TrustVault:

A privacy-first data wallet for the European Blockchain Services Infrastructure

S.E Jacobino, Dr.ir. J.A. Pouwelse

31 Augustus 2022

TU Delft

Rijksdienst voor Identiteitsgegevens
Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Outline

- Introduction
- Problem description
- Building blocks
- TrustVault Architecture & Design
- Evaluation
- Related Work
- Conclusion

Introduction

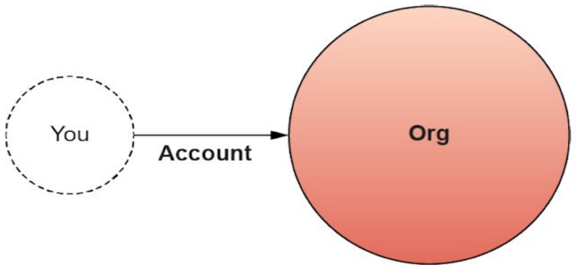
You are not in control.

Introduction

- History of identity on the Internet

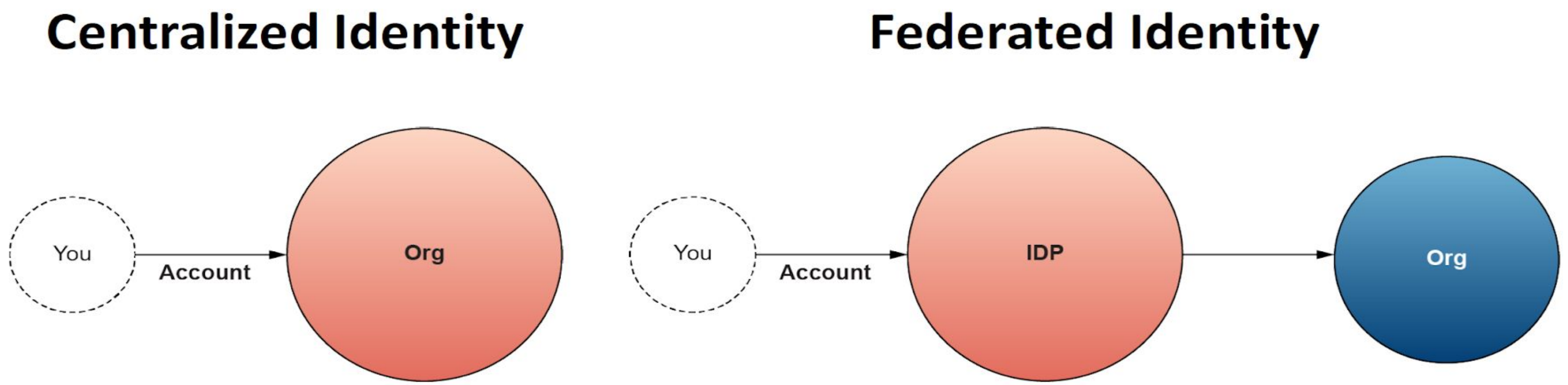
Introduction

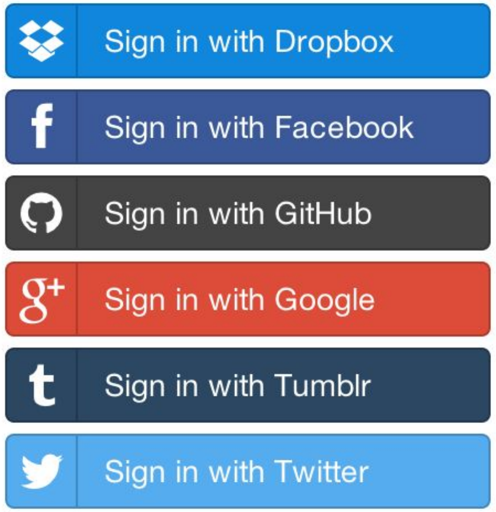
Centralized Identity



A. Preukschat and D. Reed, *Self-sovereign identity*. Manning Publications, 2021.

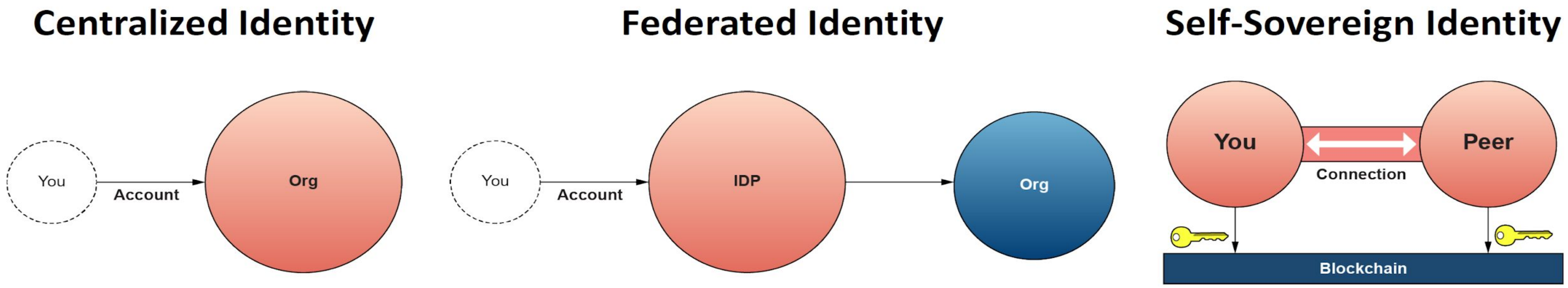
Introduction





A. Preukschat and D. Reed, *Self-sovereign identity*. Manning Publications, 2021.

Introduction



Centralized Identity

You

Account

Org

Federated Identity

You

Account

IDP

Org

Self-Sovereign Identity

You

Connection

Peer

Blockchain

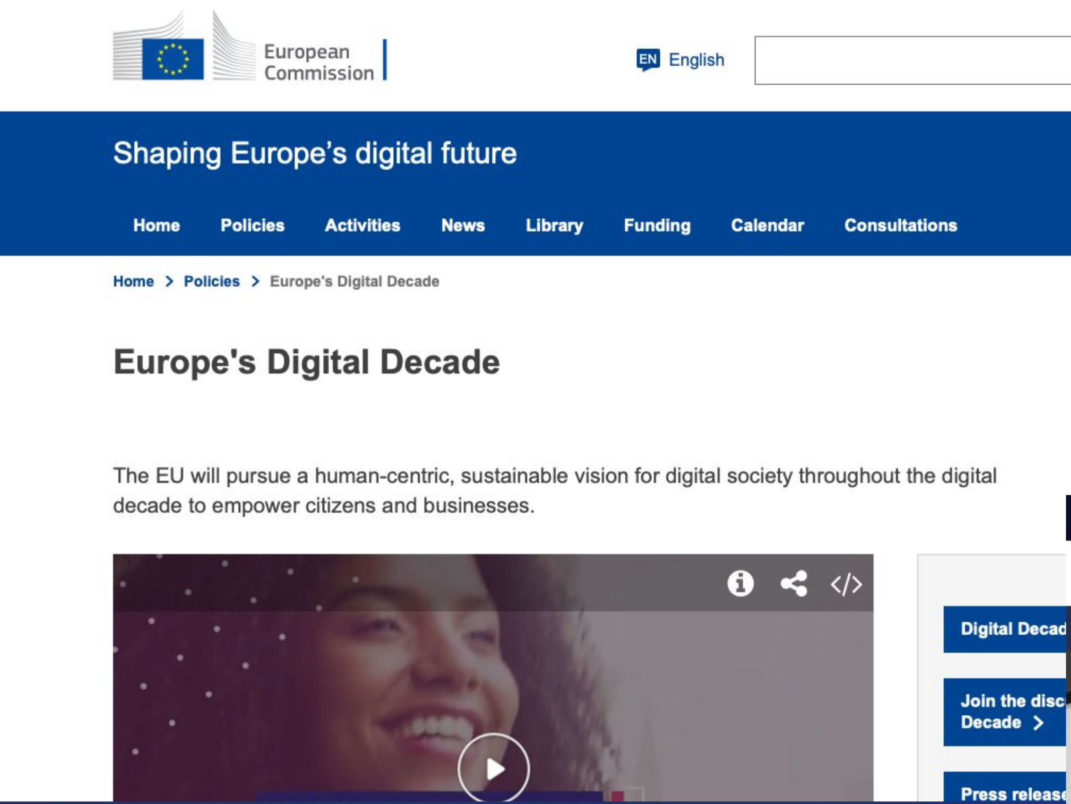
A. Preukschat and D. Reed, *Self-sovereign identity*. Manning Publications, 2021.

Introduction

- History of identity on the Internet
- Requirements for a digital identity
  - Security: identity information is protected from unintentional disclosure.
  - Control: the identity owner determines who can access their data and under what circumstances.
  - Portability: identity must not be tied to a single service or provider.
- The European Union is aware of the problem

”Every time an App or website asks us to create a new digital identity or to easily log on via a big platform, we have no idea what happens to our data in reality.”

Ursula von der Leyen, President of the European Commission



Shaping Europe's digital future

Europe's Digital Decade

The EU will pursue a human-centric, sustainable vision for digital society throughout the digital decade to empower citizens and businesses.

€26M

for European Digital Wallet

EU digital identity

- Free
- Safe
- Voluntary
- Linked to national eID
- Available across the EU
- Keeps you in control of your data

THE EU DIGITAL ID WALLET IS COMING. HERE'S WHAT IT MEANS FOR YOU

https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade
https://www.thalesgroup.com/en/worldwide-digital-identity-and-security/government/magazine/eu-digital-id-wallet-coming-heres-what

Introduction

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  - Portability: identity must not be tied to a single service or provider.
- The European Union is aware of the problem
- European Self-Sovereign Identity Framework
- Leverage blockchain technology: European Blockchain Services Infrastructure
- EU digital wallet on the app store

ebsi
European Blockchain

What about my data?

Problem description

- Still reliant on Big Tech to store and host our data
- Hard to secure centralised applications
  - Large amount of data
  - Statistical analysis on metadata and interactions
- Not under your full control
  - Access control not enforced or not flexible
  - Censorship
- Not portable
  - Incentive to retain users & data
  - Data coupled to application

L. Pesonen, D. Eyers, and B. Jean, “Access control in decentralised publish/subscribe systems,”
, S. Mu ̈ller, S. Katzenbeisser, and C. Eckert, “Distributed attribute-based encryption,”
, B. Musa Shuaibu, N. Md Norwawi, M. H. Selamat, and A. Al-Alwani, “Systematic review of web application security development model,”, J. Lee, B. Lee, J. Jung, H. Shim, and H. Kim, “Dq: Two approaches to measure the degree of decentralization of blockchain,”

Problem description

A system with true data sovereignty requires the following properties:

- Decentralised data storage on device controlled by data owner
- Fine-grained and resolutely enforced access control
  - Verified authentication
  - Decentralised identity
- Data decoupled from applications

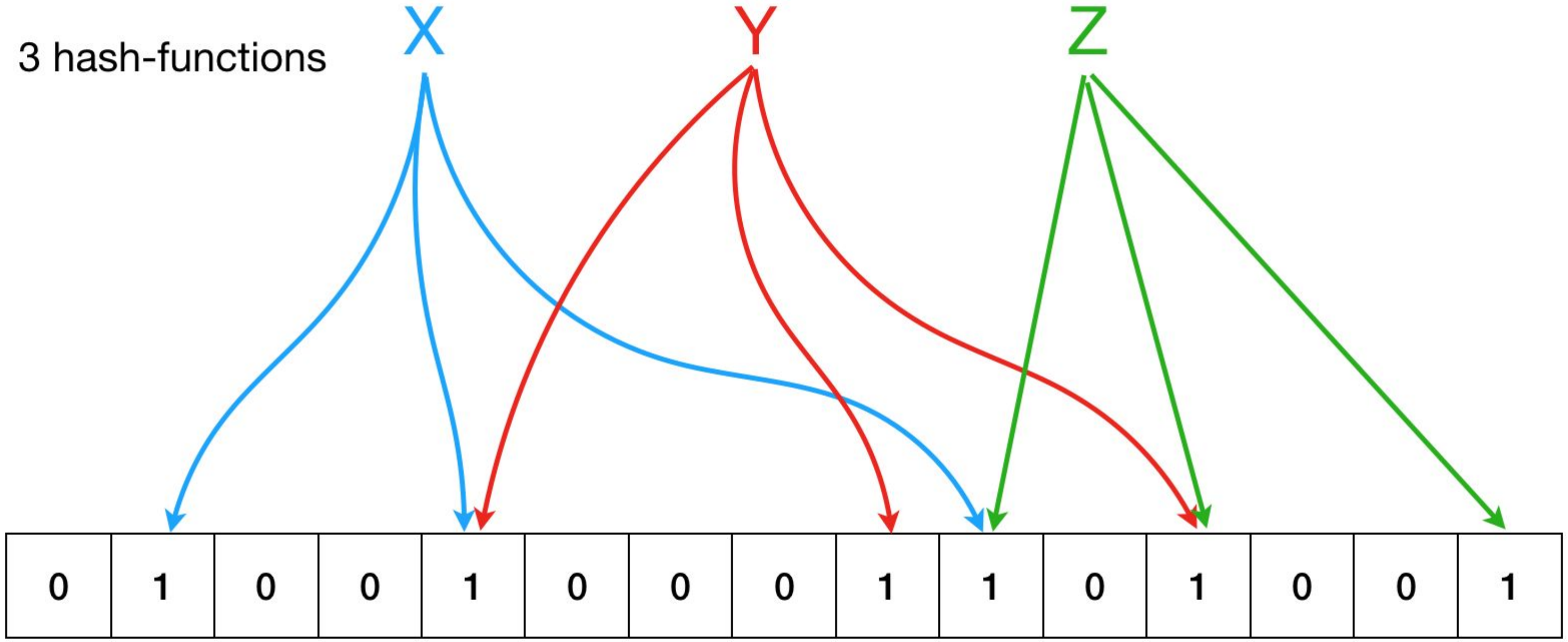
Bonus: plug into the societal infrastructure for identity

TrustVault: data wallet with attribute-based access control based on verifiable credentials from EBSI

Background

Bloom filters

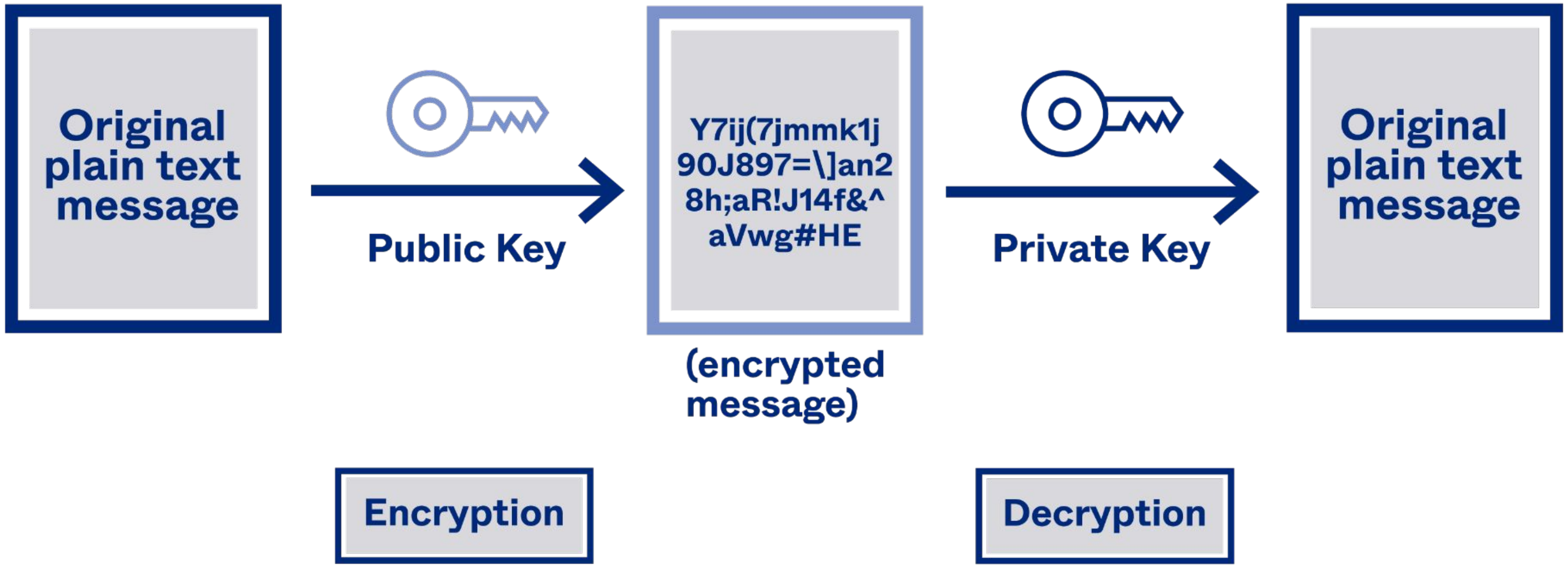
- Space-saving randomised data structure
- Membership queries
- No false negatives
- small false positive possibility



0	1	0	0	1	0	0	0	1	1	0	1	0	0	1

https://ilyasergey.net/YSC2229/week-07-bloom.html

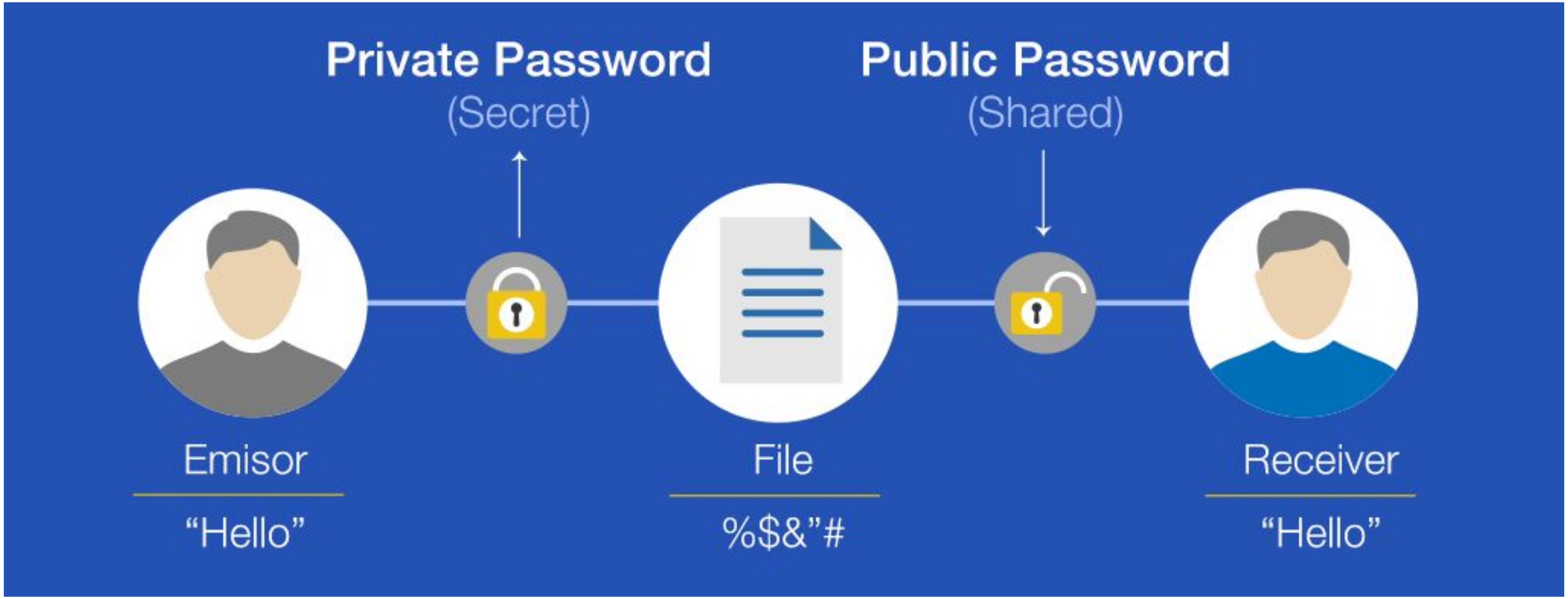
Public Key Cryptography



okta

Confidentiality

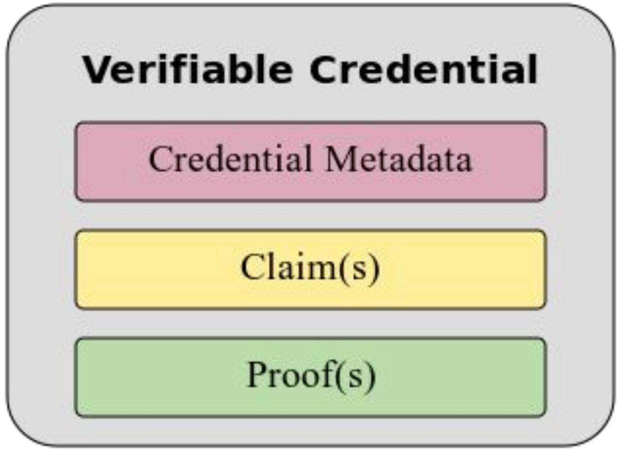
Digital Signatures



Authenticity & Non-Repudiation

Self-Sovereign Identity

- Issuers, Holders, Verifiers and a Verifiable Data Registry
- Verifiable Credentials (VC) are the building blocks of SSI
  - Contains claims about the holder and proofs that those claims are true
  - Used to convince others of the validity of claims



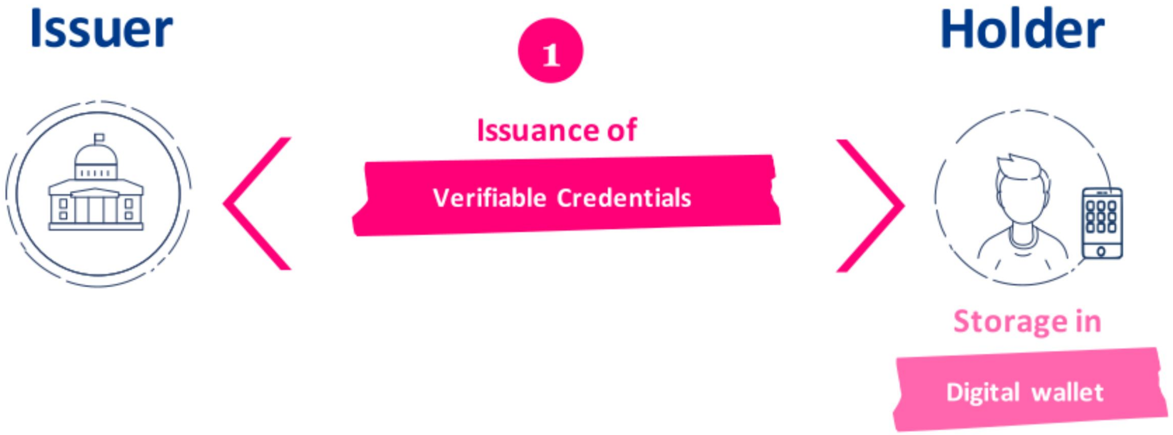
Verifiable Credential

Credential Metadata

Claim(s)

Proof(s)

Self-Sovereign Identity



https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/EBSI+Verifiable+Credentials+Playbook

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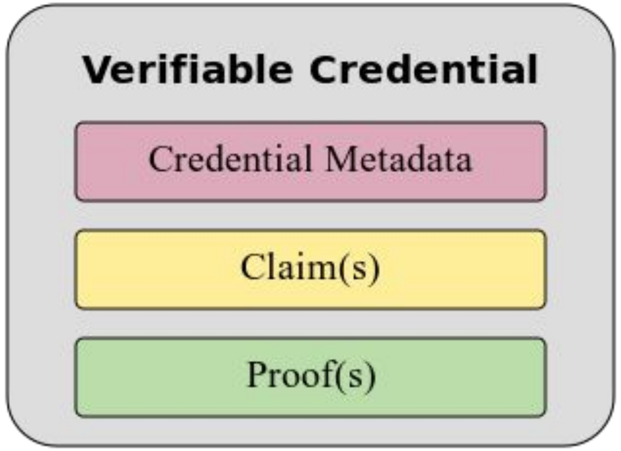
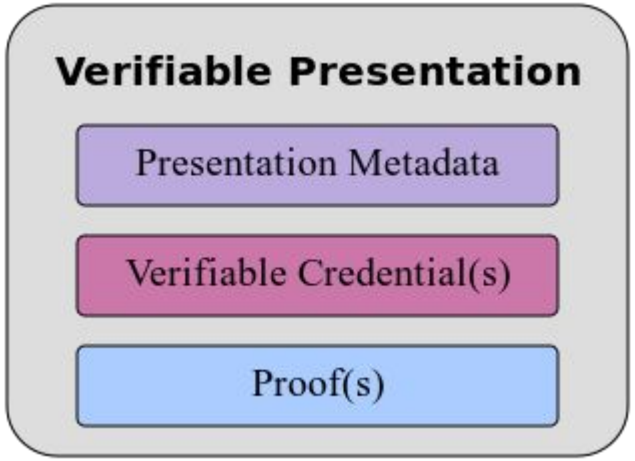
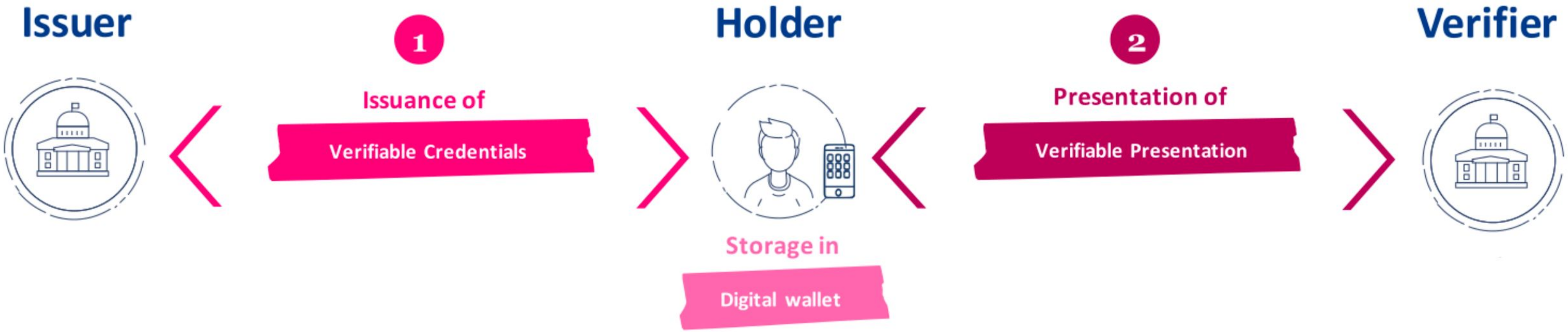
- Verifiable Presentations (VP)
  - Contains VCs and proof that the VCs are about you
  - Requested by verifiers





https://www.w3.org/TR/vc-data-model/

Self-Sovereign Identity



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- Verifiable Presentations (VP)
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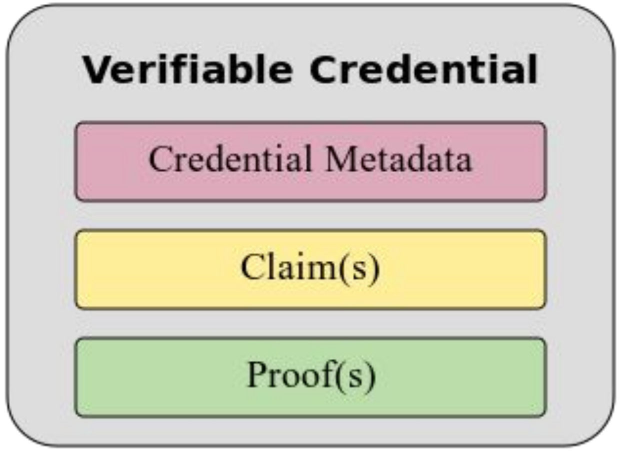
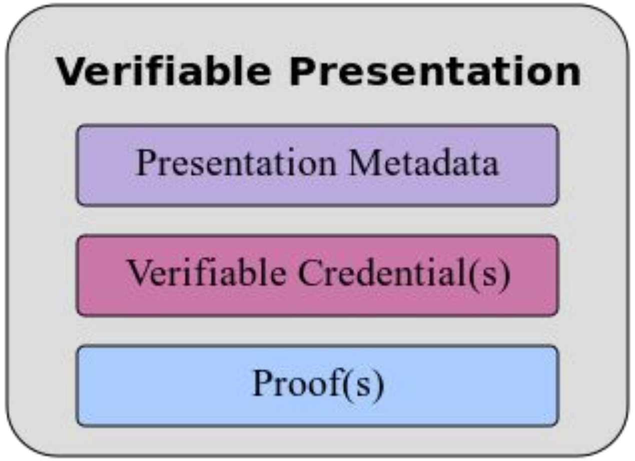
- Verifiable Data Registry is the anchor of distributed trust





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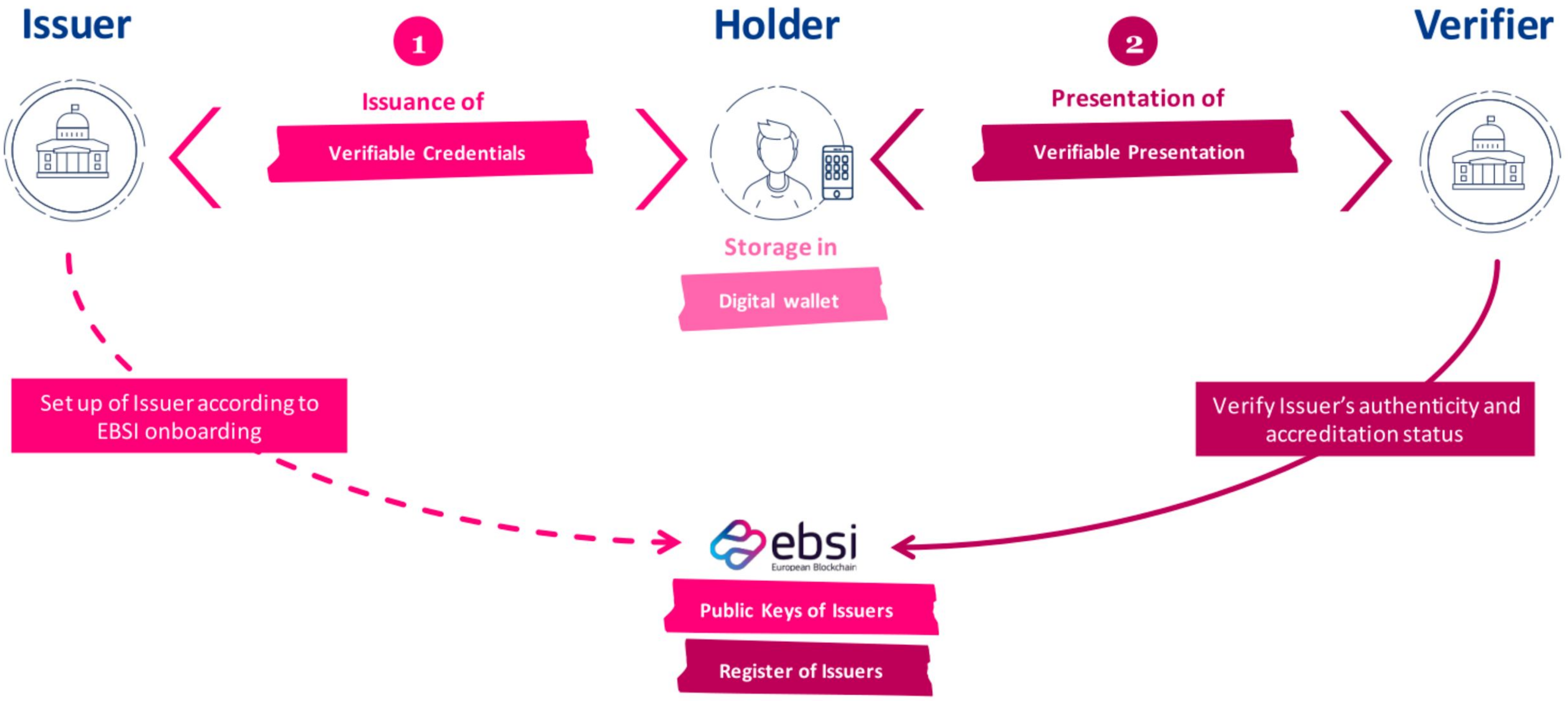
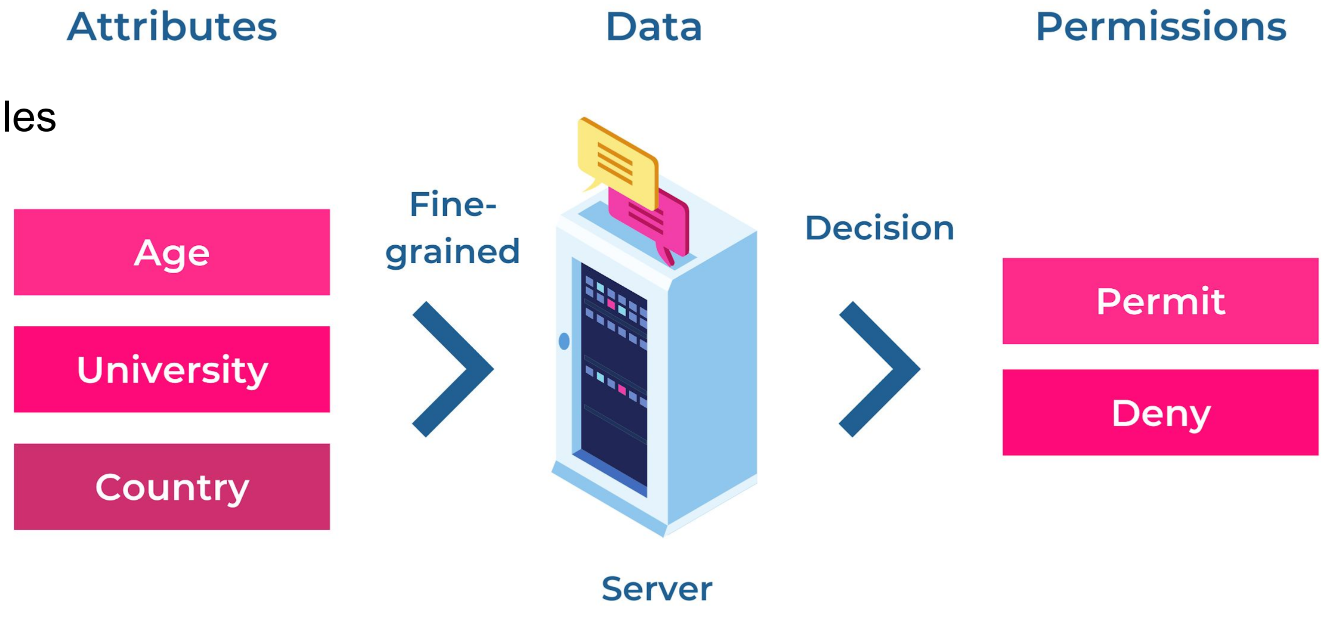
Self-Sovereign Identity



https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/EBSI+Verifiable+Credentials+Playbook

Attribute-Based Access Control

- Control access to resources
- Fine-grained control
- Evaluate set of attributes against predefined rules
- Only limited by available attributes
- Requires verifiable attributes



Attributes

Age

University

Country

Fine-grained

Data

Server

Decision

Permissions

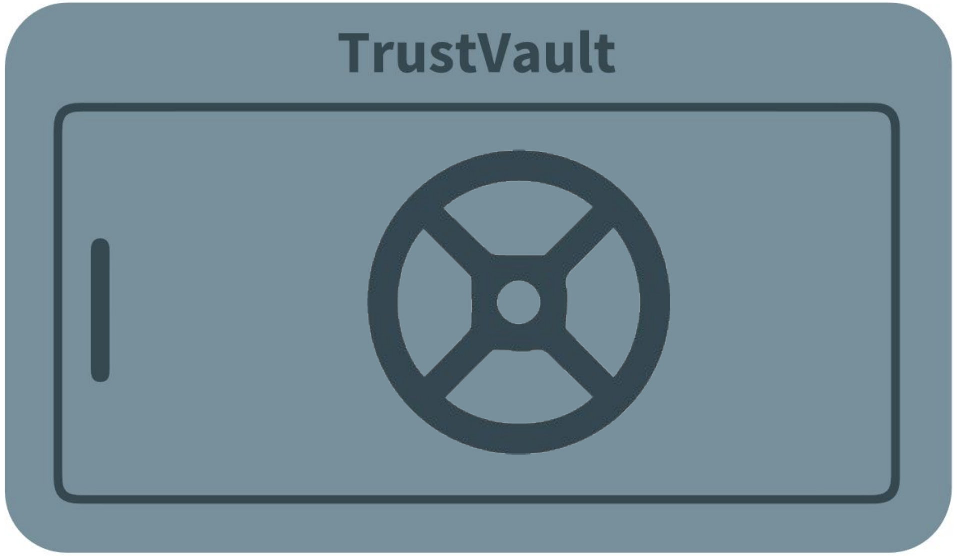
Permit

Deny

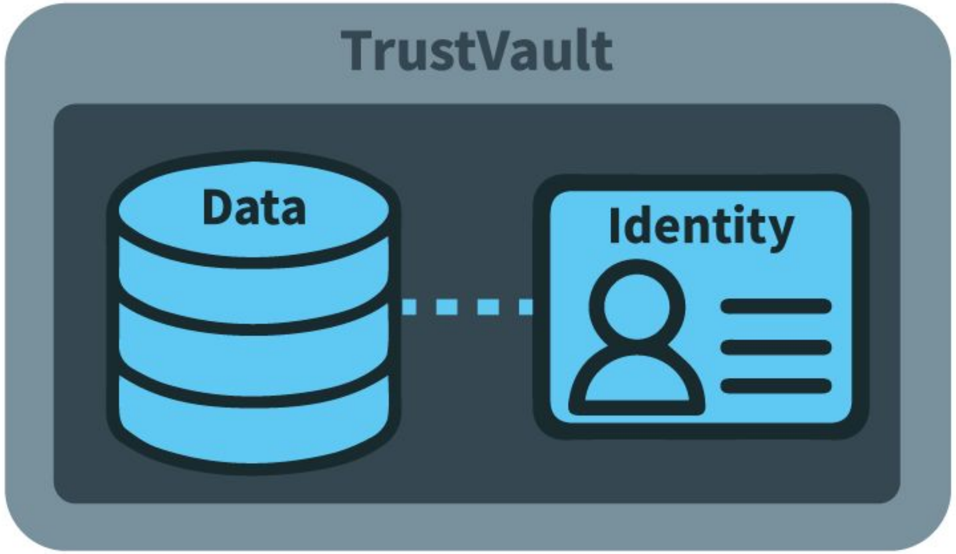
V. C. Hu, D. R. Kuhn, D. F. Ferraiolo, and J. Voas, “Attribute-based access control,”

Architecture and Design

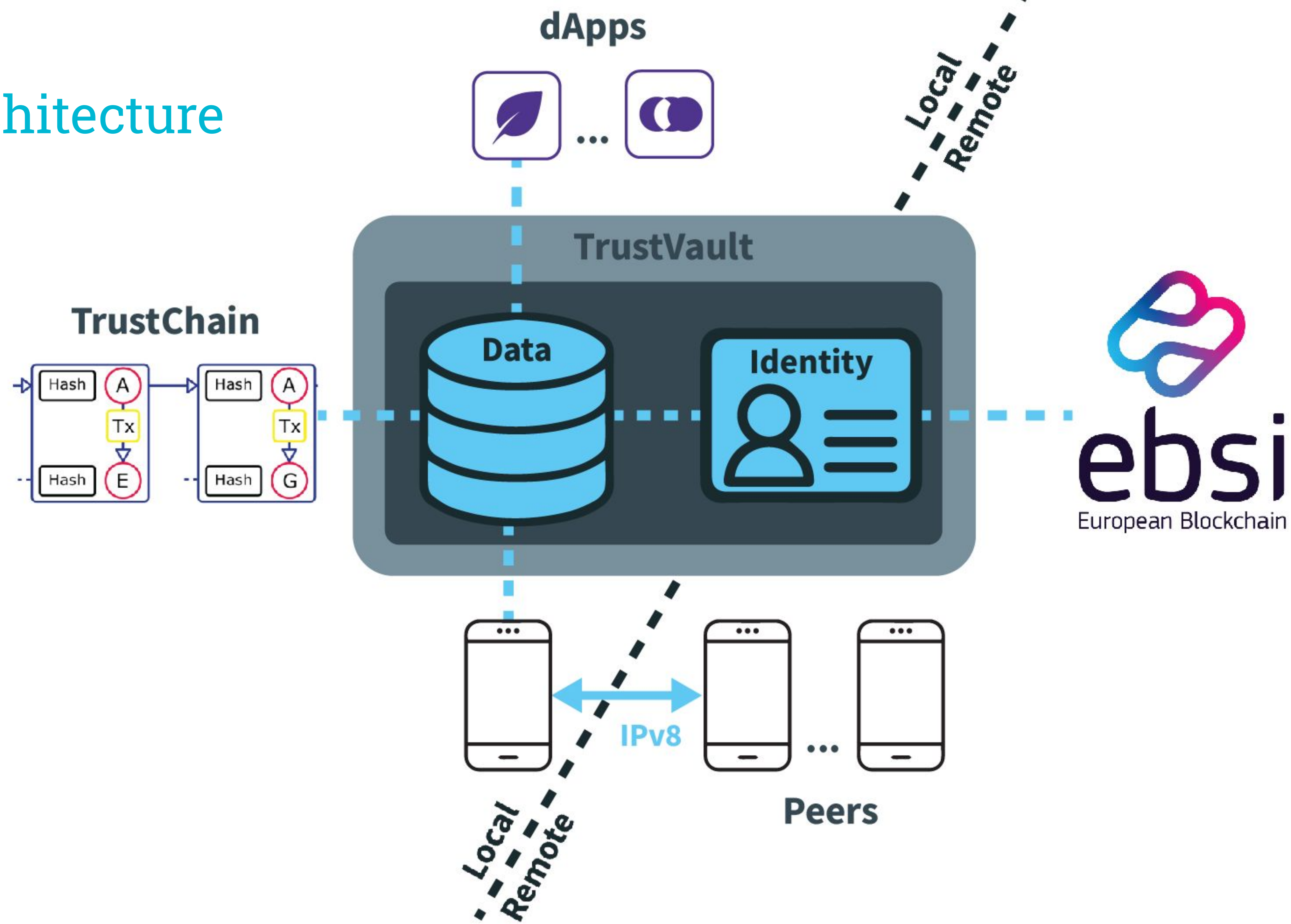
Architecture



Architecture

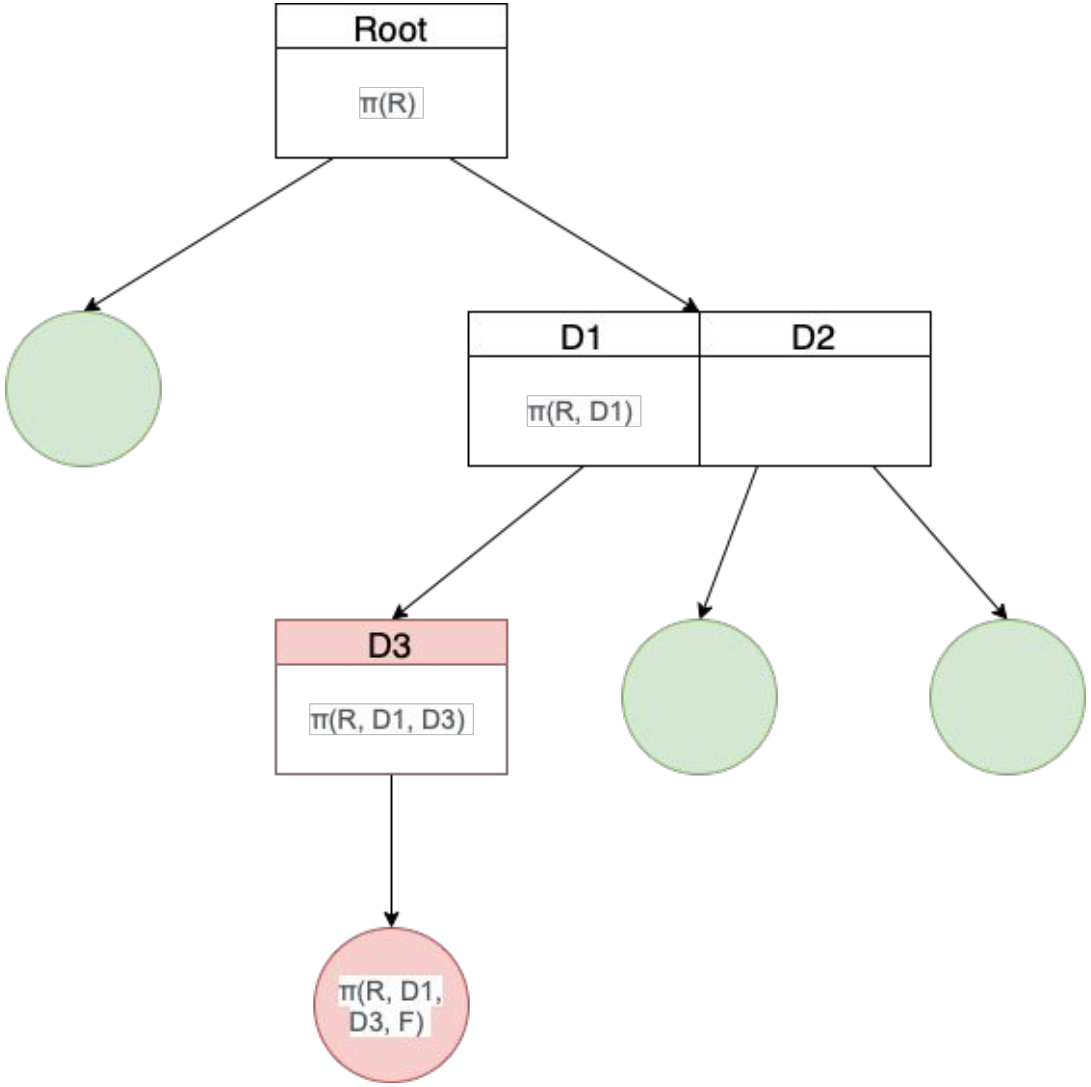


Architecture



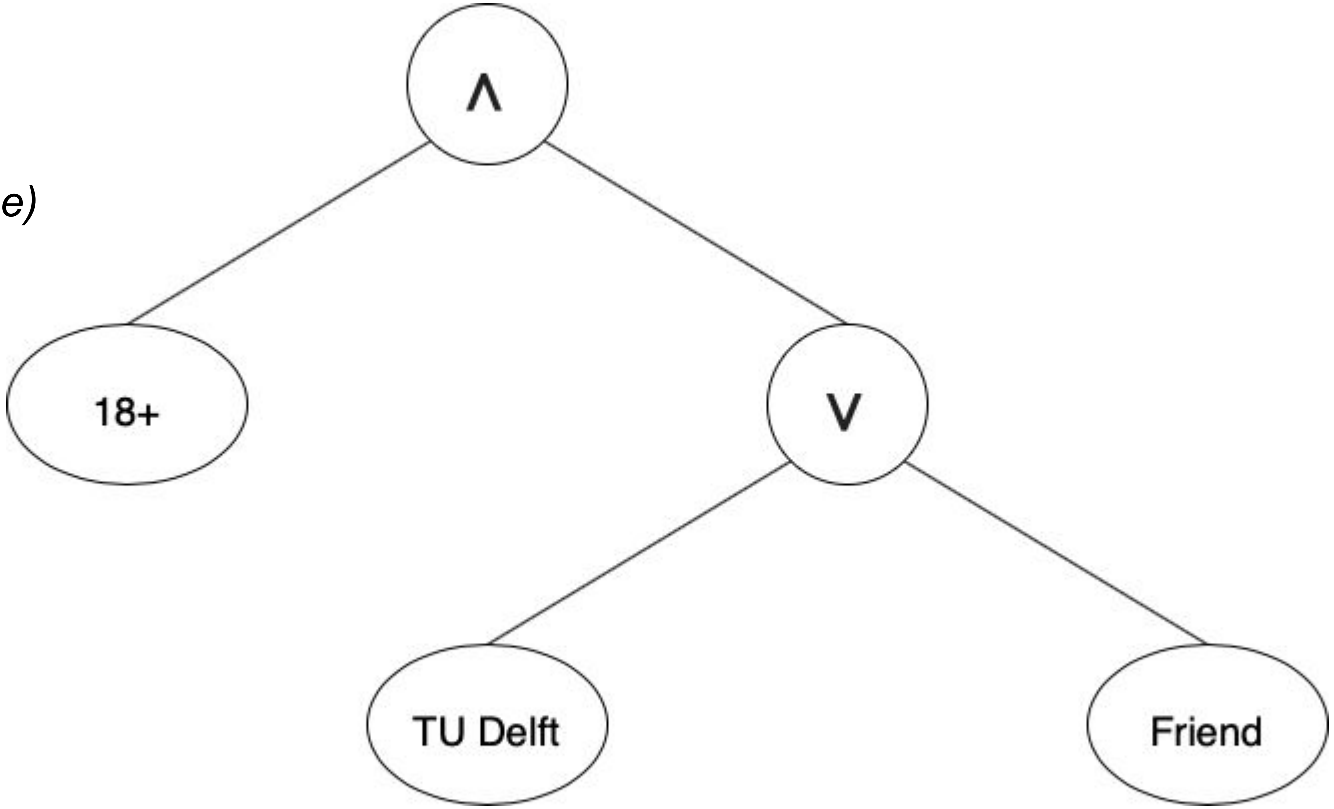
Data Vault Access Control

- Files and folders have associated access policy file
- Local policy $\pi(f)$
- Global policy $\Pi(f) = \pi(f) \wedge \Pi(P(f))$
- Satisfy every policy along the root path
- Minimal restrictions on the root folder
- Increasingly specific policies for sub-folders

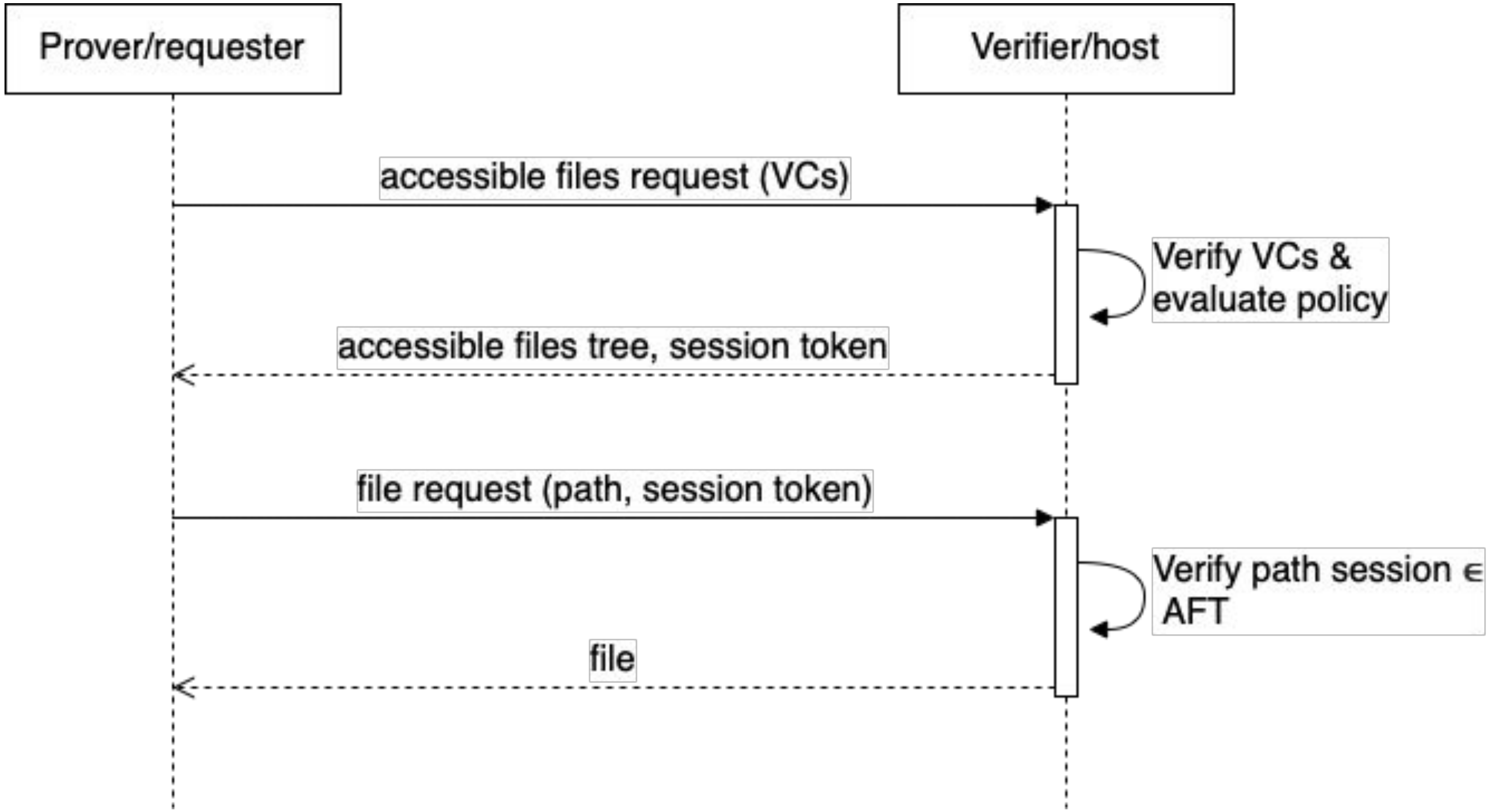


Data Vault Access Control

- Access policies are boolean expression trees
- Attribute rules at the leaves
- Triplets in the form of *(attribute, operator, value)*



Data Vault Access Control

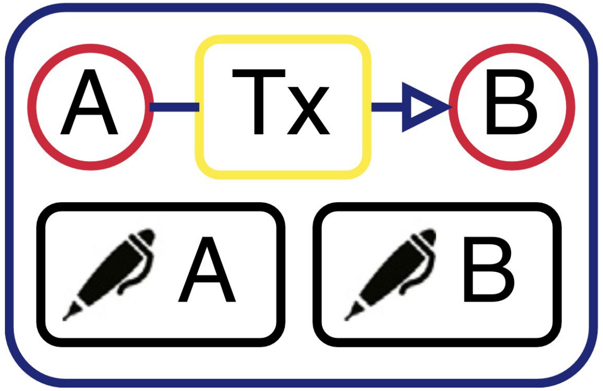

Prover/requester
Verifier/host
accessible files request (VCs)
Verify VCs & evaluate policy
accessible files tree, session token
file request (path, session token)
Verify path session ∊ AFT
file

Self-issued credentials

- Access policy based on the issuer of a credential
- Similar to follow/friend request in traditional social networks
- Attributes that give context about the relationship

Tamper-proof access log

- Keep record of accessibleFilesRequests on-chain
- Bloom filter that contains all accessible files
- Transaction with session key and bloom filter sent to requester
- Both sender and recipient sign transactions in TrustChain
- Timestamped, tamper-proof and irrefutable record
- Audits or disputes



P. Otte, M. de Vos, and J. Pouwelse, “Trustchain: A sybil-resistant scalable blockchain,”, https://freeicons.io/profile/3

Data protection

- Data protected at rest
    - AES Counter mode encryption
    - Password required to unlock data vault
- End-to-end encryption using IPv8

Evaluation

Privacy +

- Self-hosted data
- Fine-grained access control on folder and file level
  - Mistakes in defining policies may end in unintentional disclosure
- Data minimisation: requesting only the minimum of information necessary
- Selective disclosure for the requester

Privacy -

- Peer identification by public key
    - Curious verifier can aggregate enough correlatable information over time
    - Not solved by having multiple DIDs
    - Network-Level Anonymity implemented in Python, not in Kotlin
- No private transactions on TrustChain
    - On-chain access logs are public for anyone to see

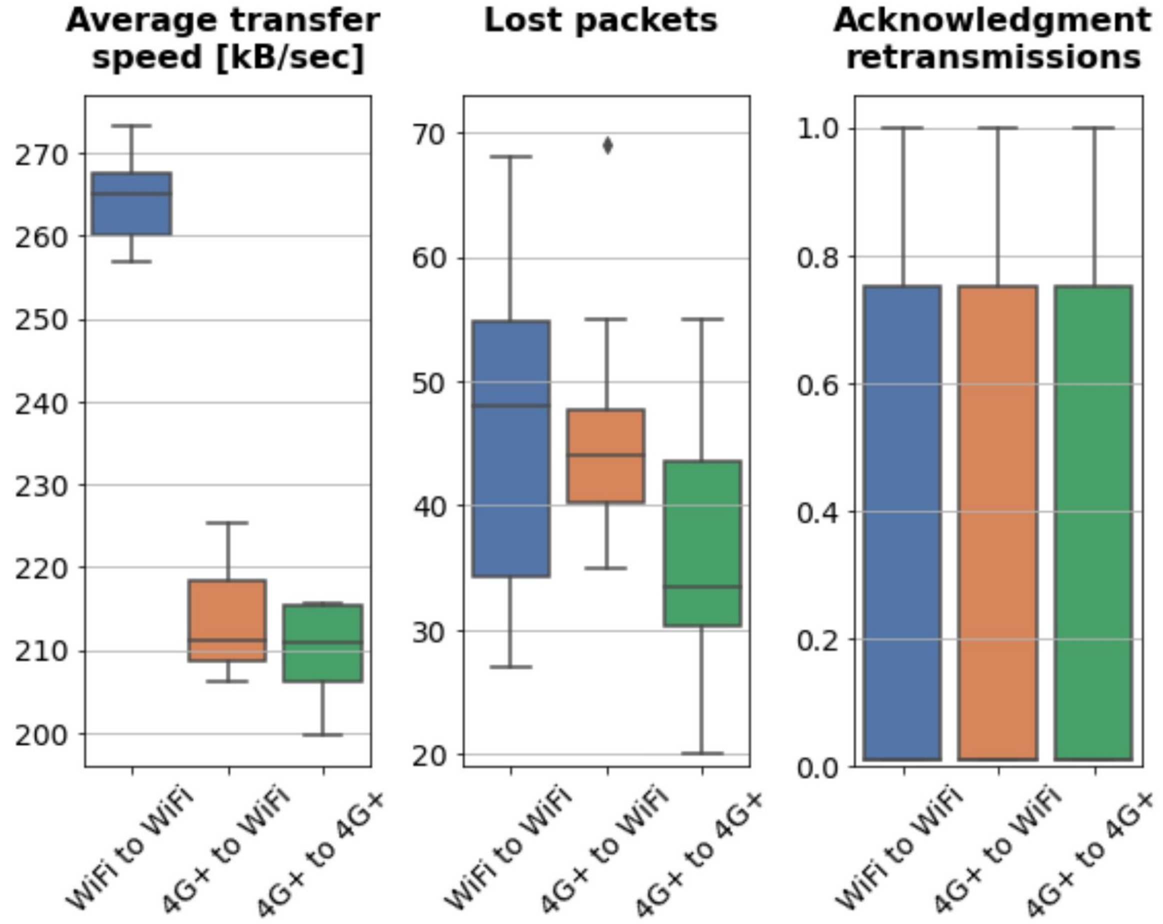
Security +

- Android internal file storage shielded from outside access
- Encryption at rest prevents unauthorised access even with physical access
- End-to-end encryption with message authentication
- IPv8 maintains p2p connection with changing physical addresses
- EBSI accreditation process for Trusted Issuers
    - Malicious, compromised or incompetent issuers could issue false credentials

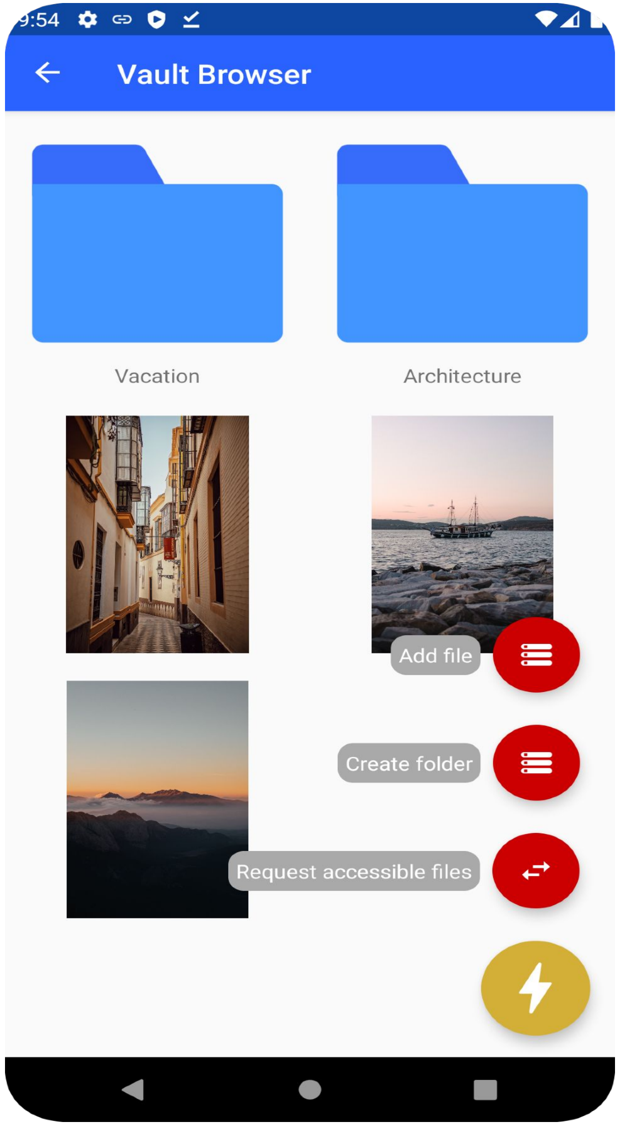
Security -

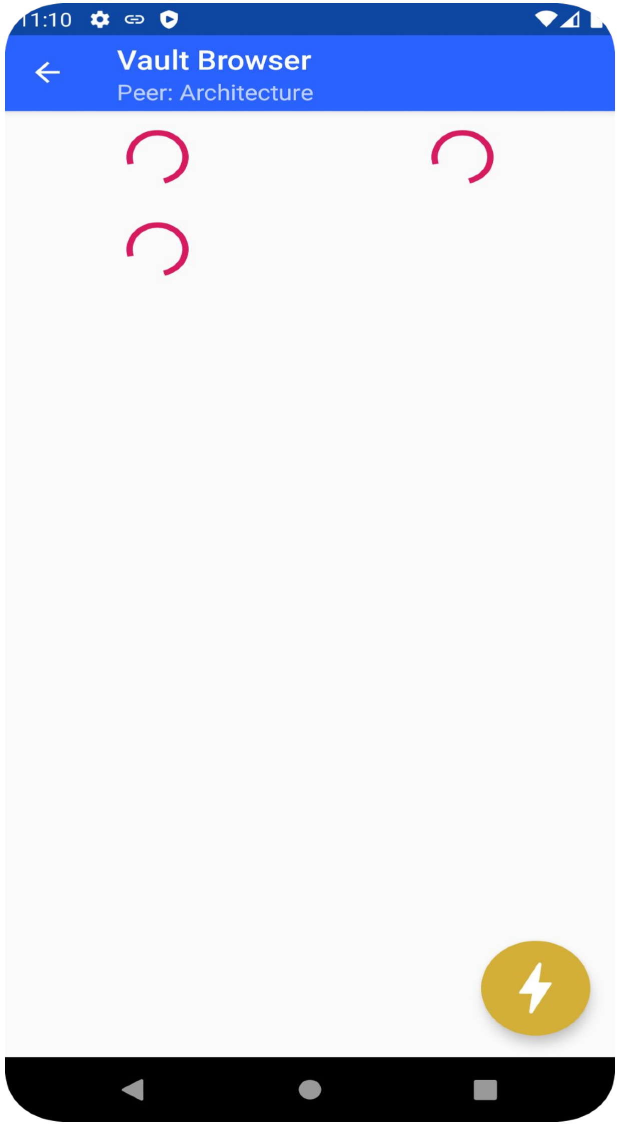
- EBSI Verifiable Data Registry not convincing in requirement of accuracy
    - Hosted API layer between user and blockchain that can corrupt read/writes
    - Single point of failure
- No redundancy
    - Mobile devices can go out of service
    - Data loss if there is no back-up

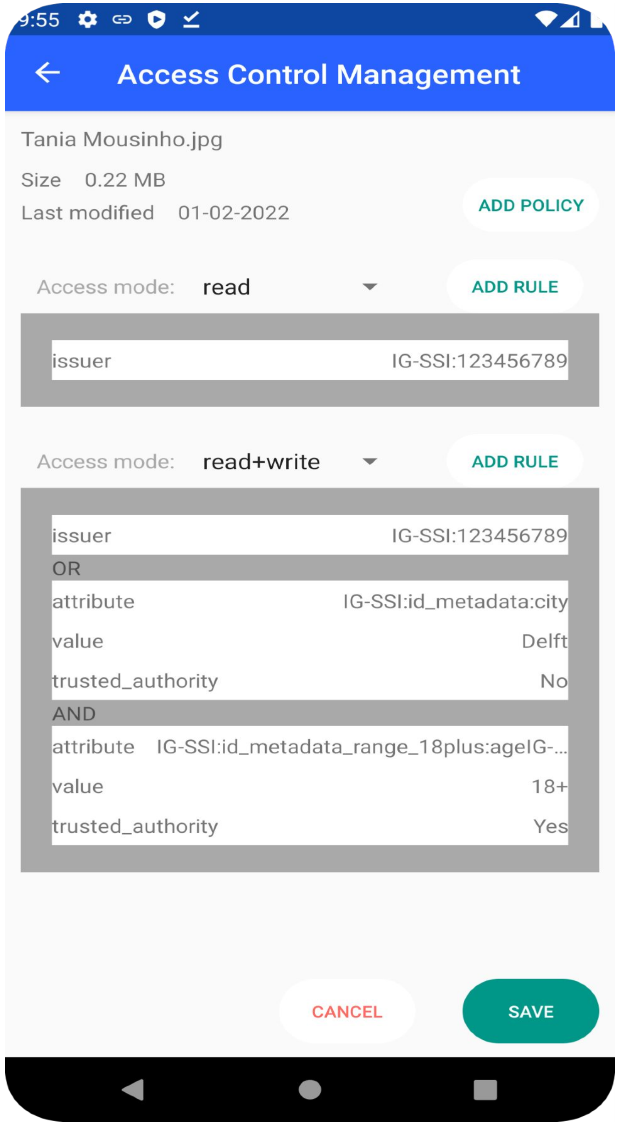
Performance



J. Bambacht and J. Pouwelse, “Web3: A decentralized societal infrastructure for identity, trust, money, and data,”







Tania Mousinho.jpg

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Last modified 01-02-2022

Access mode: read

issuer IG-SSI:123456789

Access mode: read+write

issuer IG-SSI:123456789

OR

attribute IG-SSI:id_metadata:city

value Delft

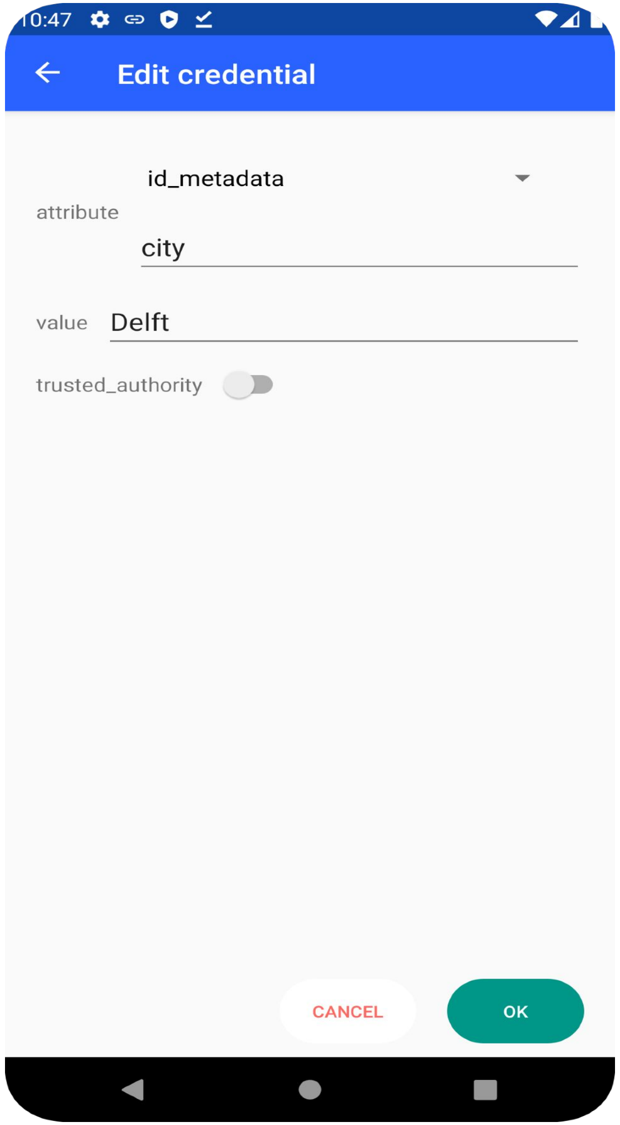
trusted_authority No

AND

attribute IG-SSI:id_metadata_range_18plus:ageIG-...

value 18+

trusted_authority Yes



id_metadata

attribute city

value Delft

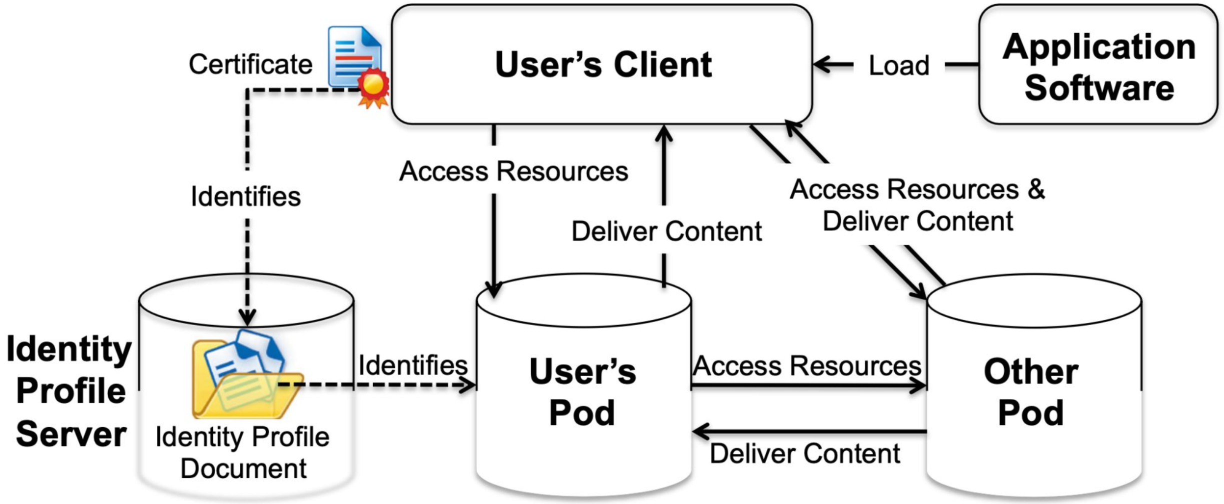
trusted_authority

Related Work

Solid protocol

- Similar concept called pods
- Data decoupled from applications
- Focused on Linked Data and Semantic Web

- Access control based on WebID
  - Self asserted, unverified credentials



E. Mansour, A. V. Sambra, S. Hawke, M. Zereba, S. Ca- padisli, A. Ghanem, A. Aboulnaga, and T. Berners-Lee, "A demonstration of the solid platform for social web applications,", P. Mainini and A. Laube-Rosenpflanzer, "Access con- trol in linked data using webid,"

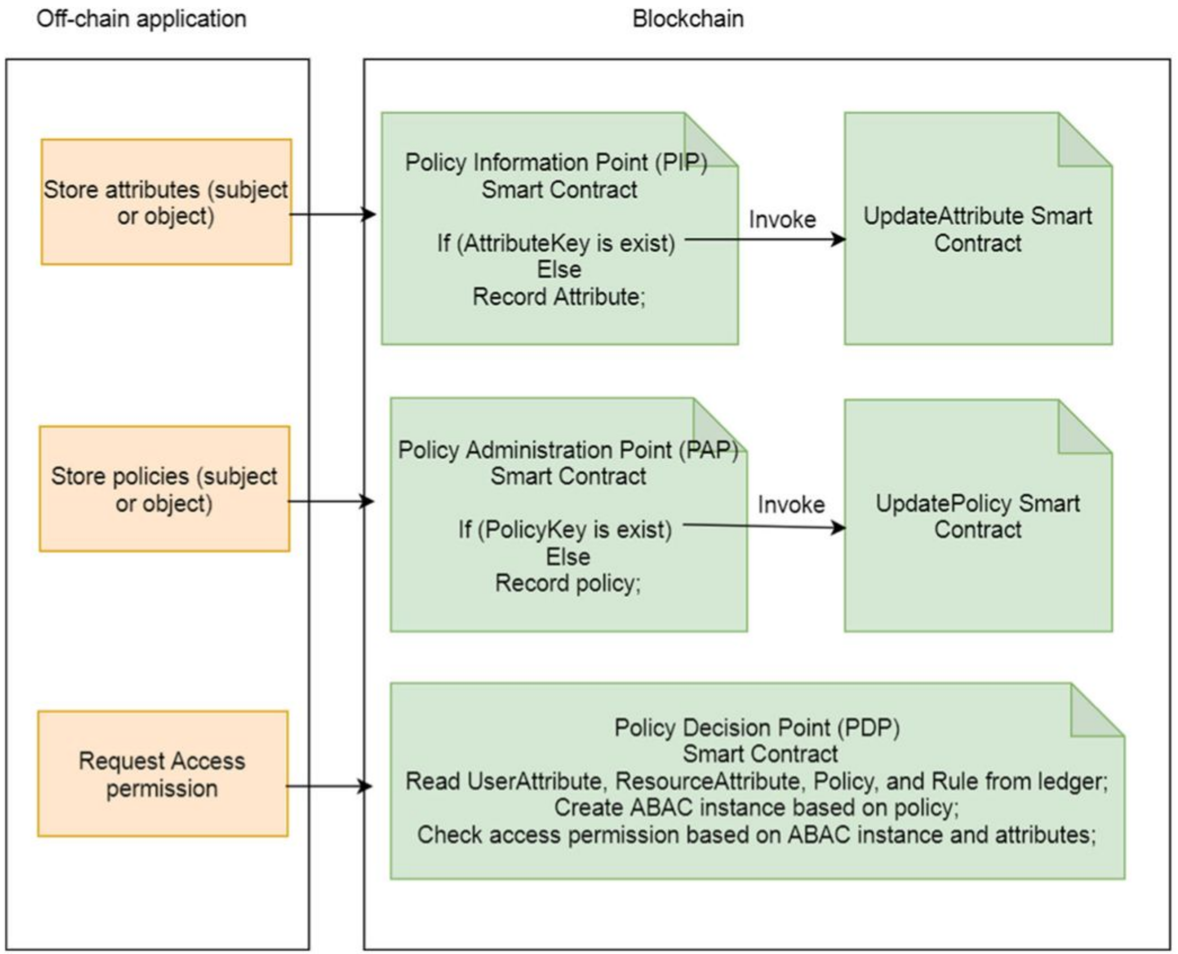
DID based access control

- Similar access control scheme

- Centralised resources
- Closed off system
- No interoperability with other systems

B. Kim, W. Shin, D.-Y. Hwang, and K.-H. Kim, “Attribute-based access control (abac) with decentralized identifier in the blockchain-based energy transaction plat- form,”

Decentralised Attribute-Based Access Control



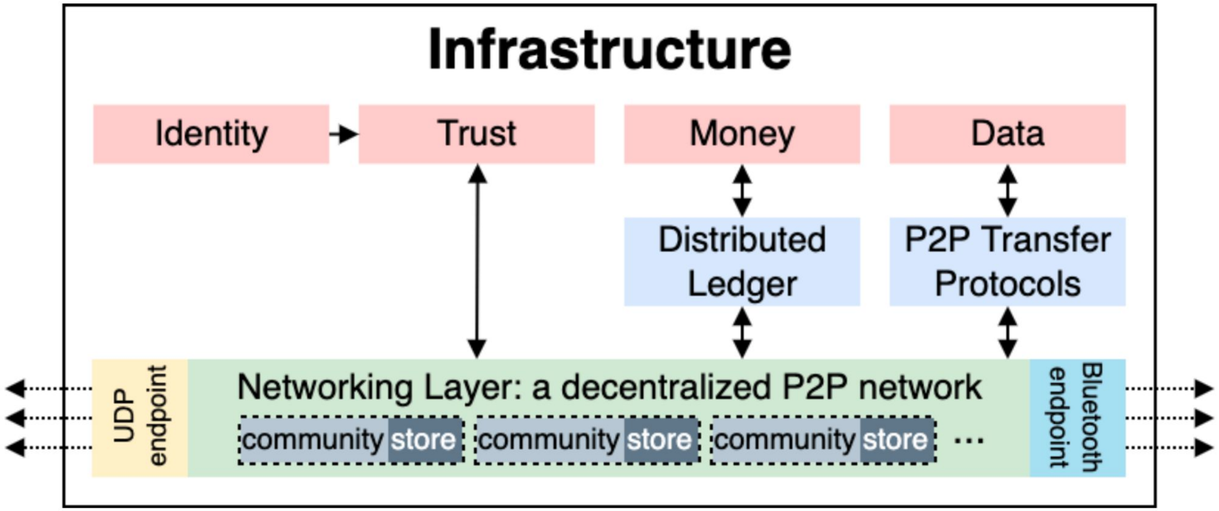
Off-chain application
Blockchain
Store attributes (subject or object)
Policy Information Point (PIP) Smart Contract
If (AttributeKey is exist)
Else
Record Attribute;
Invoke
UpdateAttribute Smart Contract
Store policies (subject or object)
Policy Administration Point (PAP) Smart Contract
If (PolicyKey is exist)
Else
Record policy;
Invoke
UpdatePolicy Smart Contract
Request Access permission
Policy Decision Point (PDP) Smart Contract
Read UserAttribute, ResourceAttribute, Policy, and Rule from ledger;
Create ABAC instance based on policy;
Check access permission based on ABAC instance and attributes;

S. Rouhani, R. Belchior, R. S. Cruz, and R. Deters, “Distributed attribute-based access control system using permissioned blockchain,”, Y. Zhu, Y. Qin, Z. Zhou, X. Song, G. Liu, and W. C.-
C. Chu, “Digital asset management with distributed permission over blockchain and attribute-based access control,”

Web3: A Decentralized Societal Infrastructure for Identity, Trust, Money, and Data

- Peer-to-peer sharing of data, money
- Uses SSI for trust between parties

- TrustVault provides platform for dApps to access
data directly and autonomously
with fine-grained access control



J. Bambacht and J. Pouwelse, “Web3: A decentralized societal infrastructure for identity, trust, money, and data,”

Decentralised Attribute-Based Access Control

- Trusted execution of access policies
- Offload policy decision making to smart contracts
- Access requests are forwarded to the smart contracts
- Auditable access log

- Introduces latency with every request
- Costly to update policies and attributes

S. Rouhani, R. Belchior, R. S. Cruz, and R. Deters, "Distributed attribute-based access control system using permissioned blockchain,", Y. Zhu, Y. Qin, Z. Zhou, X. Song, G. Liu, and W. C.-
C. Chu, "Digital asset management with distributed permission over blockchain and attribute-based access control,"

Related work

- About a dozen digital wallet implementations in the process of becoming EBSI conformant. None incorporating secure data sharing.
- Purpose built ledgers for SSI like Sovrin and Ethereum Decentralised Identity provide more credential types.
- Anonymous Credentials and Zero Knowledge Proof Schemes like BBS+
  - Selective disclosure
  - Signature blinding
  - Private holder blinding
  - Predicate proofs

https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Conformant+wallets, https://sovrin.org, https://ethereum.org/en/decentralized-identity/, https://www.evernym.com/blog/bbs-verifiable-credentials/

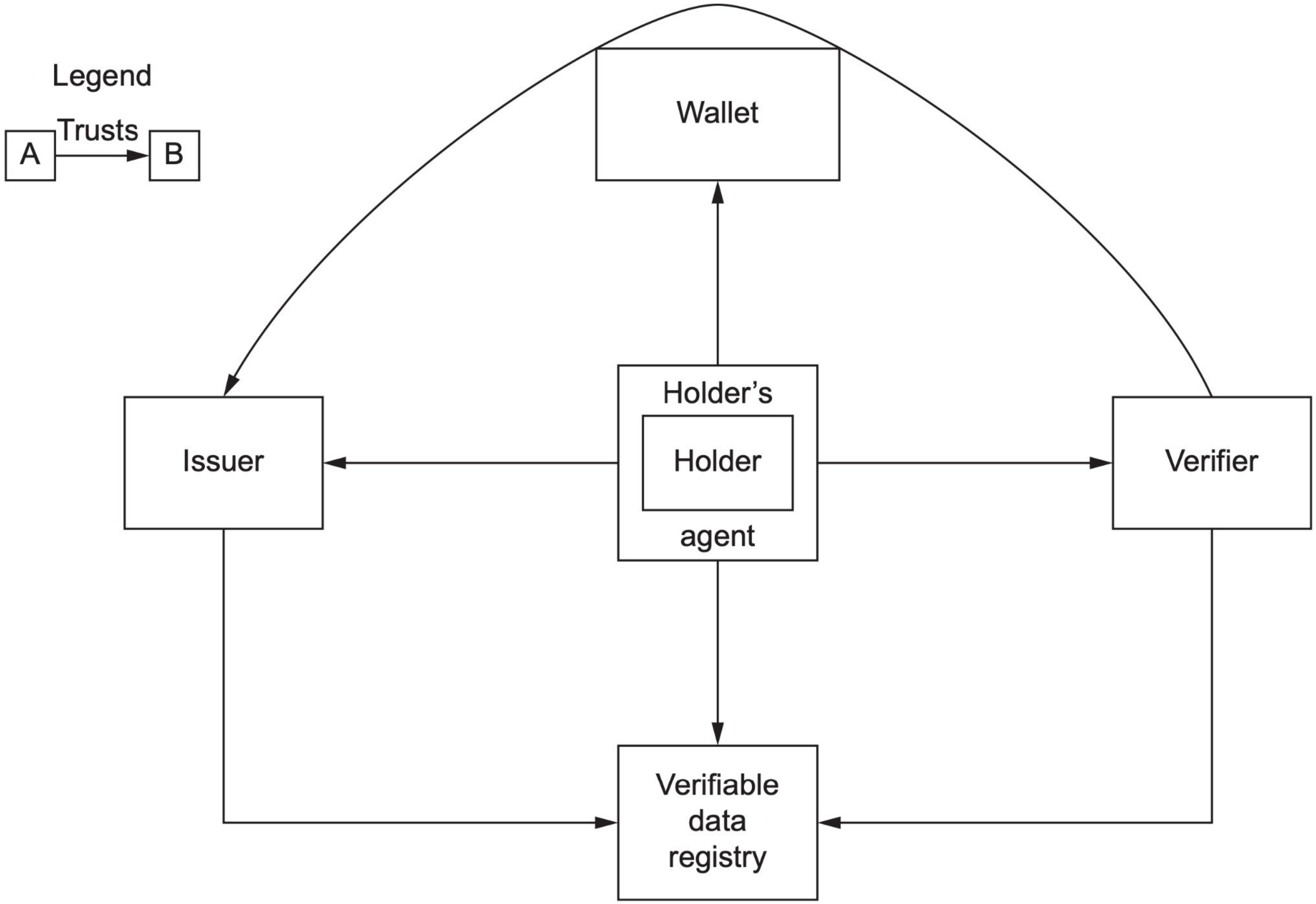
Conclussion

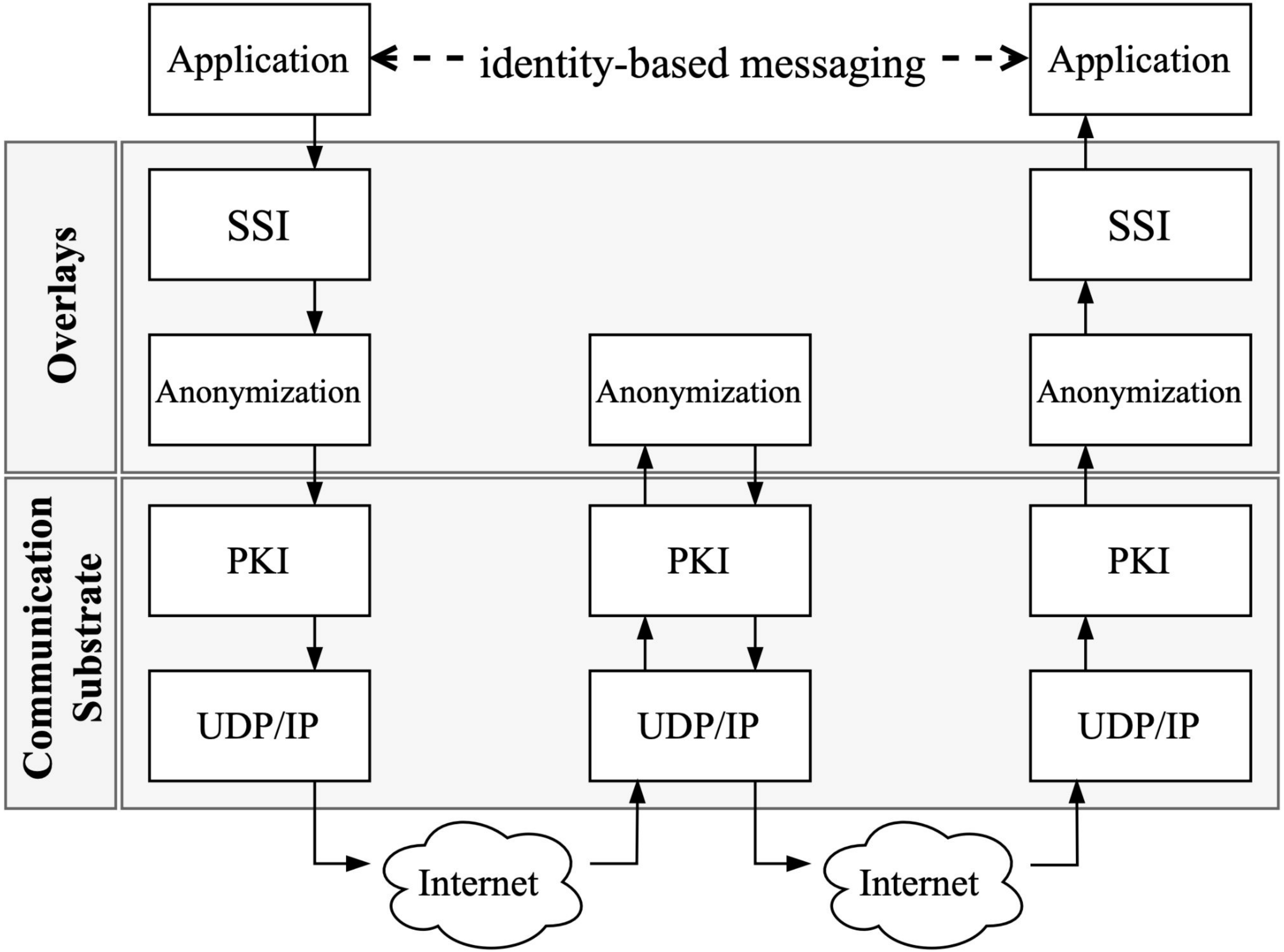
Conclusion

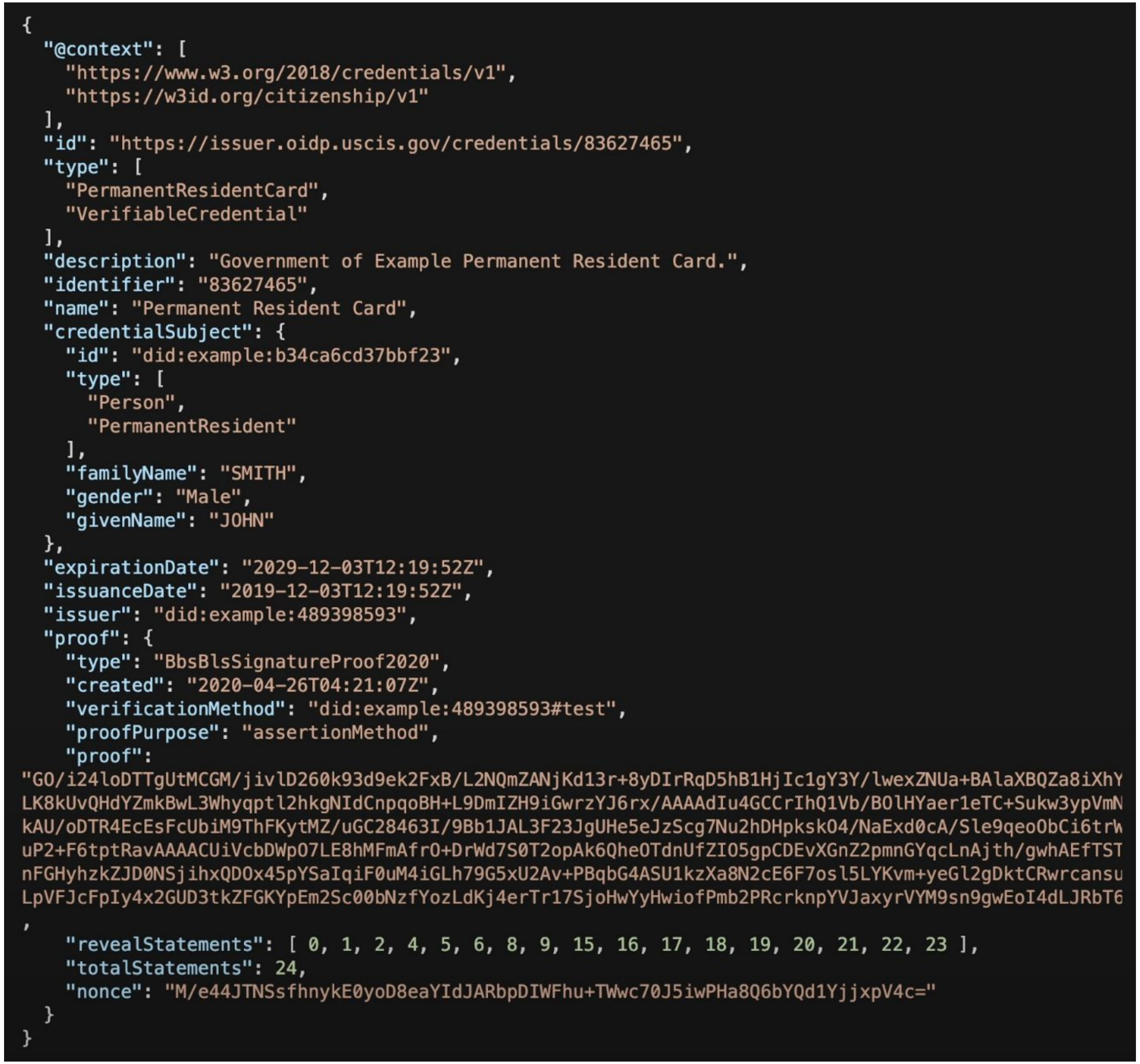
- TrustVault users are sovereign over identity and data
  - Secure, under user control and portable
- User data is stored locally, with fine-grained access control
- Build upon upcoming European Digital Identity Wallet
- EBSI is viable way of giving control to citizens
- Alternative for Big Tech
- Fair, competitive and transparent

Thanks for joining

Sharif Jacobino


Legend
A
Trusts
B
Wallet
Issuer
Holder's
Holder
agent
Verifier
Verifiable
data
registry


Application
identity-based messaging
Application
Overlays
Communication Substrate
SSI
SSI
Anonymization
Anonymization
Anonymization
PKI
PKI
PKI
UDP/IP
UDP/IP
UDP/IP
Internet
Internet



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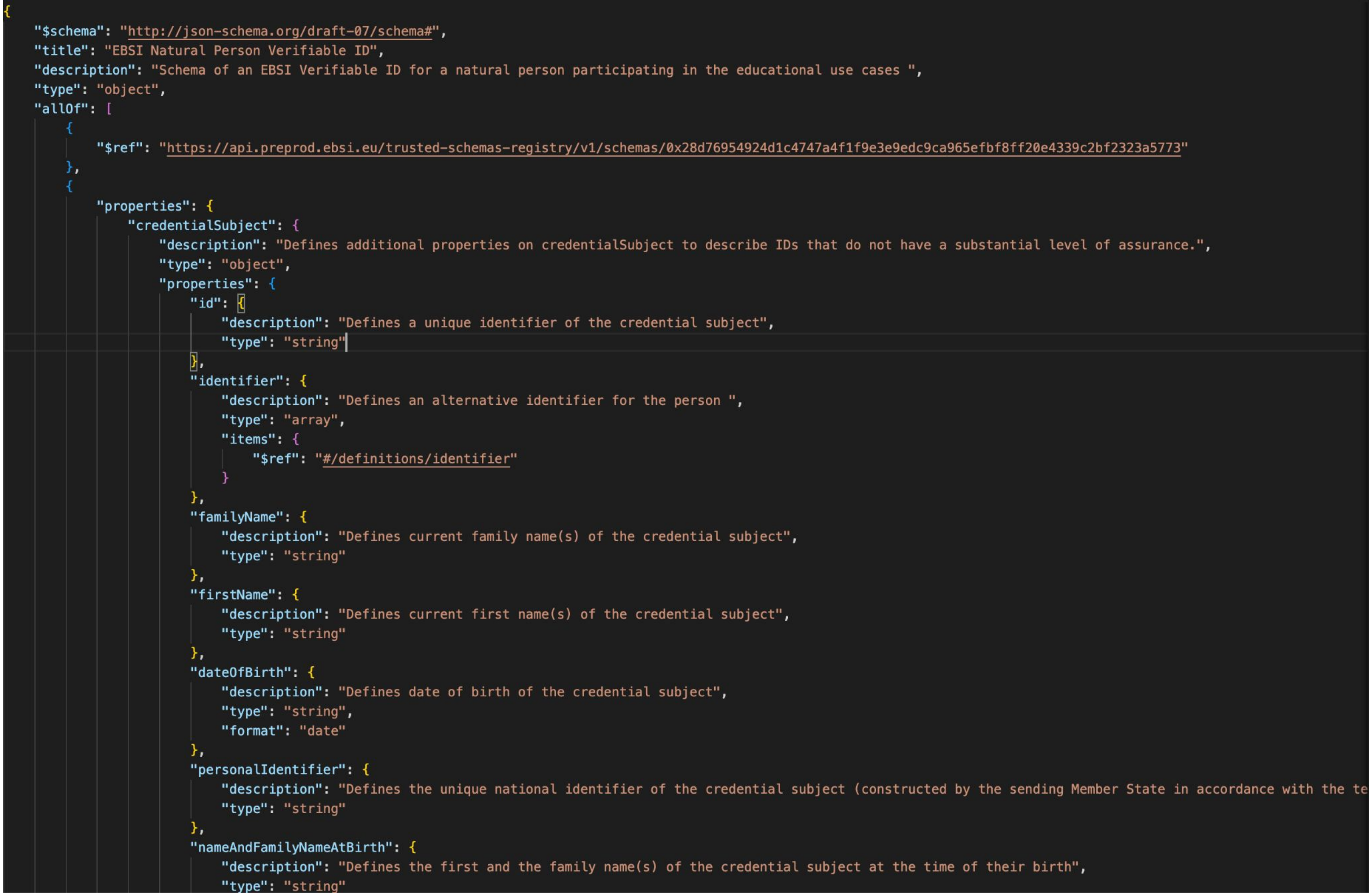
kAU/oDTR4EcEsFcUbiM9ThFKytMZ/uGC28463I/9Bb1JAL3F23JgUHe5eJzScg7Nu2hDHpksk04/NaExd0cA/Sle9qeoObCi6trW
uP2+F6tptRavAAAACUiVcbDWpO7LE8hMFmAfrO+DrWd7S0T2opAk6QheOTdnUfZIO5gpCDEvXGnZ2pmnGYqcLnAjth/gwhAEfTST
nFGHyhzkZJD0NSjihxQDOx45pYSaIqiF0uM4iGLh79G5xU2Av+PBqbG4ASU1kzXa8N2cE6F7osl5LYKvm+yeGl2gDktCRwrcansu
LpVFJcFpIy4x2GUD3tkZFGKYpEm2Sc00bNzfYozLdKj4erTr17SjoHwYyHwiofPmb2PRcrknpYVJaxyrVYM9sn9gwEoI4dLJRbT6
,
    "revealStatements": [ 0, 1, 2, 4, 5, 6, 8, 9, 15, 16, 17, 18, 19, 20, 21, 22, 23 ],
    "totalStatements": 24,
    "nonce": "M/e44JTNSsfhnykE0yoD8eaYIdJARbpDIWFhu+TWwc70J5iwPHa8Q6bYQd1YjjxpV4c="
  }
}
```



```
{
    "$schema": "http://json-schema.org/draft-07/schema#",
    "title": "EBSI Natural Person Verifiable ID",
    "description": "Schema of an EBSI Verifiable ID for a natural person participating in the educational use cases ",
    "type": "object",
    "allOf": [
        {
            "$ref": "https://api.preprod.ebsi.eu/trusted-schemas-registry/v1/schemas/0x28d76954924d1c4747a4f1f9e3e9edc9ca965efbf8ff20e4339c2bf2323a5773"
        },
        {
            "properties": {
                "credentialSubject": {
                    "description": "Defines additional properties on credentialSubject to describe IDs that do not have a substantial level of assurance.",
                    "type": "object",
                    "properties": {
                        "id": {
                            "description": "Defines a unique identifier of the credential subject",
                            "type": "string"
                        },
                        "identifier": {
                            "description": "Defines an alternative identifier for the person ",
                            "type": "array",
                            "items": {
                                "$ref": "#/definitions/identifier"
                            }
                        },
                        "familyName": {
                            "description": "Defines current family name(s) of the credential subject",
                            "type": "string"
                        },
                        "firstName": {
                            "description": "Defines current first name(s) of the credential subject",
                            "type": "string"
                        },
                        "dateOfBirth": {
                            "description": "Defines date of birth of the credential subject",
                            "type": "string",
                            "format": "date"
                        },
                        "personalIdentifier": {
                            "description": "Defines the unique national identifier of the credential subject (constructed by the sending Member State in accordance with the te
                            "type": "string"
                        },
                        "nameAndFamilyNameAtBirth": {
                            "description": "Defines the first and the family name(s) of the credential subject at the time of their birth",
                            "type": "string"
```

1.Summary of the report

This report certifies the conformance of Web Wallet 0.2.0 distributed by walt.id
to the EBSI specifications v1.0.0 on 01/03/2022.
The results and details of the tests can be found hereunder:

Test ID	Timestamp	Results
ONBOARD_01_A	2022-02-15 16:02:00	Successful
ONBOARD_02_A	2022-02-15 16:02:00	Successful
ONBOARD_051	N/A	N/A
ONBOARD_052	2022-02-15 16:02:00	Successful
ONBOARD_061	2022-02-15 16:02:00	Successful
ONBOARD_062	N/A	N/A
ONBOARD_063	N/A	N/A
ISSUE_011	2022-02-15 16:02:00	Successful
ISSUE_021	2022-02-15 16:02:00	Successful
ISSUE_031	2022-02-15 16:02:00	Successful
VERIFY_011	2022-02-15 16:02:00	Successful
VERIFY_031	2022-02-15 16:02:00	Successful
ISSUE_041	N/A	N/A
ISSUE_051	N/A	N/A
ISSUE_052	N/A	N/A
ISSUE_061	N/A	N/A
ISSUE_062	N/A	N/A
ISSUE_065	N/A	N/A
VERIFY_041	N/A	N/A
VERIFY_051	N/A	N/A
VERIFY_061	N/A	N/A
VERIFY_064	N/A	N/A

2.Detailed results

ISSUE_011 - Requests Verifiable Attestation (VA)

ISSUE_011

2022-02-15 11:02:00

```
{"logNumber":18,"body":{"state":"teststate","code":"202f157ab816626a4826"},"conformance":"286dc8c9-15ce-4f4b
-a32b-8ce5a5b7c4f5","date":"2022-02-15T10:50:47.000Z","service":"conformance","url":"/conformance/v1/issuer-m
ock/authorize?scope=openid&claims=%7B%22credentials%22%3A%5B%7B%22type%22%3A%22https%3A%5C%2
F%5C%2Fapi.preprod.ebsi.eu%5C%2Ftrusted-schemas-registry%5C%2Fv1%5C%2Fschemas%5C%2F0x14b05b921
3dbe7d343ec1fe1d3c8c739a3f3dc5a59bae55eb38fa0c295124f49%23%22%7D%5D%7D&response_type=code&redire
ct_uri=http%3A%2F%2Fblank&state=teststate&nonce=testnonce&client_id=http%3A%2F%2Fblank","type":"respon
se","method":"GET","status":200}
```

2022-02-15 11:02:00

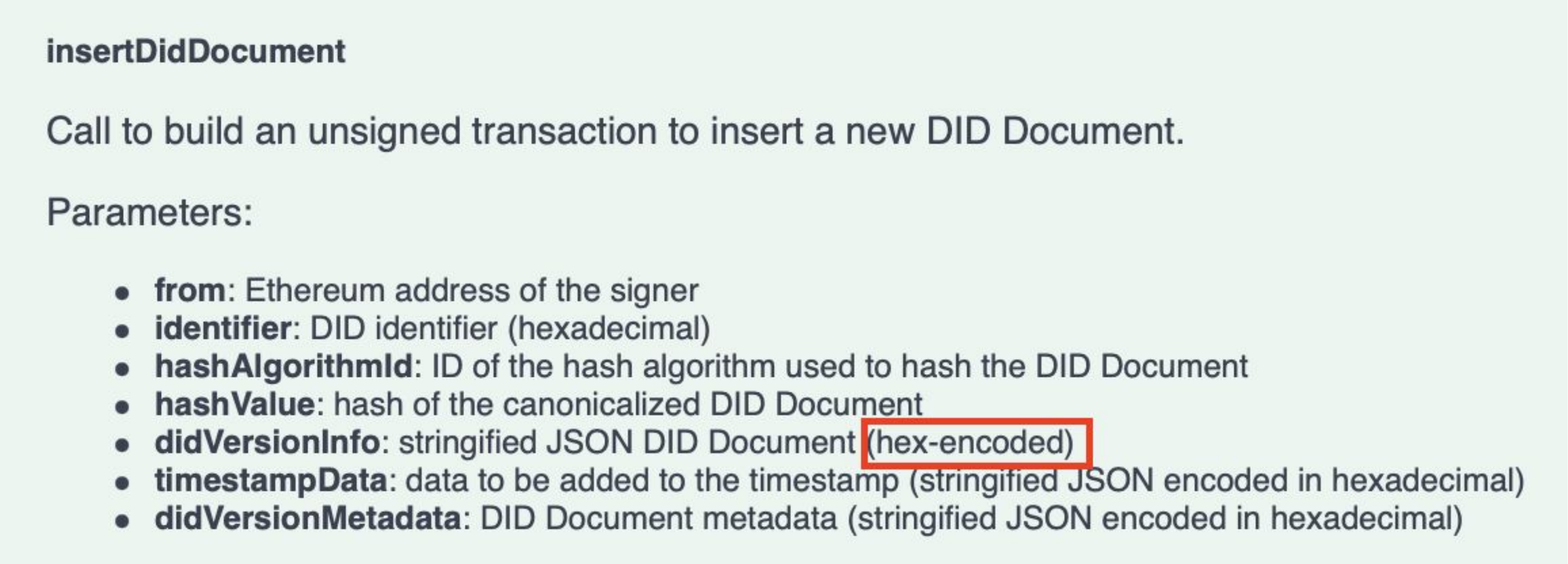
```
{"logNumber":26,"body":{"state":"teststate","code":"b4afa21fba719bff0d03"},"conformance":"286dc8c9-15ce-4f4b-
a32b-8ce5a5b7c4f5","date":"2022-02-15T10:55:44.000Z","service":"conformance","url":"/conformance/v1/issuer-mo
ck/authorize?scope=openid&claims=%7B%22credentials%22%3A%5B%7B%22type%22%3A%22https%3A%5C%2F
%5C%2Fapi.preprod.ebsi.eu%5C%2Ftrusted-schemas-registry%5C%2Fv1%5C%2Fschemas%5C%2F0x14b05b9213
dbe7d343ec1fe1d3c8c739a3f3dc5a59bae55eb38fa0c295124f49%23%22%7D%5D%7D&response_type=code&redirec
t_uri=http%3A%2F%2Fblank&state=teststate&nonce=testnonce&client_id=http%3A%2F%2Fblank","type":"respons
e","method":"GET","status":200}
```

2022-02-15 11:02:00

```
{"logNumber":34,"body":{"state":"teststate","code":"2131761da6cfb1fb4608"},"conformance":"286dc8c9-15ce-4f4b
-a32b-8ce5a5b7c4f5","date":"2022-02-15T10:58:40.000Z","service":"conformance","url":"/conformance/v1/issuer-m
ock/authorize?scope=openid&claims=%7B%22credentials%22%3A%5B%7B%22type%22%3A%22https%3A%5C%2
F%5C%2Fapi.preprod.ebsi.eu%5C%2Ftrusted-schemas-registry%5C%2Fv1%5C%2Fschemas%5C%2F0x14b05b921
3dbe7d343ec1fe1d3c8c739a3f3dc5a59bae55eb38fa0c295124f49%23%22%7D%5D%7D&response_type=code&redire
ct_uri=http%3A%2F%2Fblank&state=teststate&nonce=testnonce&client_id=http%3A%2F%2Fblank","type":"respon
se","method":"GET","status":200}
```

2022-02-15 12:02:00

```
{"logNumber":42,"body":{"state":"teststate","code":"823703526ef2c2a0c890"},"conformance":"286dc8c9-15ce-4f4b
-a32b-8ce5a5b7c4f5","date":"2022-02-15T11:07:59.000Z","service":"conformance","url":"/conformance/v1/issuer-m
ock/authorize?scope=openid&claims=%7B%22credentials%22%3A%5B%7B%22type%22%3A%22https%3A%5C%2
F%5C%2Fapi.preprod.ebsi.eu%5C%2Ftrusted-schemas-registry%5C%2Fv1%5C%2Fschemas%5C%2F0x14b05b921
3dbe7d343ec1fe1d3c8c739a3f3dc5a59bae55eb38fa0c295124f49%23%22%7D%5D%7D&response_type=code&redire
```



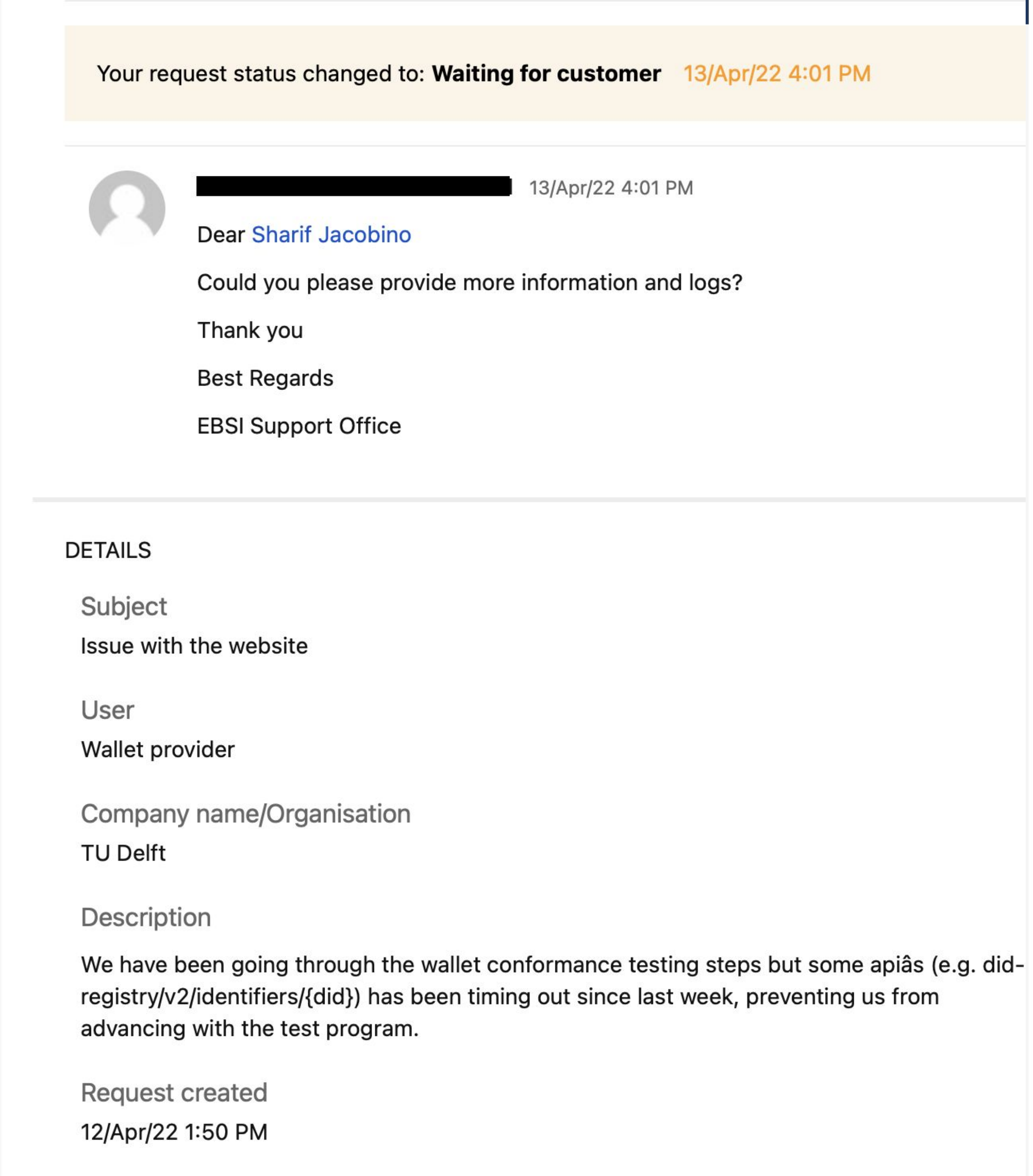
insertDidDocument

Call to build an unsigned transaction to insert a new DID Document.

Parameters:

- **from**: Ethereum address of the signer
- **identifier**: DID identifier (hexadecimal)
- **hashAlgorithmId**: ID of the hash algorithm used to hash the DID Document
- **hashValue**: hash of the canonicalized DID Document
- **didVersionInfo**: stringified JSON DID Document (hex-encoded)
- **timestampData**: data to be added to the timestamp (stringified JSON encoded in hexadecimal)
- **didVersionMetadata**: DID Document metadata (stringified JSON encoded in hexadecimal)

- Create a JSON-LD format DID Document compliant with W3C format (https://www.w3.org/TR/did-core/) and following ESSIF Model.
- Canonise the JSON-LD with URNDA2012 (using https://github.com/digitalbazaar/rdf-canonize-native)
- Encode in Base64url



Your request status changed to: **Waiting for customer** 13/Apr/22 4:01 PM

[redacted] 13/Apr/22 4:01 PM

Dear Sharif Jacobino

Could you please provide more information and logs?

Thank you

Best Regards

EBSI Support Office

DETAILS

Subject

Issue with the website

User

Wallet provider

Company name/Organisation

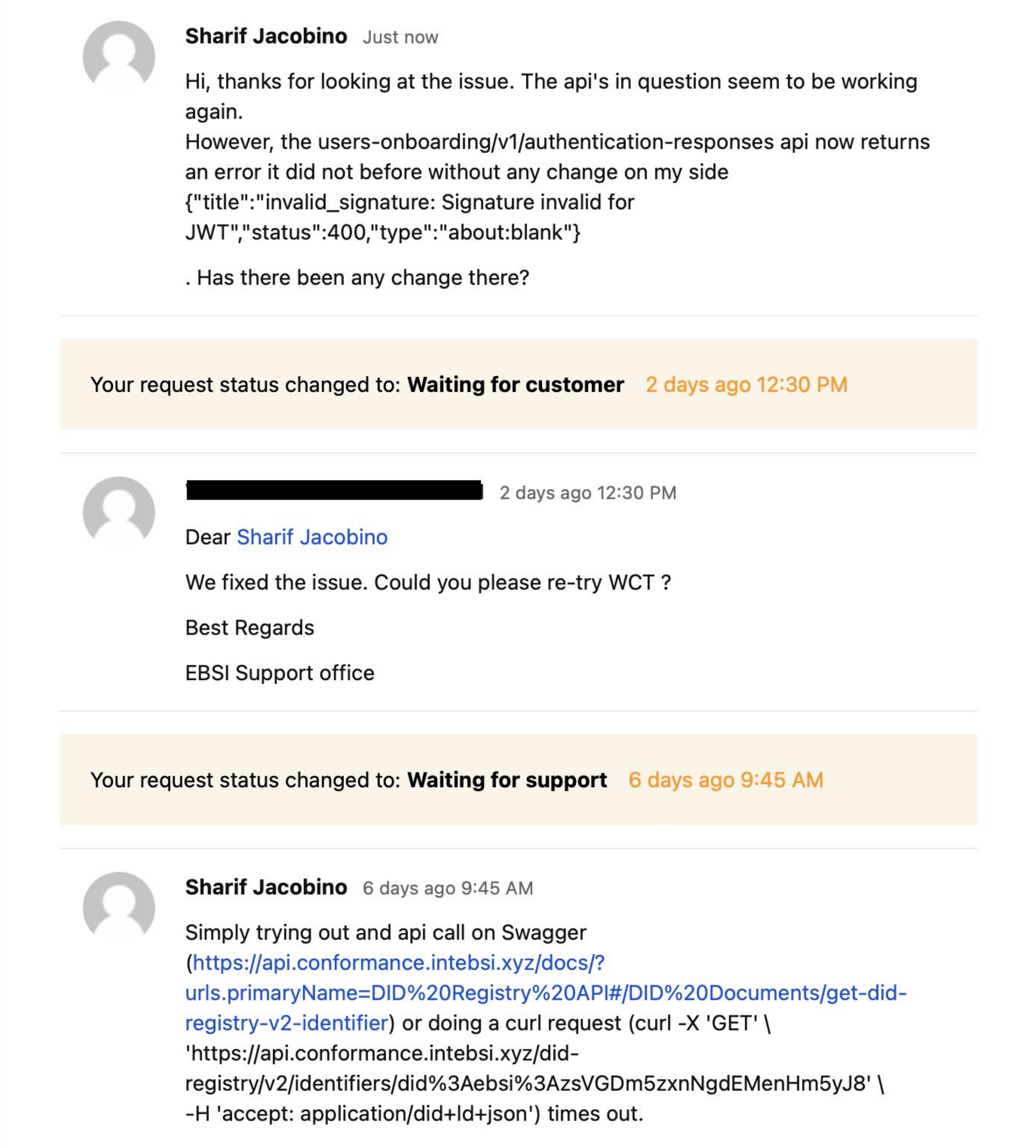
TU Delft

Description

We have been going through the wallet conformance testing steps but some apiâs (e.g. did-registry/v2/identifiers/{did}) has been timing out since last week, preventing us from advancing with the test program.

Request created

12/Apr/22 1:50 PM



Sharif Jacobino Just now

Hi, thanks for looking at the issue. The api's in question seem to be working again.
However, the users-onboarding/v1/authentication-responses api now returns an error it did not before without any change on my side
{"title":"invalid_signature: Signature invalid for JWT","status":400,"type":"about:blank"}

. Has there been any change there?

Your request status changed to: **Waiting for customer** 2 days ago 12:30 PM

[redacted] 2 days ago 12:30 PM

Dear Sharif Jacobino

We fixed the issue. Could you please re-try WCT ?

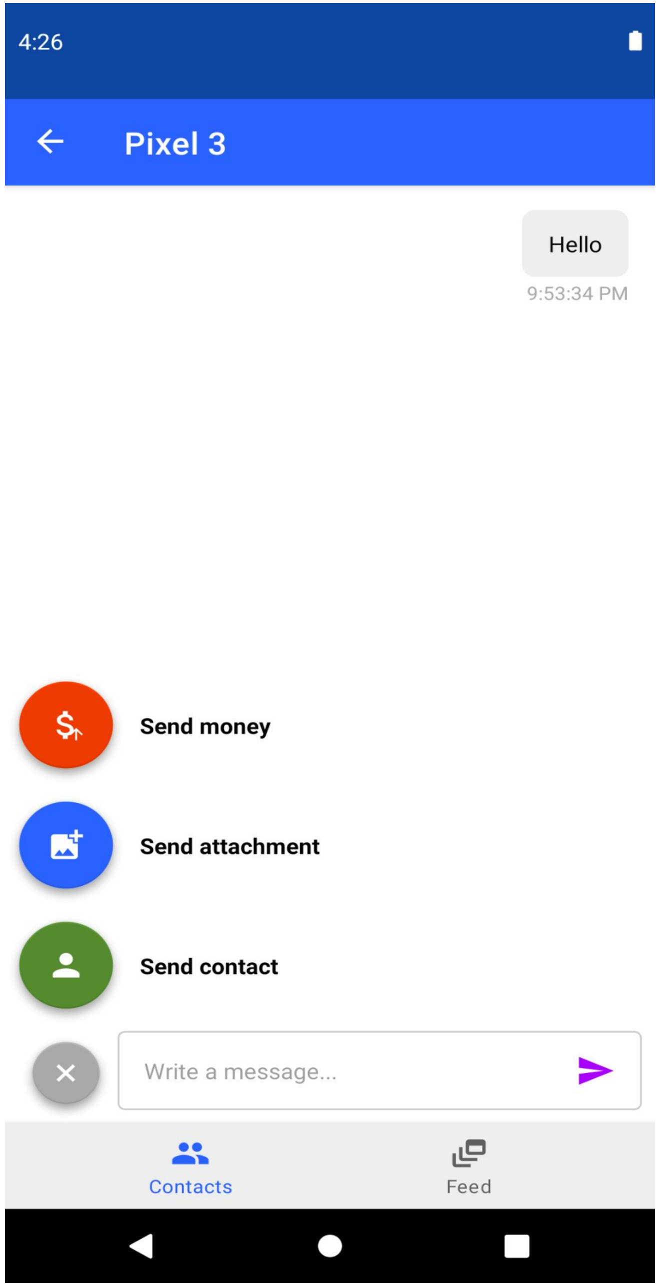
Best Regards

EBSI Support office

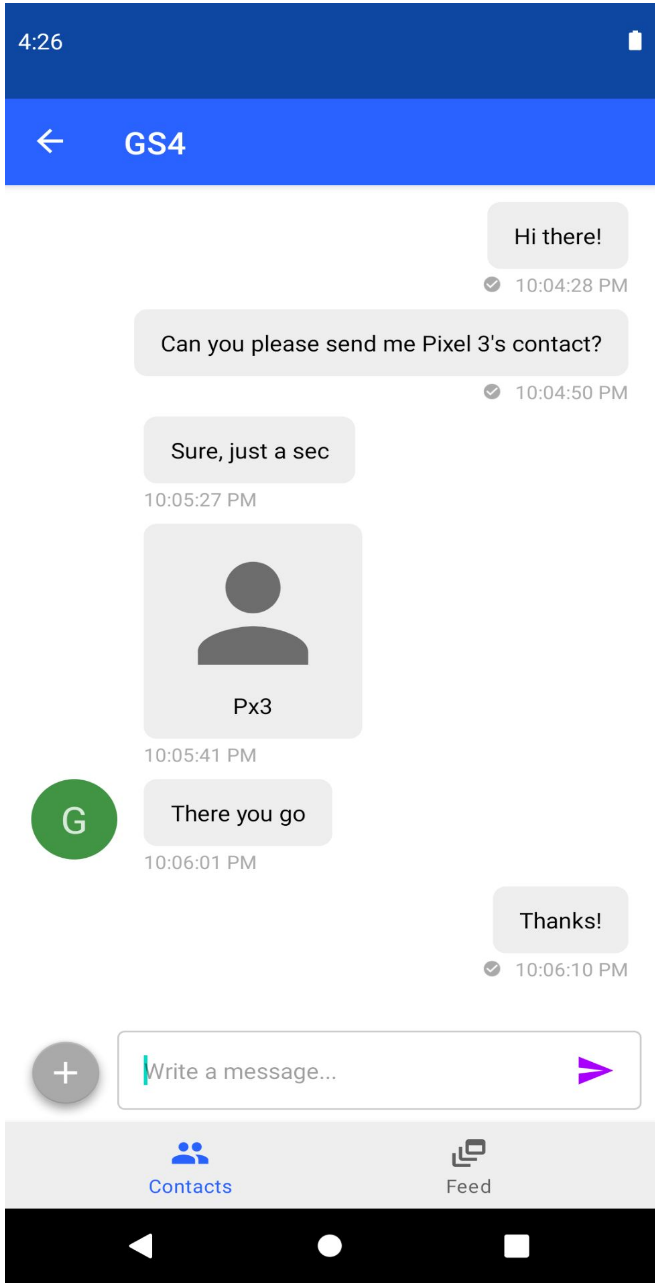
Your request status changed to: **Waiting for support** 6 days ago 9:45 AM

Sharif Jacobino 6 days ago 9:45 AM

Simply trying out and api call on Swagger (https://api.conformance.intebsi.xyz/docs/?urls.primaryName=DID%20Registry%20API#/DID%20Documents/get-did-registry-v2-identifier) or doing a curl request (curl -X 'GET' \
'https://api.conformance.intebsi.xyz/did-registry/v2/identifiers/did%3Aebsi%3AzsVGDm5zxnNgdEMenHm5yJ8' \
-H 'accept: application/did+ld+json') times out.



Hello
9:53:34 PM



Hi there!
10:04:28 PM

Can you please send me Pixel 3's contact?
10:04:50 PM

Sure, just a sec
10:05:27 PM

Px3
10:05:41 PM

G
There you go
10:06:01 PM

Thanks!
10:06:10 PM