Fully-Featured Anonymous Credentials with Reputation System

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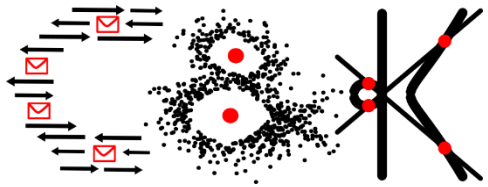
Lukas Eilers, Jan Haltermann, Jakob Juhnke,
Burhan Otour, Laurens Porzenheim, Simon Pukrop,
Erik Schilling, Michael Schlichtig, Marcel Stienemeier



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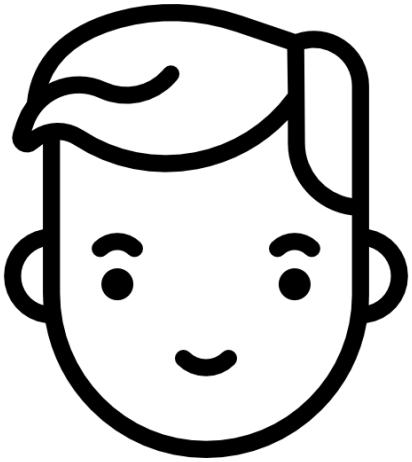
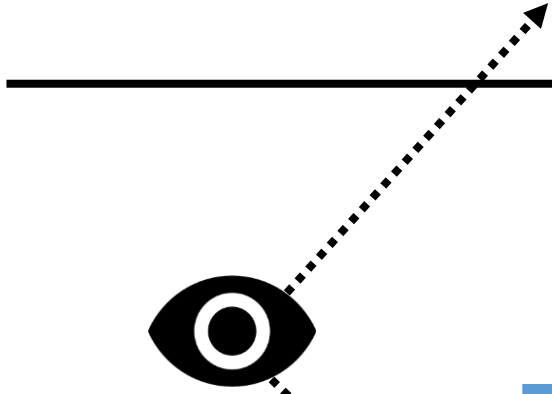
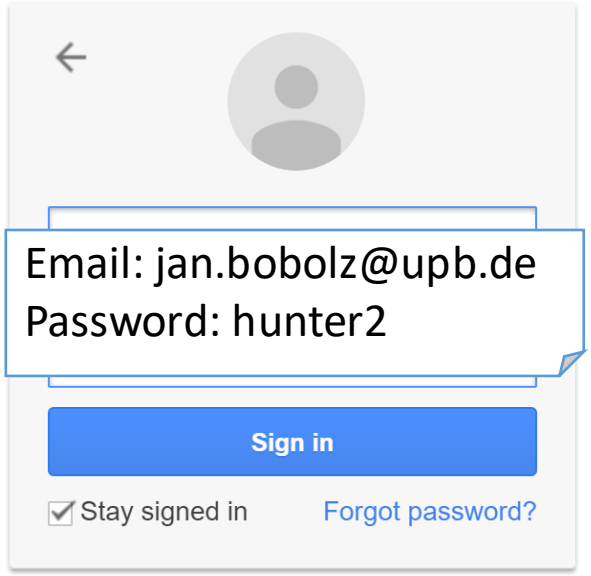
Access control: current state



User

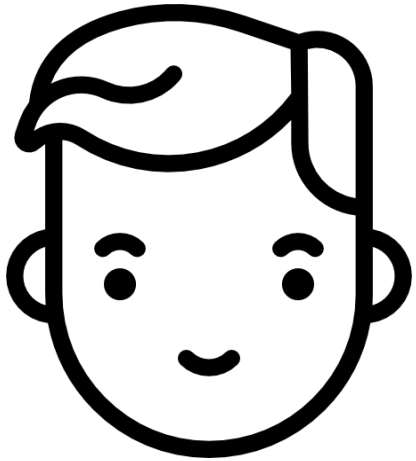


Service Provider



User	Password (*hashed*)
john@doe.com	password123
test@example.com	Lsrzr/?9s.yru3
jan.bobolz@upb.de	hunter2
h4xx0r@gmail.com	w1tn3ssh1d1ng
⋮	⋮

The problem(s)



jan.bobolz@upb.de

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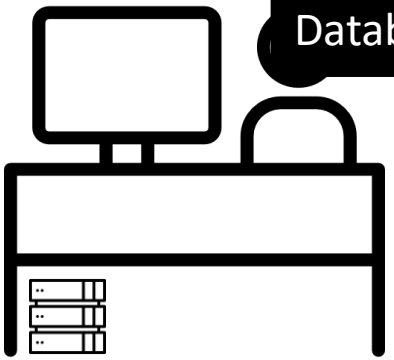
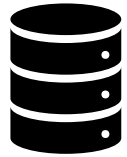


Database of payment data



jan.bobolz@upb.de

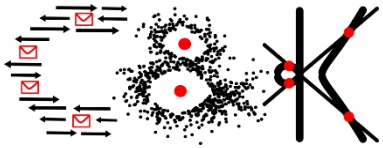
Database of movie tastes

The fix:

- Get rid of identifying information during authentication.
- Instead: Enforce access control through **anonymous credentials**.

CLARC

Cryptographic Library
for Anonymous Reputation and Credentials



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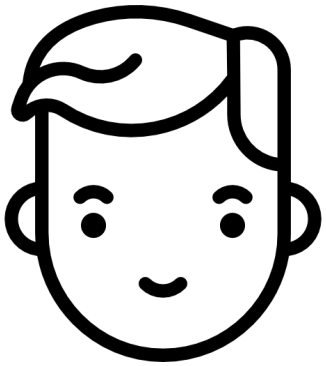
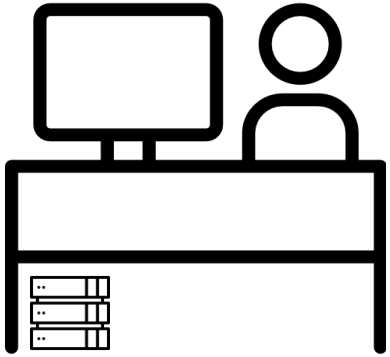
Overview of CLARC



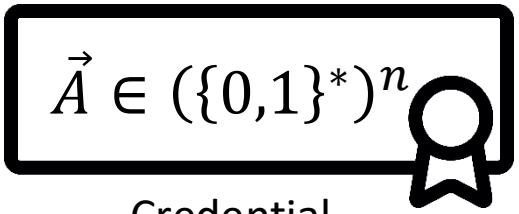
User

Pseudonym 1: request credential

Issue credential



Credential Issuer



Credential

Pseudonym 2: proof of credential with attributes fulfilling policy Φ

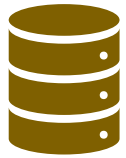
Service Provider

Issue rating token

Rating token

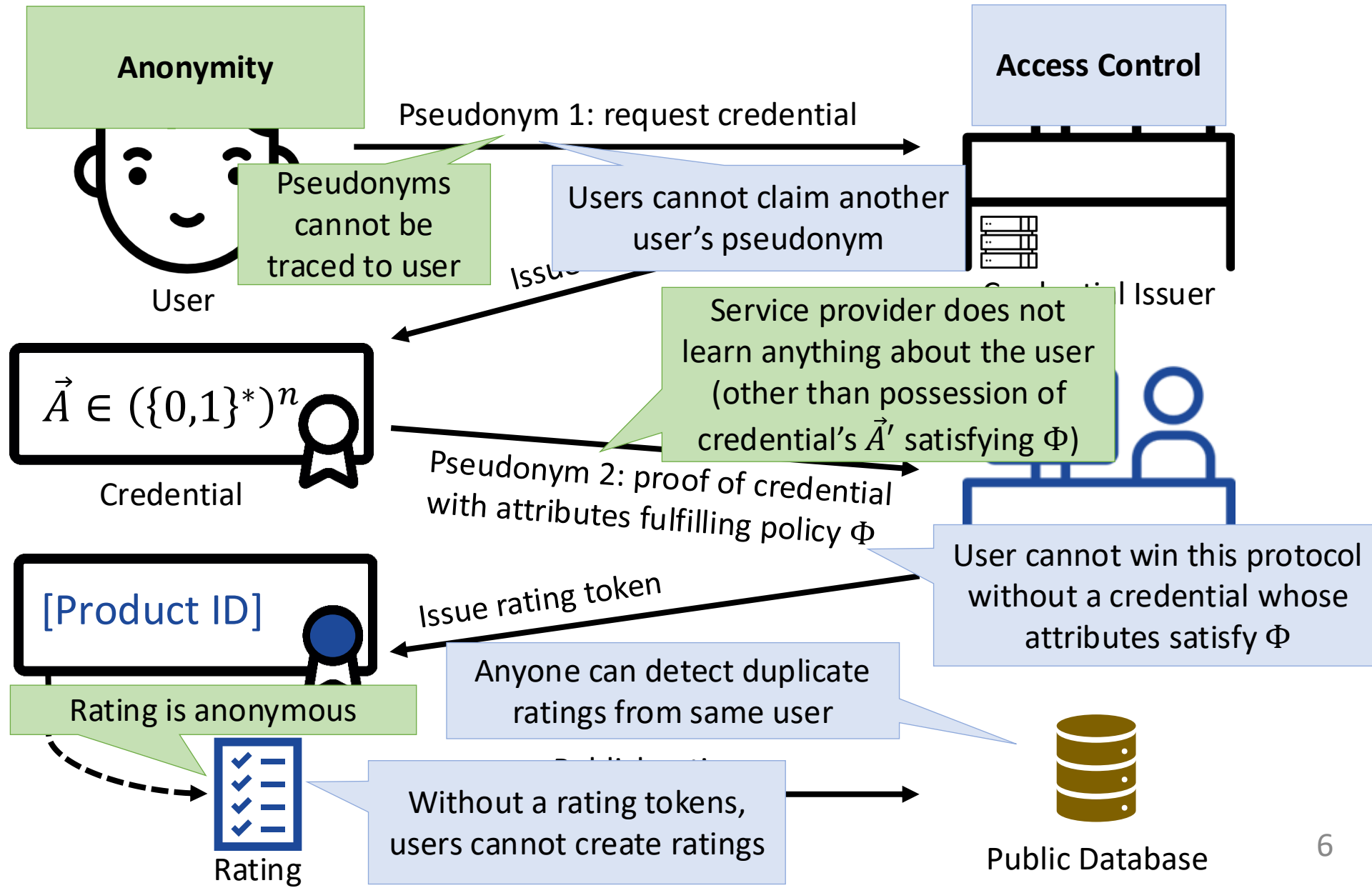
Rating

Publish rating

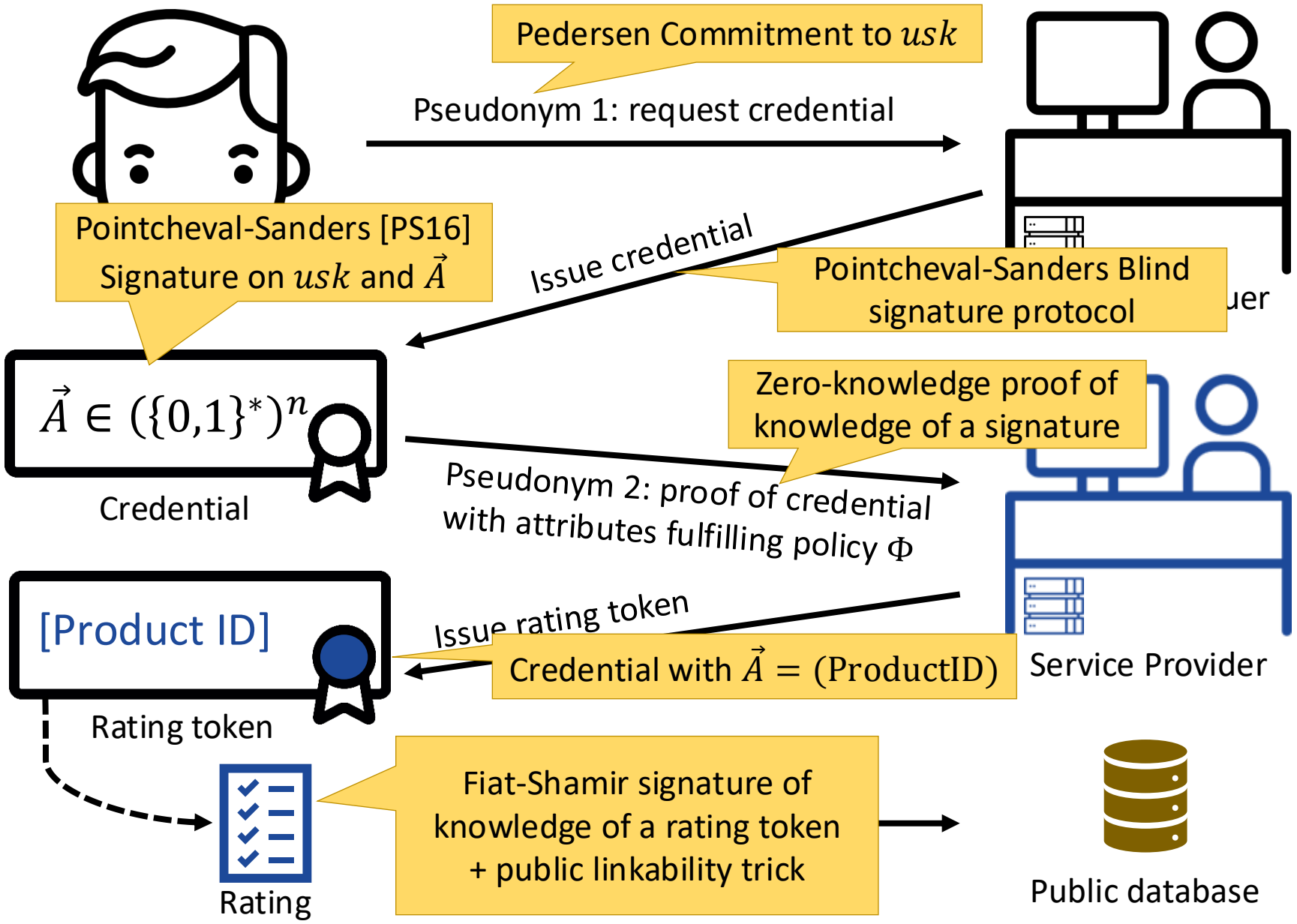


Public Database

Security


Anonymity
Access Control
Pseudonym 1: request credential
Pseudonyms cannot be traced to user
Users cannot claim another user's pseudonym
User
Issuer
$\vec{A} \in (\{0,1\}^*)^n$
Credential
Service provider does not learn anything about the user (other than possession of credential's $\vec{A}'$ satisfying Φ)
Pseudonym 2: proof of credential with attributes fulfilling policy Φ
User cannot win this protocol without a credential whose attributes satisfy Φ
[Product ID]
Issue rating token
Anyone can detect duplicate ratings from same user
Rating is anonymous
Without a rating tokens, users cannot create ratings
Rating
Public Database

Instantiation overview



[PS16] David Pointcheval and Olivier Sanders. Short Randomizable Signatures. In CT-RSA 2016

Implementation

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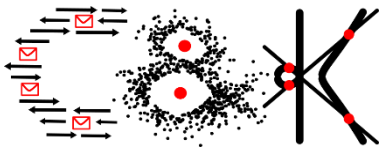
- Available at https://github.com/upbcuk/upb.crypto.clarc

- Implemented in Java, based on `upb.crypto` libraries for elliptic curves, hashing, secret sharing, etc.
  - https://github.com/upbcuk

Credential show protocol



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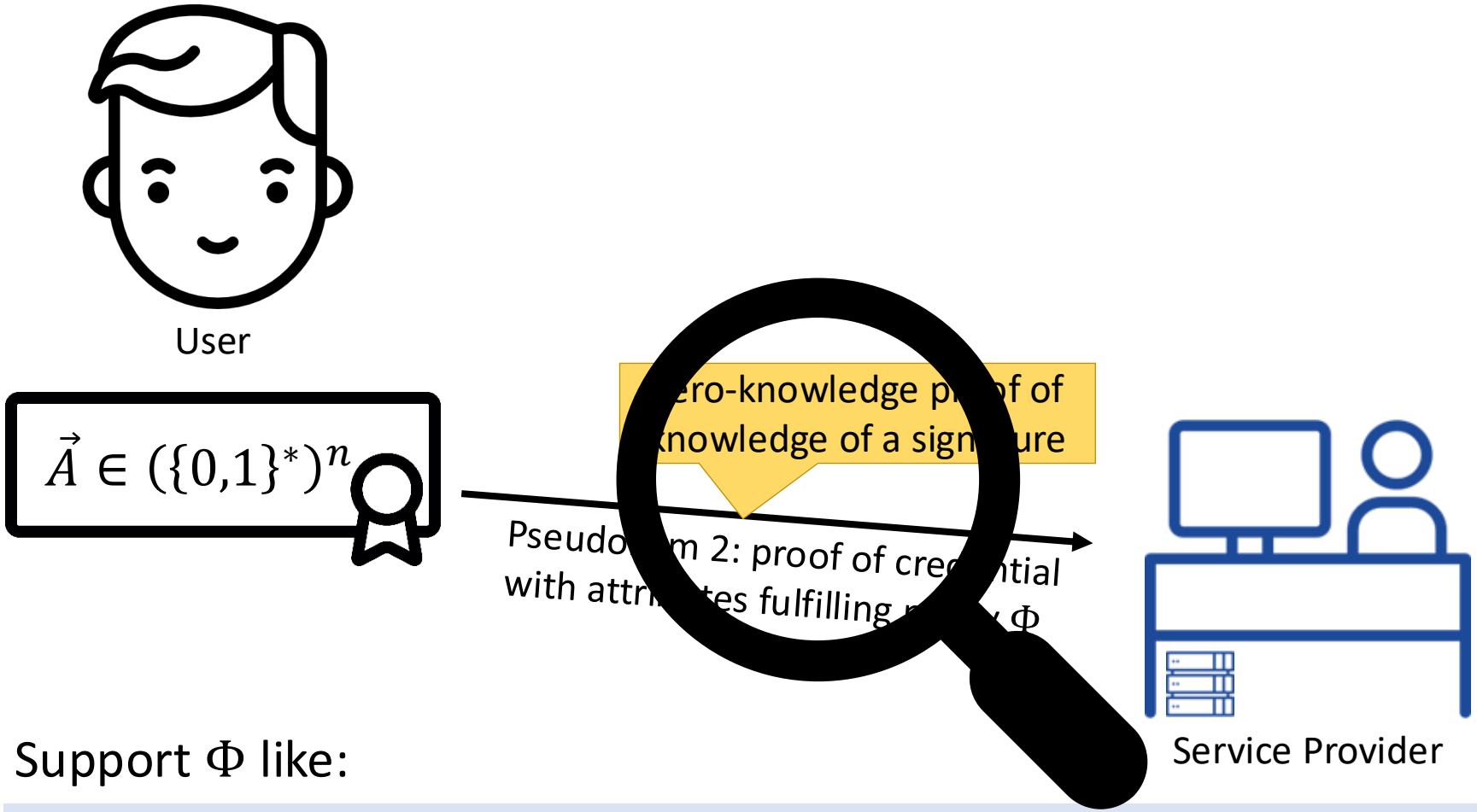
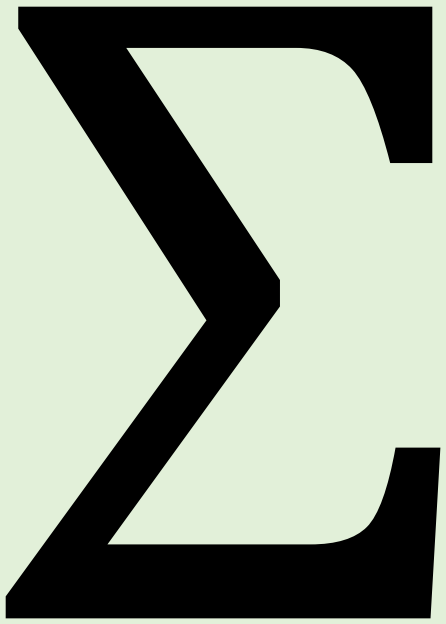
Protocol composition



Support Φ like:

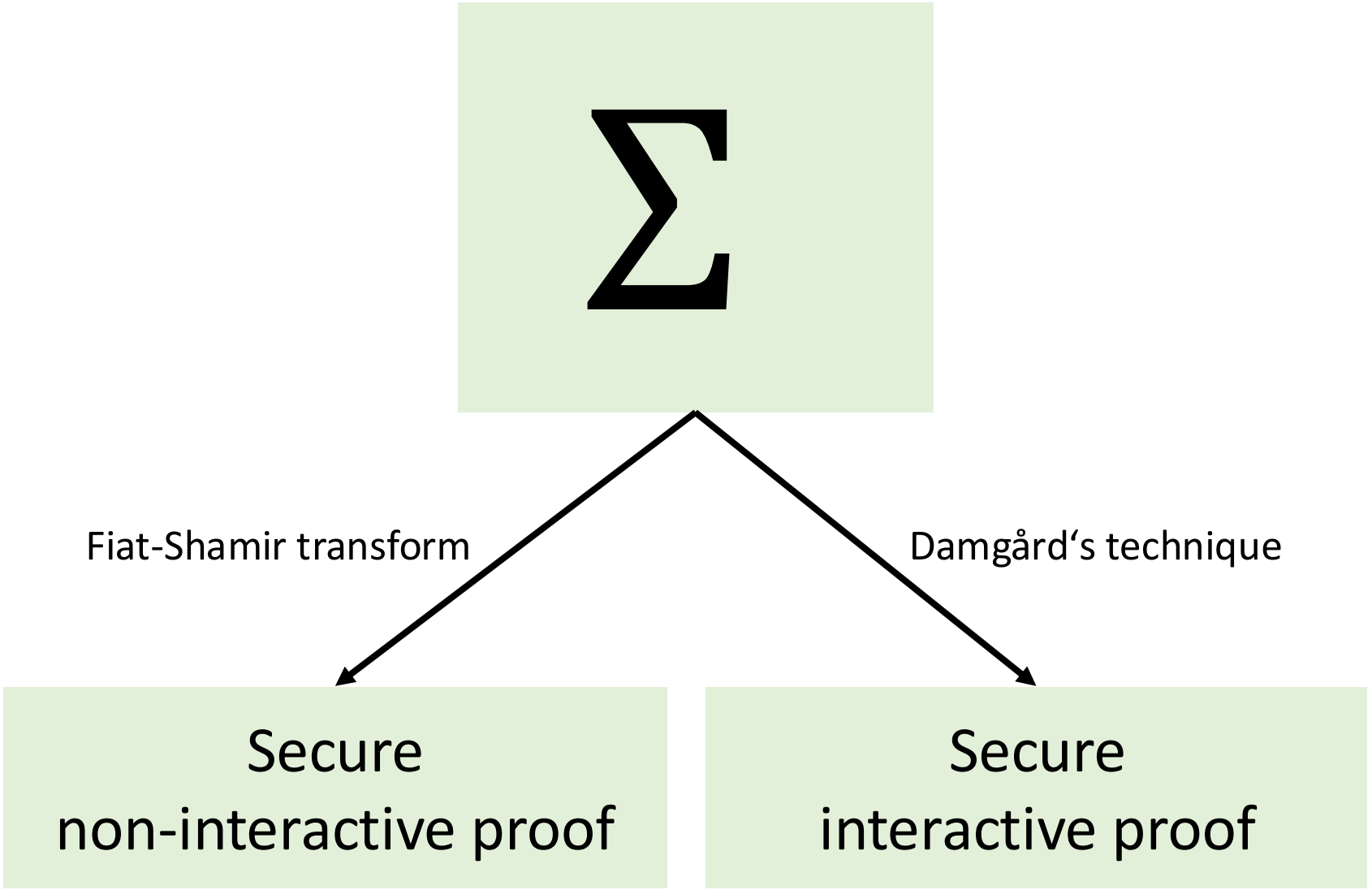
```
citizenship = Germany
∧ (status = student ∨ 0 ≤ age ≤ 17 ∨ age ≥ 66)
∧ residence ∈ {Germany, Austria, Switzerland}
```

Protocol composition



Techniques:
- Sigma protocols
- Schnorr-style protocols
- Accumulator membership proof [Nguyen05]
- Range proofs [Schoenmakers01]
- Proofs of Partial Knowledge [CDS94]

Protocol composition – last step



Performance

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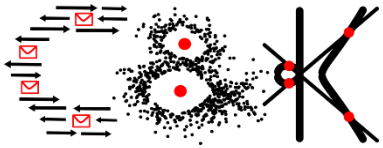
- Test on i7-8650U using bn256 as group/pairing [5]
- Noninteractive proofs of credential possession

Policy	Prove	Verify
`citizenship = Germany`	32 ms	28 ms

`citizenship = Germany`
`∧ (status = student ∨ 0 ≤ age ≤ 17 ∨ age ≥ 66)`
`∧ residence ∈ {Germany, Austria, Switzerland}`
	211 ms	170 ms

[5] mcl: A portable and fast pairing-based cryptography library. https://github.com/herumi/mcl

That‘s it. Questions?



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That‘s it. Any questions?

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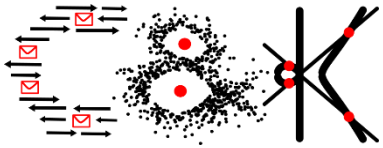
- **CLARC**: Cryptographic Library for Anonymous Reputation and Credentials
- Combines **anonymous authentication** with **anonymous rating** of services
  - Removes the need to identify yourself to authenticate
- Allows proving **complex policies** about credential attributes
  - Compiles Sigma protocol for policy **at runtime**
- **Ratings are anonymous**, but we ensure:
  - Only users who used a service can rate it
  - Users **cannot rate twice**

- **Available** at github.com/upbcuk

Appendix



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Code

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github.com/upbcuk

Features that didn‘t make the presentation

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- **Anonymity escrow**: verifier can demand that user‘s anonymity can be rescinded by trusted third party
- **Revocation of users:** misbehaving users can be identified and put on a blacklist by a trusted party
- **Revocation of credentials**: a credential can be declared void by its issuer (e.g., if attributes should change)
- **Revocation of ratings**: a rating can be declared invalid by a trusted third party
- **Attribute-based ratings**: the rater can choose to prove possession of additional certified attributes (e.g., “expert reviewer”)
- **Anonymity between multiple credential issuers**: Prove possession of credential by one of multiple issuers.

How to express a policy

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```
policy(pp, true)
        .forIssuer(issuerPublicIdentity)
        .attribute(countryDef.getAttributeName()).isEqual("Germany")
        .and()
        .forIssuer(issuerPublicIdentity)
        .attribute(statusDef.getAttributeName()).isEqual("Student")
        .or()
        .attribute(ageDef.getAttributeName()).isInRange(0, 17)
        .or()
        .attribute(ageDef.getAttributeName()).isInRange(66, 200)
        .and()
        .forIssuer(issuerPublicIdentity)
        .attribute(residenceDef.getAttributeName())
          .isInSet("Germany", "Austria", "Switzerland")
        .build();
```

Public Linkability

- Public: g
- Choose $\zeta \leftarrow \mathbb{Z}_p$
- Compute and publish $H(\text{ProductID})^{\zeta+usk}$ and g^{ζ}
  - and prove within the signature of knowledge that those are well-formed
  - Basically ElGamal encryption of $H(\text{ProductID})^{usk}$ (but pairing makes comparison possible)

$\Rightarrow$ Can compute $e(H(\text{ProductID}), g)^{usk}$ and use that for linking.

Johannes Blömer, Jakob Juhnke, and Christina Kolb. 2015. Anonymous and Publicly Linkable Reputation Systems. In FC 2015 (LNCS),

Pointcheval Sanders signatures

- $sk = (x, y_1, \dots, y_n) \in \mathbb{Z}_p^{n+1}$
- $pk = (\tilde{g}, \tilde{g}^x, \tilde{g}^{y_1}, \dots, \tilde{g}^{y_n}) \in \mathbb{G}_2^{n+2}$

- Signatures: $\left(h, h^{x+\sum y_i m_i}\right)$ for random $h \leftarrow \mathbb{G}_1 \setminus \{1\}$

Protocol composition