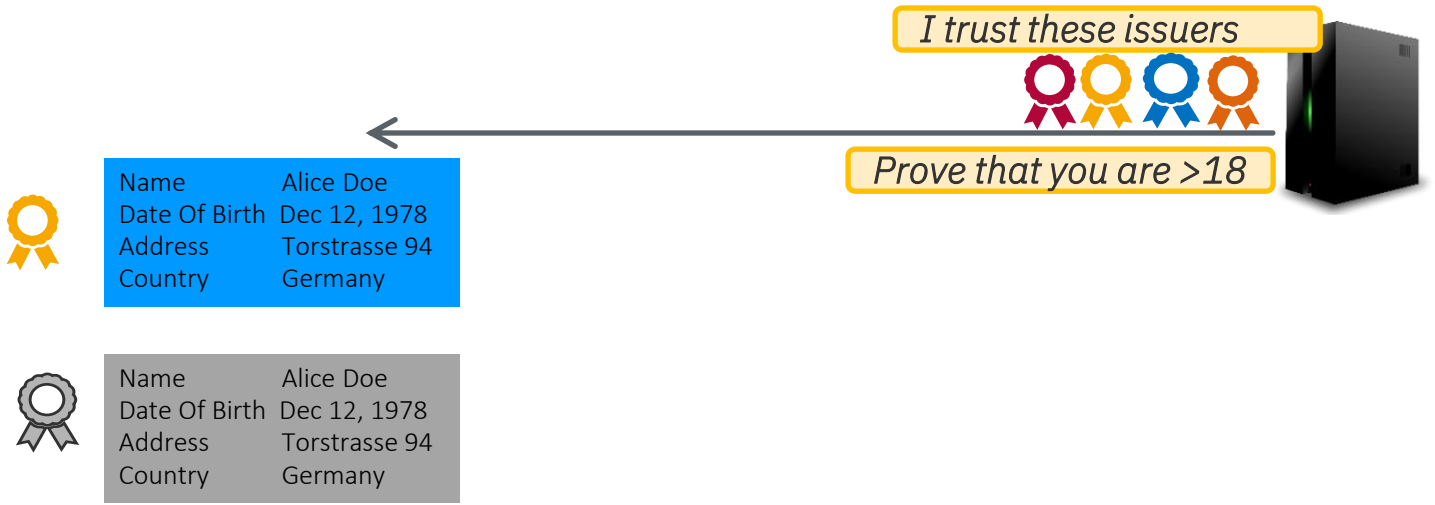

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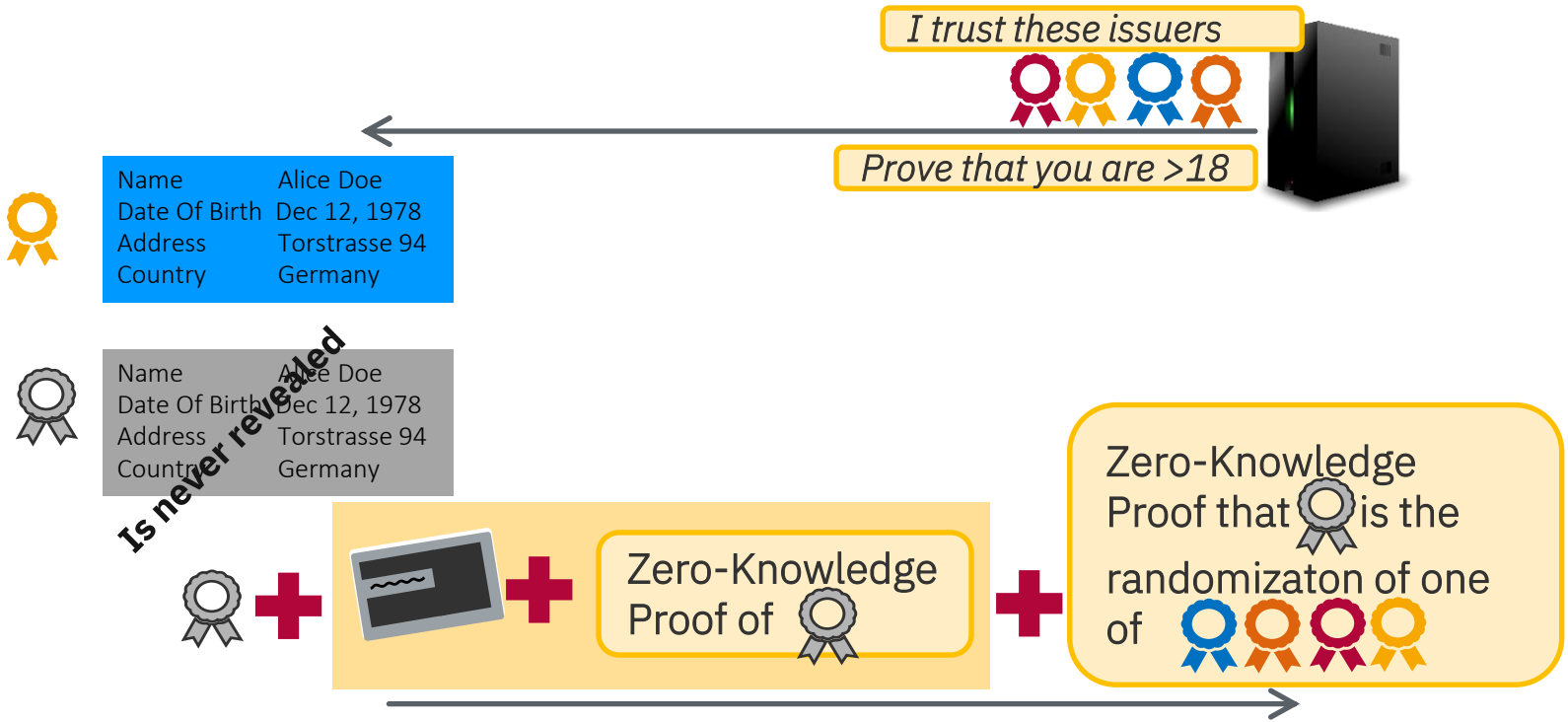

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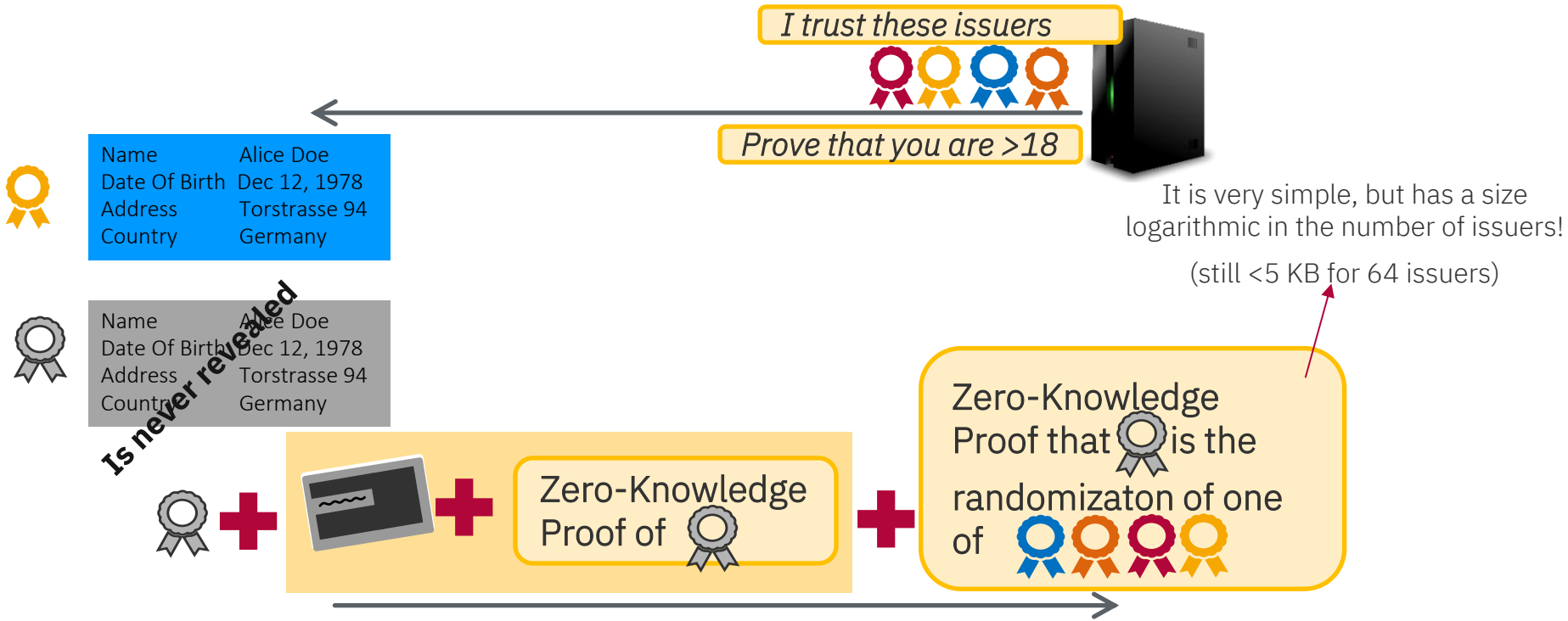

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It is very simple, but has a size logarithmic in the number of issuers!

(still <5 KB for 64 issuers)

- https://ia.cr/2026/870

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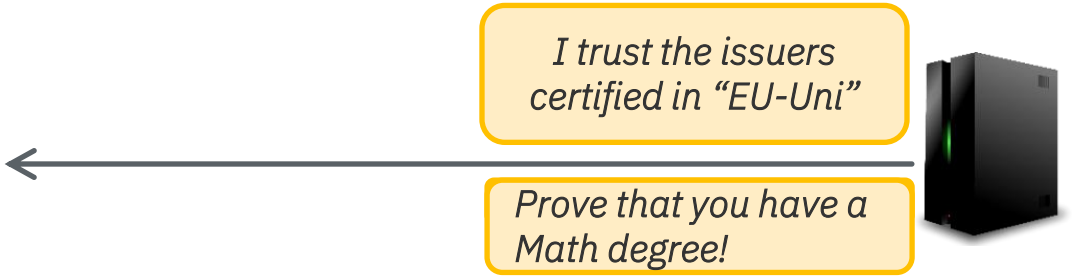

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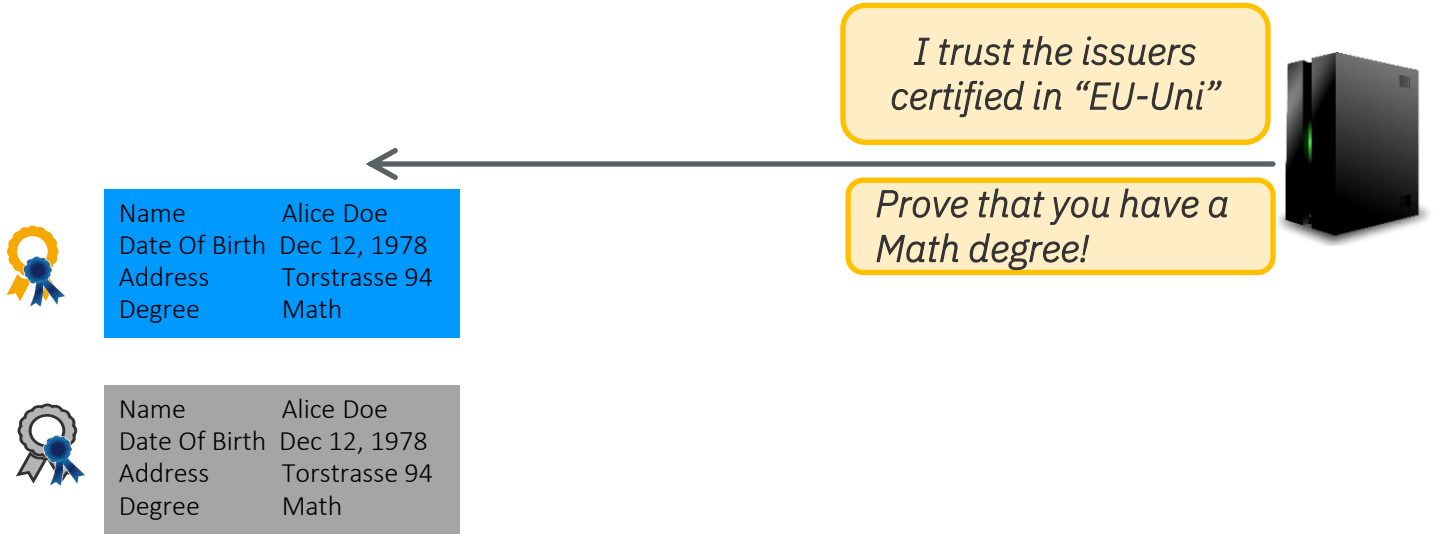

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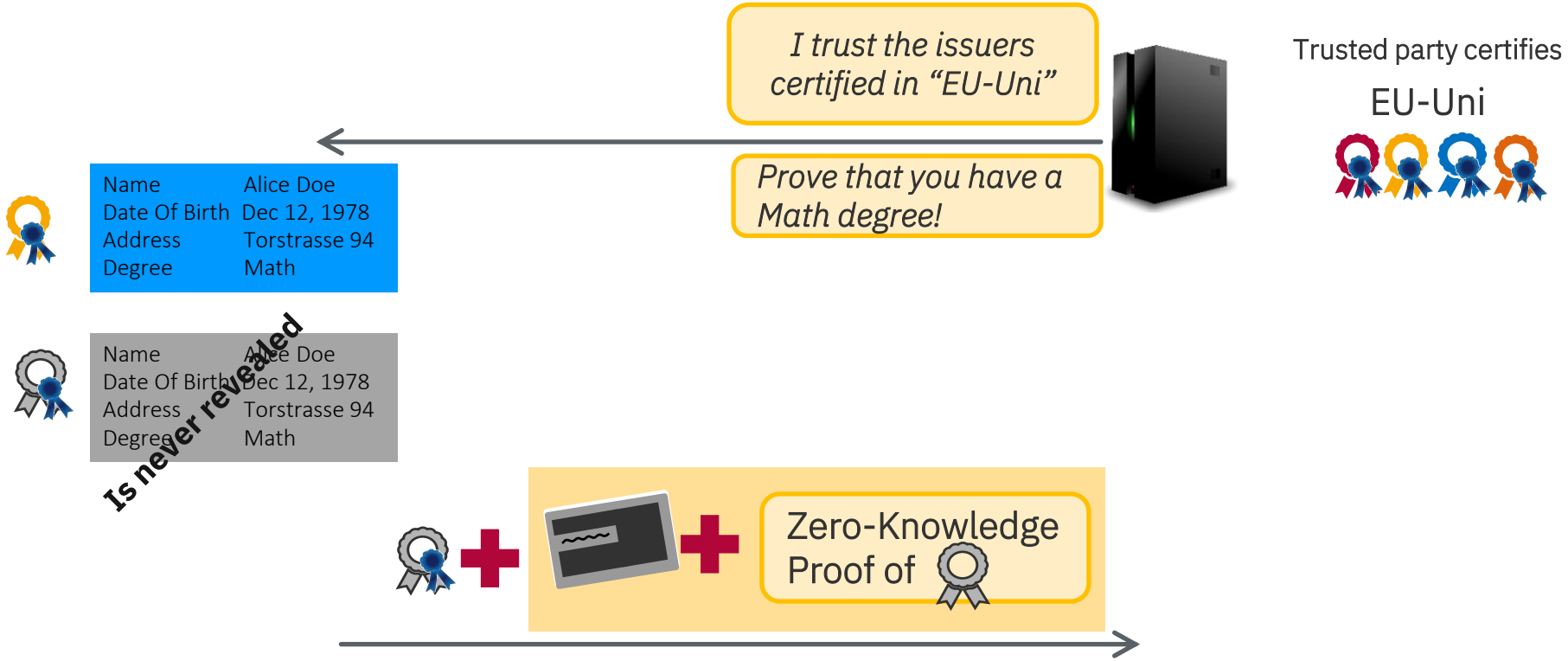

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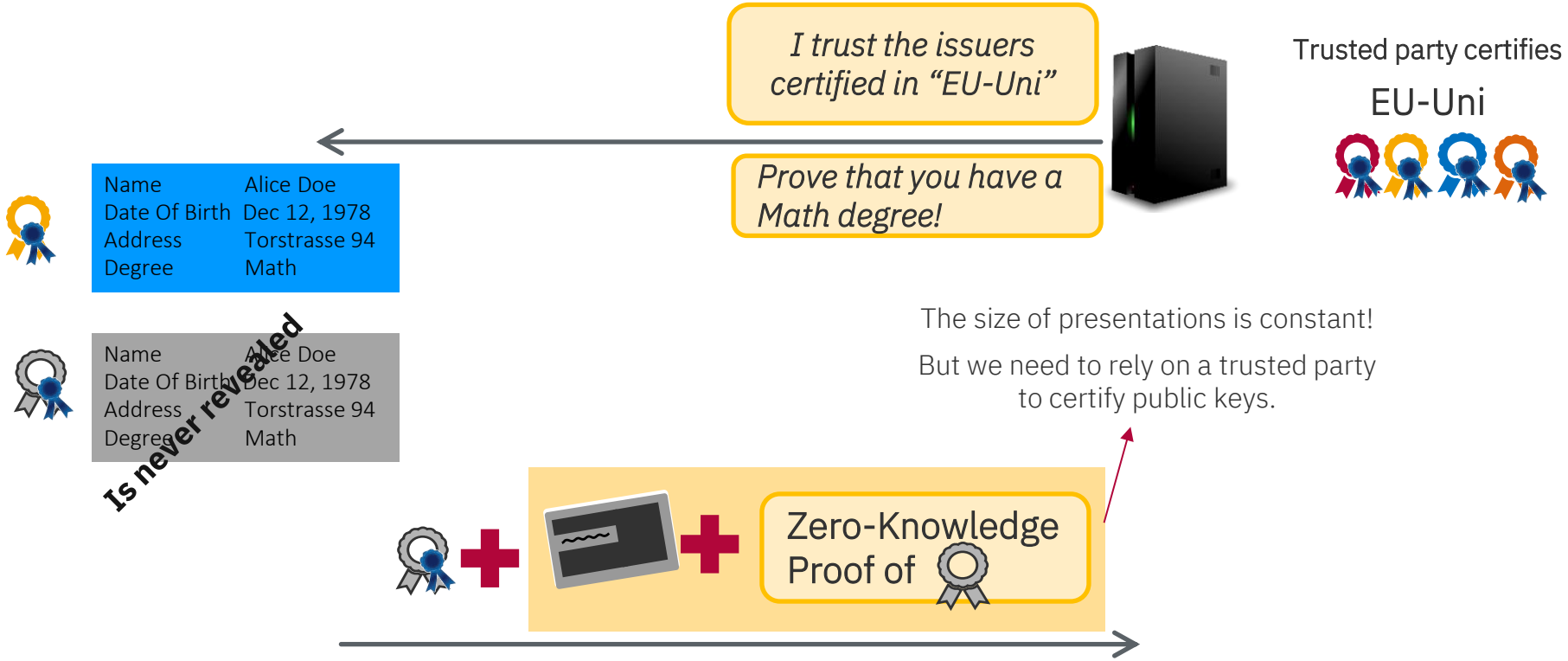

The size of presentations is constant!

But we need to rely on a trusted party to certify public keys.

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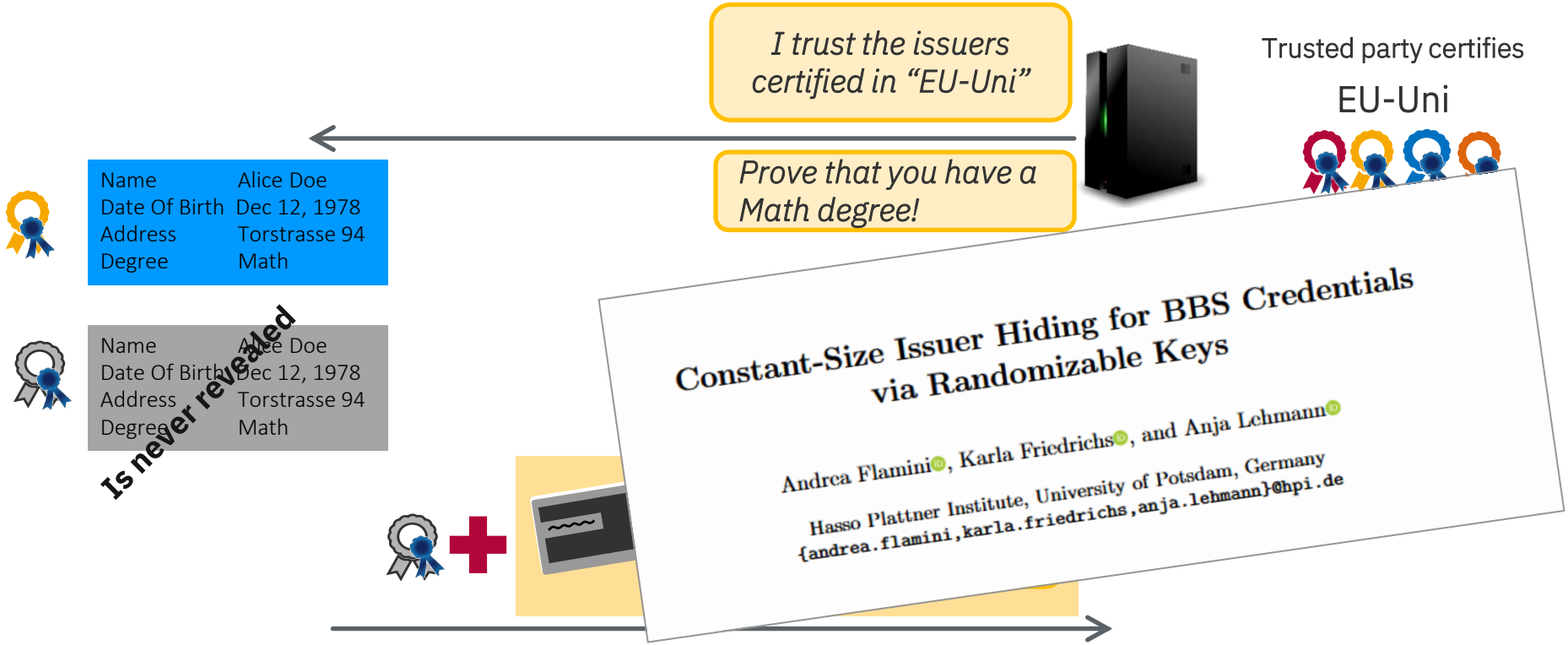


- https://ia.cr/2026/369

Conclusion

The tricks we have shown do not work also for single-show credentials (due to salted hashes)

But we have shown that this is possible for BBS credentials!

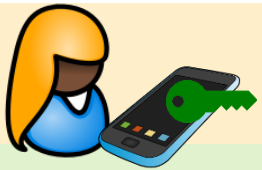
- We know how to build Issuer-Hiding presentations efficiently.
- The protocols are very simple.
- The constructions do not require updating the issuance of BBS credentials.
- Issuer-Hiding presentations use standard BBS presentations as building blocks, and require only a few additional operations.

Towards Deploying Anonymous Credentials

1 | Standardisation of all required cryptographic protocols → interoperability

IETF: ongoing standards for all core crypto primitives (e.g., BBS)
ETSI: dedicated standard for ZKP-based EUDI Wallet under development

2 | Realize cloning-prevention for anonymous credentials
Usually done through device binding



→ Solved: Device-binding from ECDSA Secure Elements

3 | Ensure that privacy strong enough for real-world use case, e.g., for age proofs?

→ Solved: Issuer-hiding protocols, e.g. for BBS

ZKP-EUDI Roadmap | Next Steps

Short/Mid-term: show feasibility and benefits

- Use ZKP for use cases with high privacy demands
- ZKP-compatible protocols (OID4VC) & data formats
- Many additional features: pseudonyms, blind issuance, …
  → Build modular & crypto-agile protocols

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Longterm: full post-quantum security

- Current solutions have PQC-privacy, but classic soundness
- PQC solutions need (a bit) more research & time to analyse
  - Current work provides concrete target for PQC research
    Insights from pre-PQC serve as blueprint
  - Shape PQC base standards & hardware APIs now(ish)

Summary

- Anonymous credentials = only path to strong & multi-show unlinkability

  Can even provide issuer hiding
- Start where privacy matters most, e.g., age proofs

  (but whether we want age proofs is a different story …)
- Main deployment blockers are solved: device binding & standards underway
- Cryptography for transitional phase is ready!

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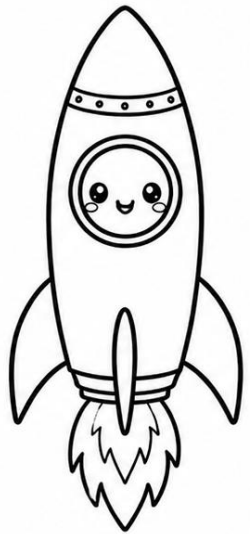
eIDAS: lets fly to the moon!
ARF: but you must use a car …

eIDAS: privacy-preserving eID

ARF: ECDSA

Ready to use & built for this: anonymous credentials



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Interested in using ZKP? Please reach out:
https://hpi.de/lehmann/eudi

ARF: ECDSA

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