PAXPORT: Analysis of the Spanish Age Verification System

David Balbás, Diego Castejón

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IMDEA Software Institute

Outline

- Digital identity systems
- PAXPORT: the Spanish age verification system
  - Design
  - Problems
  - Solutions
- The EUDI Wallet and Next Steps

Digital Identity Systems

The Problem

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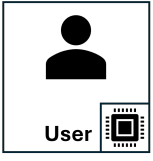
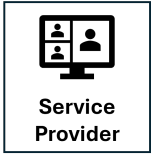
  - Scam and fraud prevention.
  - Digital agility and interoperability within EU countries.
  - Increased privacy and security.
- *Privacy and security* are central to system design:
  - Selective disclosure / data minimization.
  - Unlinkability across service providers.
  - Non-transferability / unforgeability.
  - Anonymity / pseudonymity.
  - ...

The Setting


Registration
Authority


Credential
Issuer


User


Service
Provider

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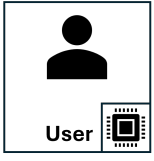
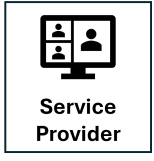
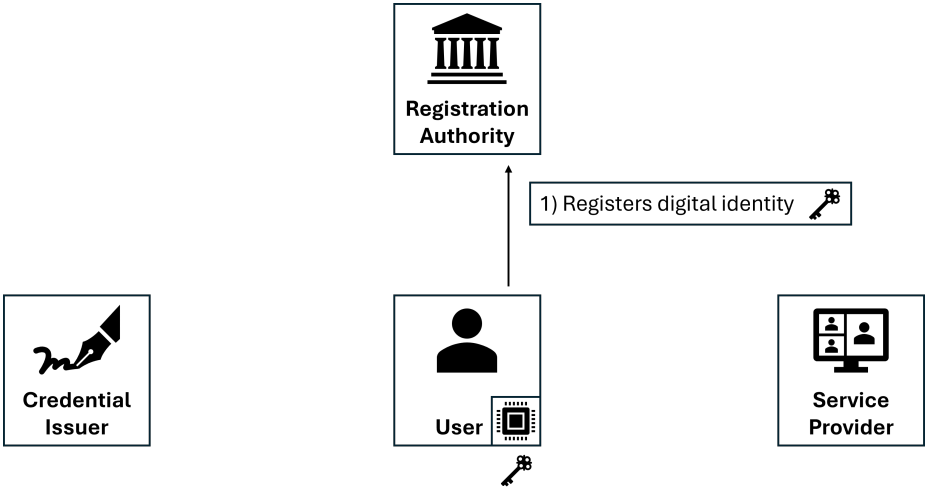


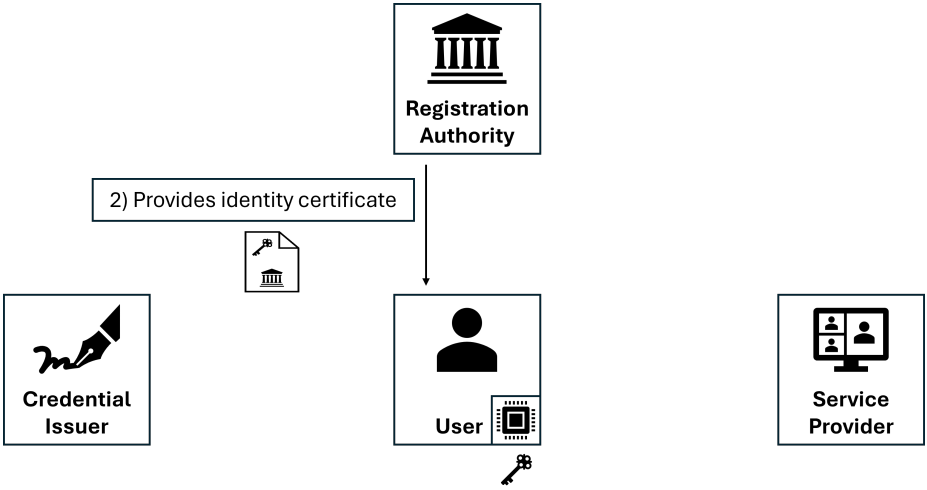


0) Generates digital identity

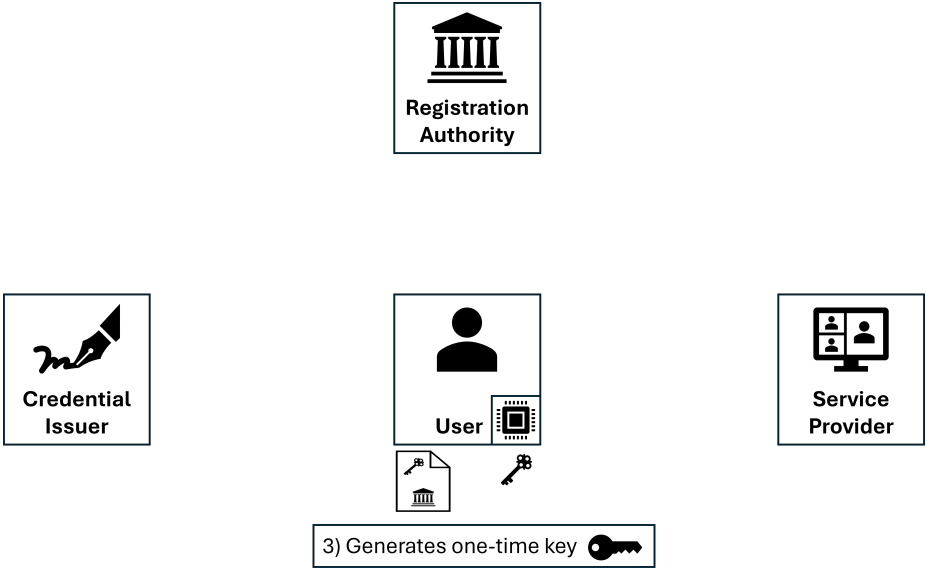
The Setting


Registration Authority
1) Registers digital identity
Credential Issuer
User
Service Provider

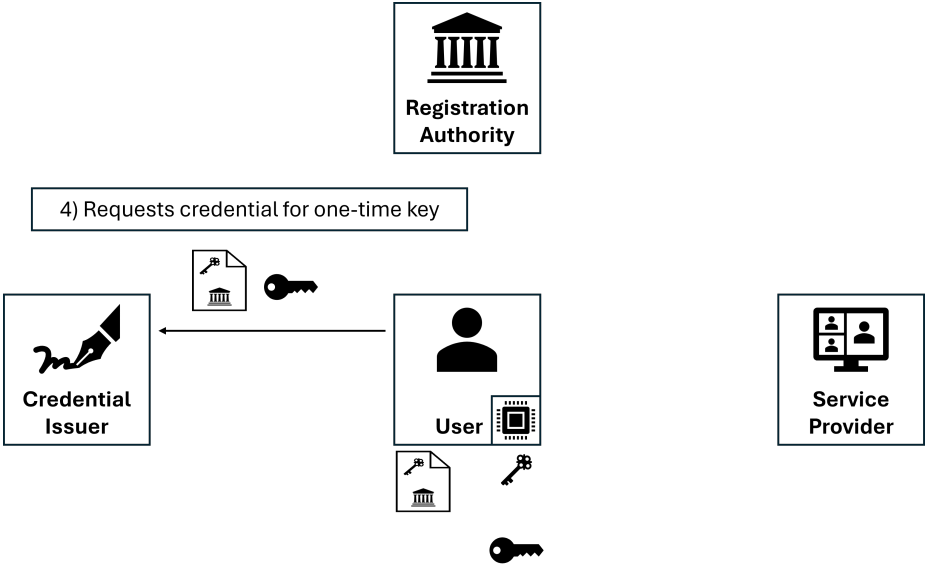
The Setting


Registration Authority
2) Provides identity certificate
Credential Issuer
User
Service Provider

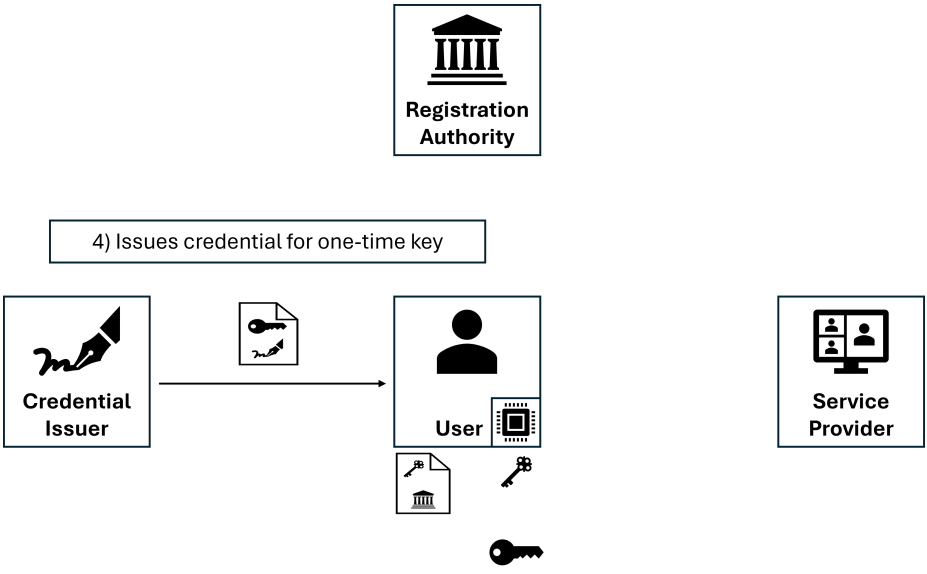
The Setting


Registration Authority
Credential Issuer
User
Service Provider
3) Generates one-time key

The Setting


Registration Authority
4) Requests credential for one-time key
Credential Issuer
User
Service Provider

The Setting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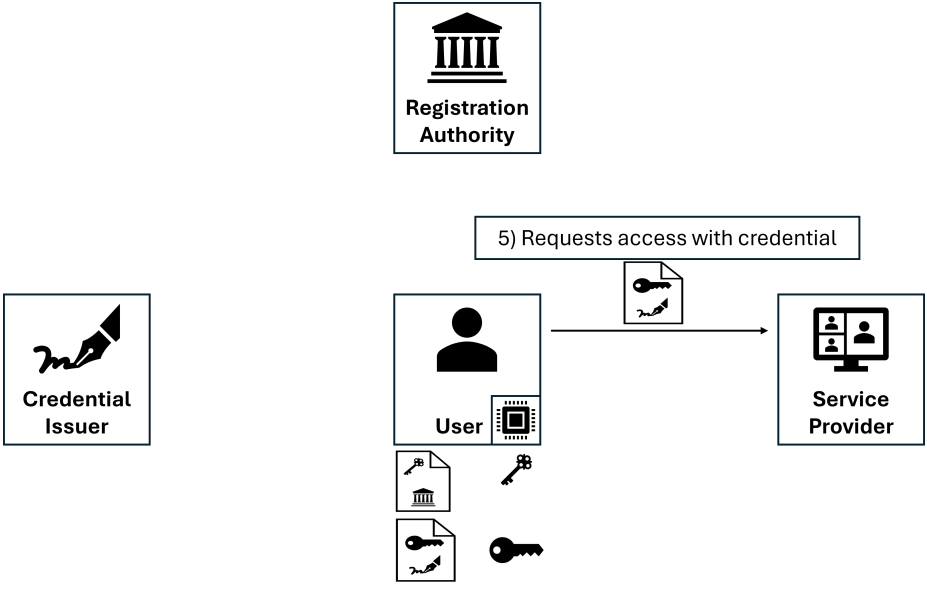
Registration Authority
5) Requests access with credential
Credential Issuer
User
Service Provider

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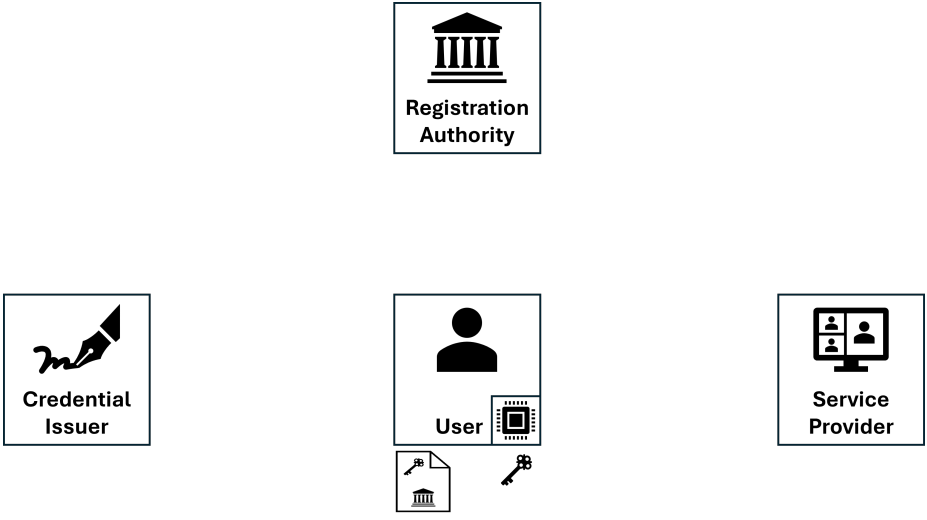
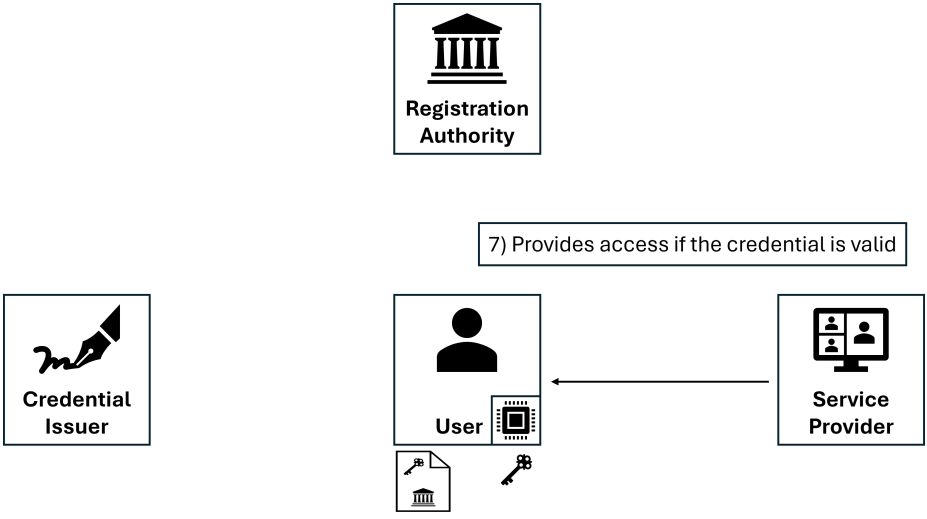

Registration Authority
Credential Issuer
User
Service Provider
6) User deletes one-time key

The Setting


Registration Authority
7) Provides access if the credential is valid
Credential Issuer
User
Service Provider

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- **Device binding:** Credentials should not leave the device to prevent users from sharing or selling them.

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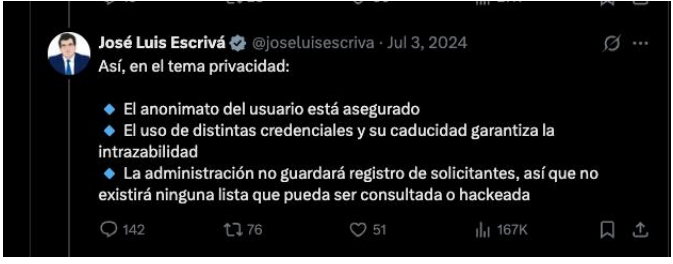
- *Data minimization* is central.

The PaXport

PAXPORT Security Goals



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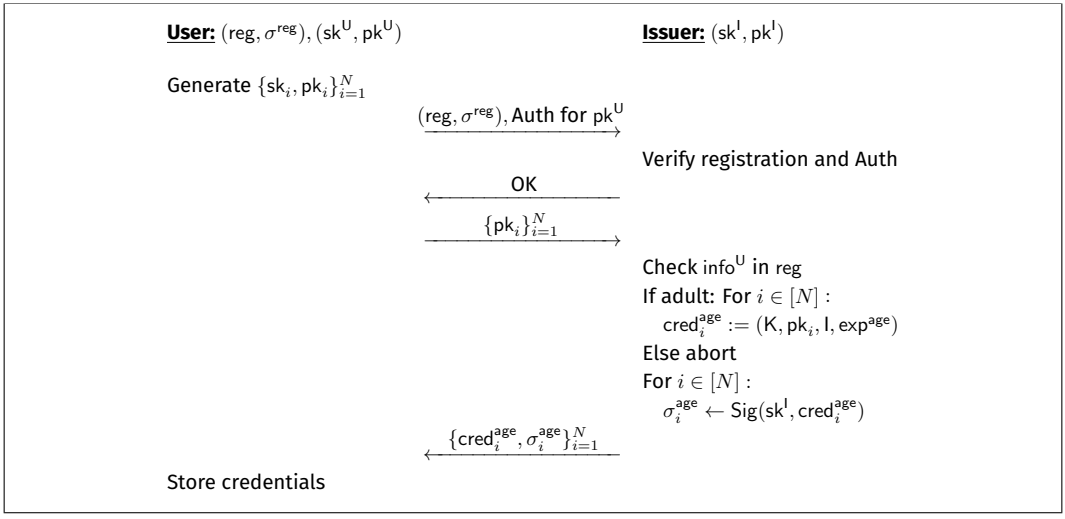
- The issuer **signs** the credential:

$$\mathsf{cred}_i^{\mathsf{age}} = (K, \mathsf{pk}_i, I, \mathsf{exp}^{\mathsf{age}})$$

Where I is the issuer.

PAXPORT Credential Issuing



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- User gets a *challenge* c from the service provider.
- User **signs** c using sk_i and sends the signed challenge and the issuer-signed credential.
- Service provider **checks**:
  - the *signature* on c,
  - the credential *validity* (using the issuer's public key),
  - the *expiration* date

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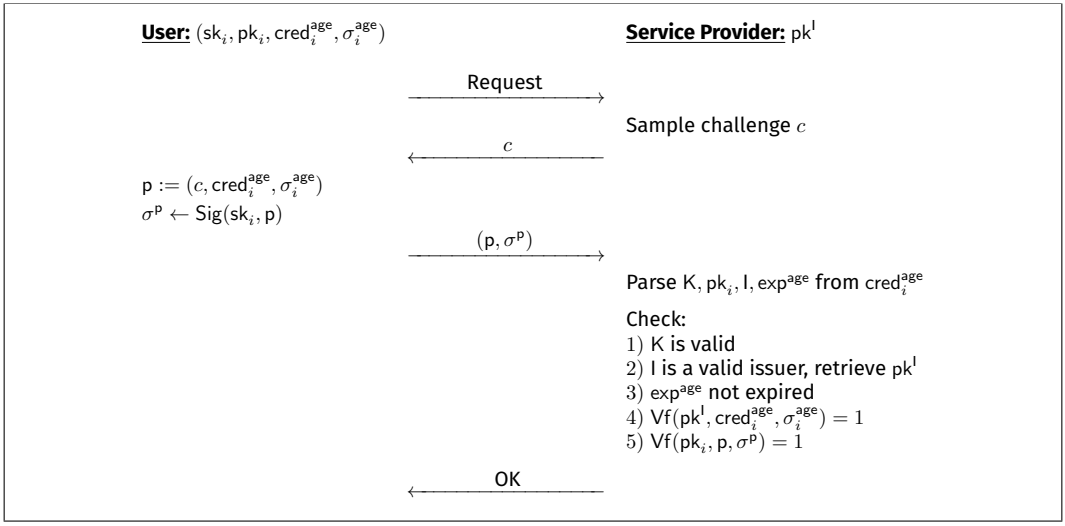
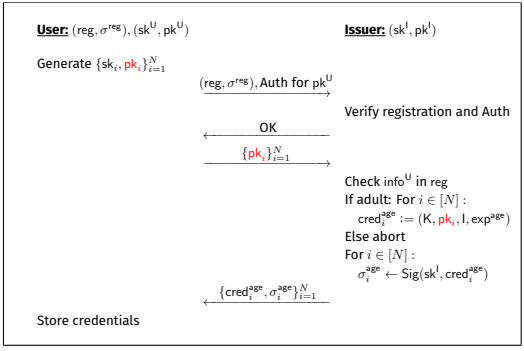
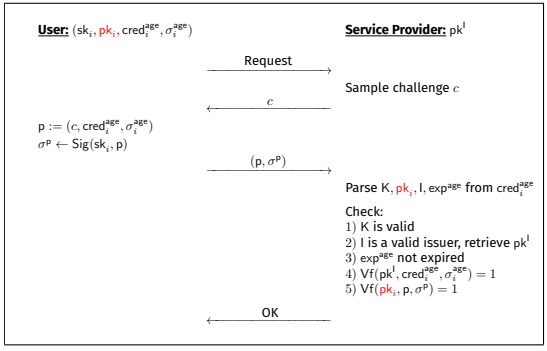


PAXPORT in a Nutshell

Issuance:



Presentation:



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- **Unlinkability:** $\times$
  Only holds under the assumption that the issuer is uncorruptible.

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A *security breach* in the issuer *exposes* this information to attackers.

The problem is that this data *exists at all* beyond the user's device.

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- **Possible deanonymization due to secure enclaves' key signing.**

Solutions

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1. **A simple, quick patch:** fixing the current system with enhanced privacy.
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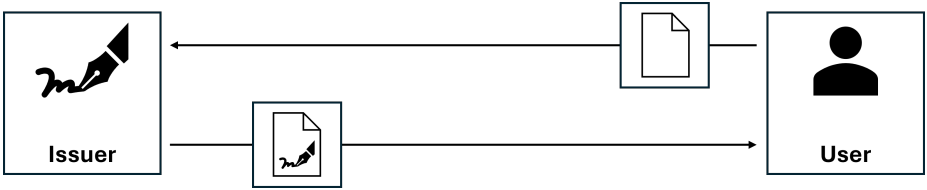
   - These are standardized and readily available.
2. **A necessary redesign:** Work towards an overall better design of the system based on *anonymous credentials*.

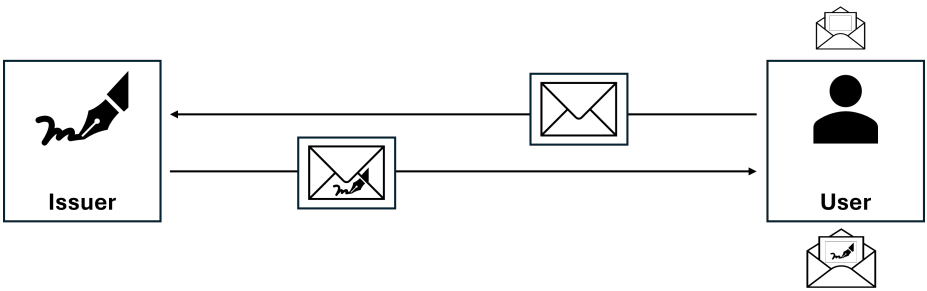
A Quick Patch: Partially Blind Signatures

Credentials are now digitally signed by the issuer.



A Quick Patch: Partially Blind Signatures

The user can hide pk_i in the signing process.

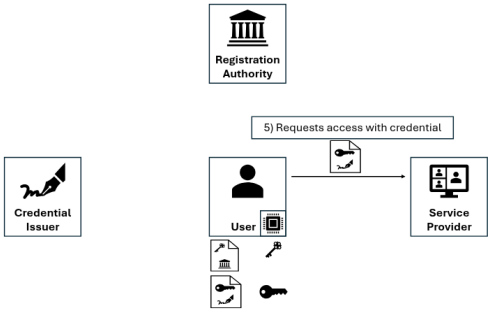


A Redesign: Anonymous Credentials

Anonymous credential systems enable users to:

- *Re-randomize* the credential signature at every presentation.
- *Prove* (in zero-knowledge) statements about the credential without disclosing the attributes fully.

There are many systems available.

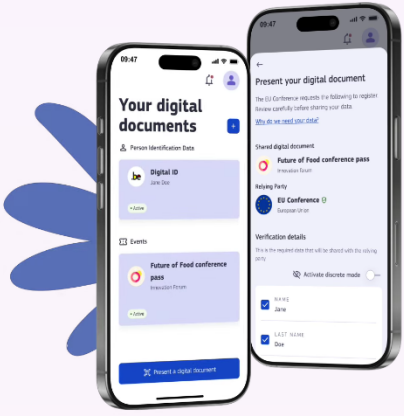


The EUDI Wallet and Next Steps

Current Designs: EUDI Wallet

A digital ID and personal digital wallet for EU citizens, residents and businesses

EU Digital Identity Wallets will provide a safe, reliable, and private means of digital identification for everyone in Europe. Every Member State will provide at least one wallet to all its citizens, residents, and businesses allowing them to prove who they are, and safely store, share and sign important digital documents.



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The European Digital Identity (EUDI) Wallet describes a system with good privacy properties that must be implemented by all EU countries.[1]

> The EUDI Wallet **shall** enable the user to share only the information they intend to share. The Wallet **shall** ensure an appropriate level of privacy, implementing policies about non-traceability and unlinkability of user's activities for third parties as appropriate considering:

[1] https://digital-strategy.ec.europa.eu/en/library/european-digital-identity-architecture-and-reference-framework-outline

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Implementation: batch issuance of one-time credentials that support *selective disclosure*. This is insufficient.[2]

Properties	Classic Signatures	„Patched" Signatures
Unobservability	✓	✓
Selective Disclosure	✗	Salted hashes ✓
RP ↔ RP Unlinkability	✗	Batch issuance ✓
IdP ↔ RP Unlinkability	✗	Impossible ✗

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EUDI Wallet and ZKPs

The good news: EUDI Wallet is actually considering ZKP implementation in future versions.[3]

Specification for ZKP Implementation in EUDI Wallet

Abstract

The present document specifies the technical specification and requirements for Zero-Knowledge Proof (ZKP) Implementation in EUDI Wallet.

GitHub discussion

Versioning

Version	Date	Description
0.1	03.04.2025	Initial version for discussion
0.2	23.04.2025	Updates based on first group meeting
0.3	02.05.2025	Updates based on second group meeting
1.0	21.05.2025	Final version

[3] https://github.com/eu-digital-identity-wallet/eudi-doc-standards-and-technical-specifications/blob/main/docs/technical-specifications/ts4-zkp.md

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Overall, *zero-knowledge proofs* generated by the holder are a good solution.

How do they work?

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- User *signs* $\sigma \leftarrow \mathsf{Sig}(\mathsf{sk}, c)$ on the secure enclave.
- User *proves* that it knows $(\mathsf{pk}, \sigma_{\mathsf{cred}}, \mathsf{cred})$ such that:

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Presentation:

- Service provider sends *challenge* c.
- User *signs* $\sigma \leftarrow \mathsf{Sig}(\mathsf{sk}, c)$ on the secure enclave.
- User *proves* that it knows $(\mathsf{pk}, \sigma_{\mathsf{cred}}, \mathsf{cred})$ such that:
  - Challenge signature verifies: $\mathsf{Vf}(\sigma, \mathsf{pk}, c) = 1$.
  - Credential (including pk) is signed: $\mathsf{Vf}(\mathsf{cred}, \mathsf{pk}^{\mathsf{I}}, \sigma_{\mathsf{cred}}) = 1$.
  - $P(a_1, \ldots, a_k) = 1$ for some predicate P.

  User never reveals pk. Also, sk *is not used in the proof*.

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  - Careful design and specification to avoid forgeries (e.g. malleability, Fiat-Shamir attacks).
  - Proper, unambiguous parsing of attributes for all supported data formats.
  - Integration within a larger protocol, realistic security models.
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  - Proper, unambiguous parsing of attributes for all supported data formats.
  - Integration within a larger protocol, realistic security models.
  - Trusted setups.
- **Efficiency:**
  - Proving and verification time trade-offs.
  - Support for proof-unfriendly cryptographic primitives (e.g. ECDSA).
  - Credential-specific optimizations.

Bonus: The Google ZKP Library

- Anonymous Credentials for ECDSA.[4]

[4] https://blog.google/technology/safety-security/opening-up-zero-knowledge-proof-technology-to-promote-privacy-in-age-assurance/

Bonus: The Google ZKP Library

- Anonymous Credentials for ECDSA.[4]
- *Cryptographically sound*, but some things left open:
  - Current proposal cannot hide issuers.
  - Only specifies two specific data formats for US drivers licenses.
  - Extending ZK proofs to complex data formats is not easy.
  - Heavily optimized for ECDSA – extending to other algorithms is open.

[4] https://blog.google/technology/safety-security/opening-up-zero-knowledge-proof-technology-to-promote-privacy-in-age-assurance/