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A Decentralised Public Key Infrastructure for X-Road

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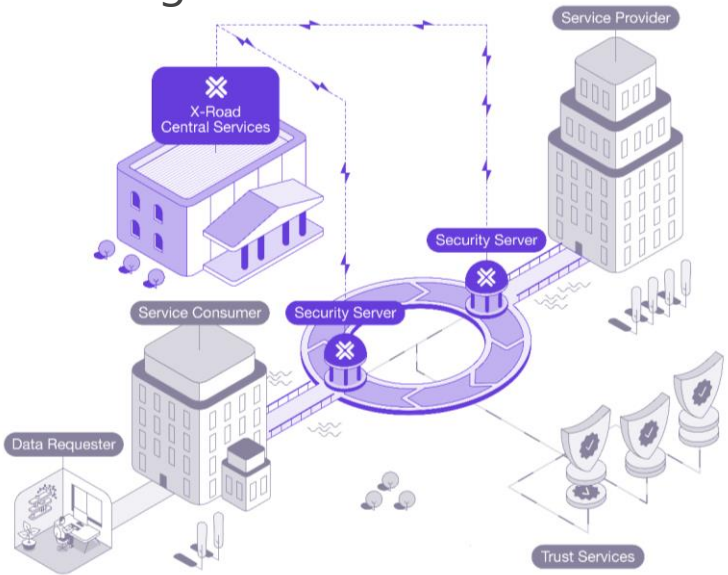
Case description

X-Road© is a centrally managed distributed data exchange system that provides unified and secure data exchange between organisations

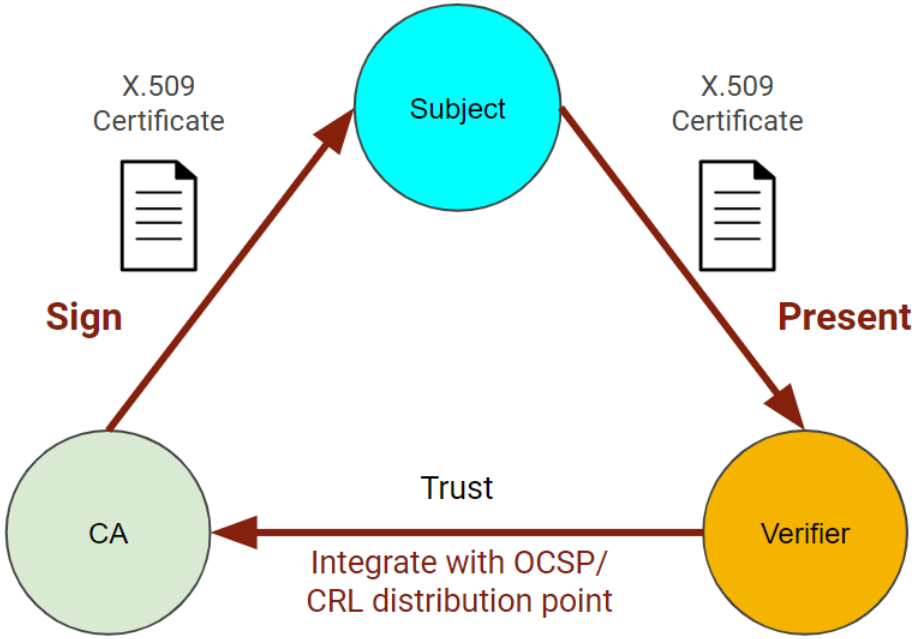
- What is trust? Credentials?
  - Centralised root of trust (PKI X.509, i.e. PKIX)



X-Road architecture
https://x-road.global/architecture

Motivation

- PKIX requires (manual) identity verification for certificate issuance
- PKIX is prone to the threat of DoS and to a single point of failure



PKI with X.509

Motivation

- Rise of Self-Sovereign identity brings new standards & technologies
  - DID
  - VC / VP

did:ethr:0x03fdd57adec3d438ea237fe46

Decentralised Identifier (DID) created without the help of centralised authorities

```
{
  "@context": [ "https://www.w3.org/ns/did/v1" ]
  "id": "did:ethr:0x03fdd57adec3d438ea237fe46",
  "authentication": [{
    "id": "did:ethr:0x03fdd57adec3d438ea237fe46#keys-1",
    "type": "Ed25519VerificationKey2020",
    "publicKeyMultibase":
       "zH3C2AVvLMv6gmMNam3uVAjZpfkcJCwDwnZn6z3wXmqPV"
  }]
}
```

DID document on distributed ledger

Motivation

- Rise of Self-Sovereign Identity brings new standards & technologies
  - DID
  - VC / VP

```
{
  "@context":
["https://www.w3.org/2018/credentials/v1"],
  "type":
["VerifiableCredential","UniversityDegreeCredential"],
  "issuer": "did:btcr:x705-jznz-q3nl-srs",
  "credentialSubject": {
    “id”: "did:ethr:0x03fdd57adec3d438ea237fe46",
    "degree": {
      "name": "Bachelor of Science and Arts",
      "college": "College of Engineering"
    }
  },
  // credential-holder binding, revocation status
  "proof": { … }
}
```

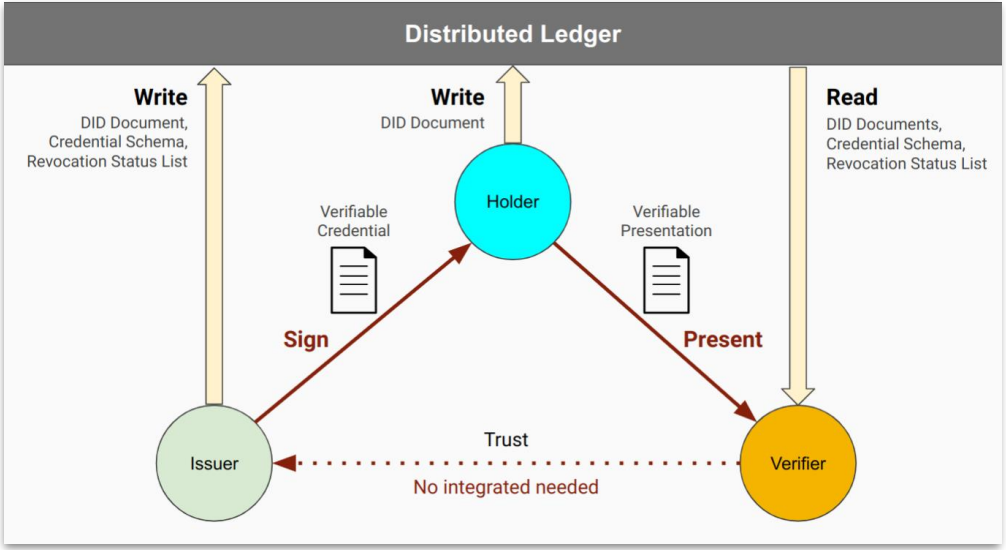
Verifiable Credential (VC) – a tamper-evident credential that has authorship and can be cryptographically verified,
+ can be presented in a form of **Verifiable Presentation (VP)**

Motivation

Self-Sovereign Identity (SSI) was primarily developed for physical entities

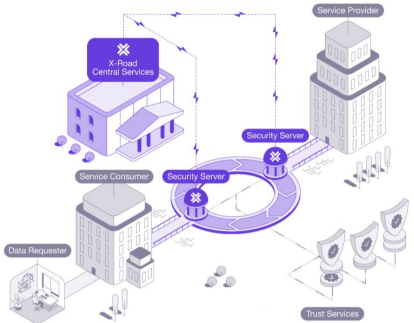
How about organisational identity?

Can DPKI be enable organisational identity management?



DPKI with SSI technologies

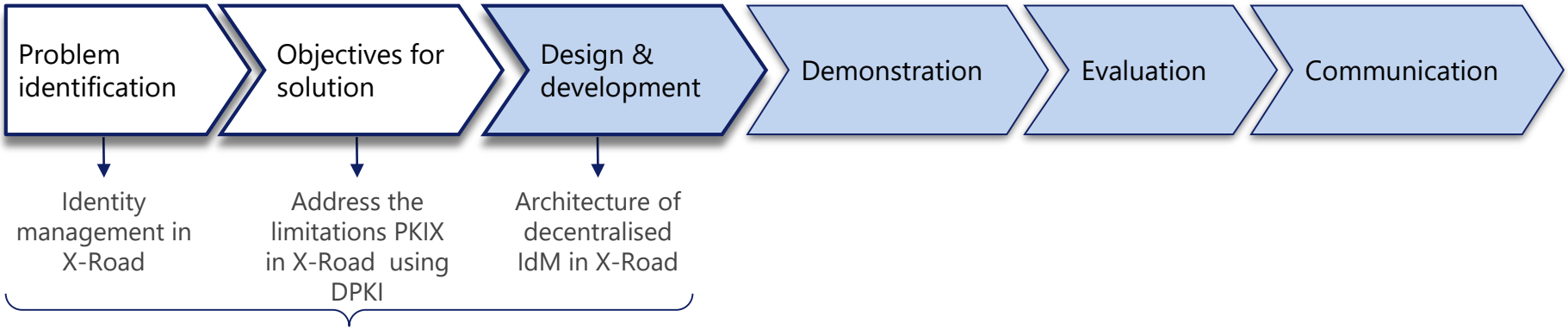
+



Research Question

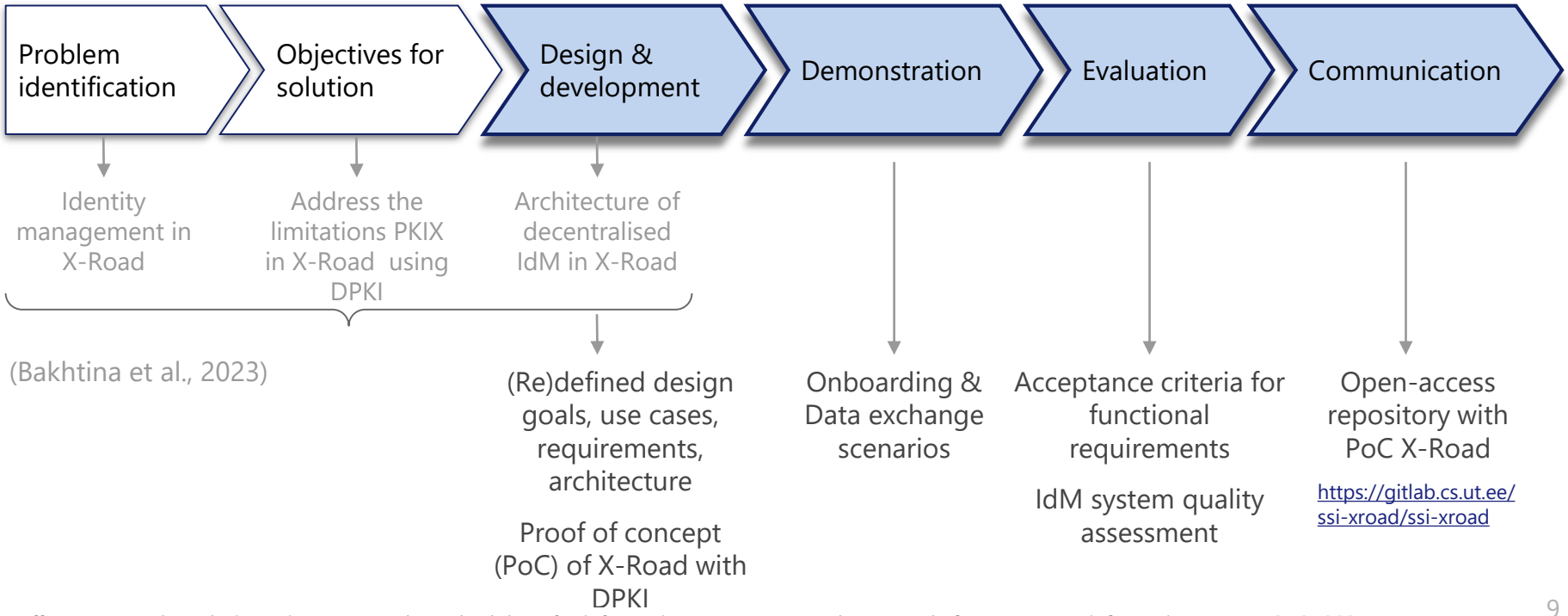
How to establish trust between information systems using a decentralised public key infrastructure in X-Road?

Design Science Research Method



(Bakhtina et al., 2023)

Design Science Research Method



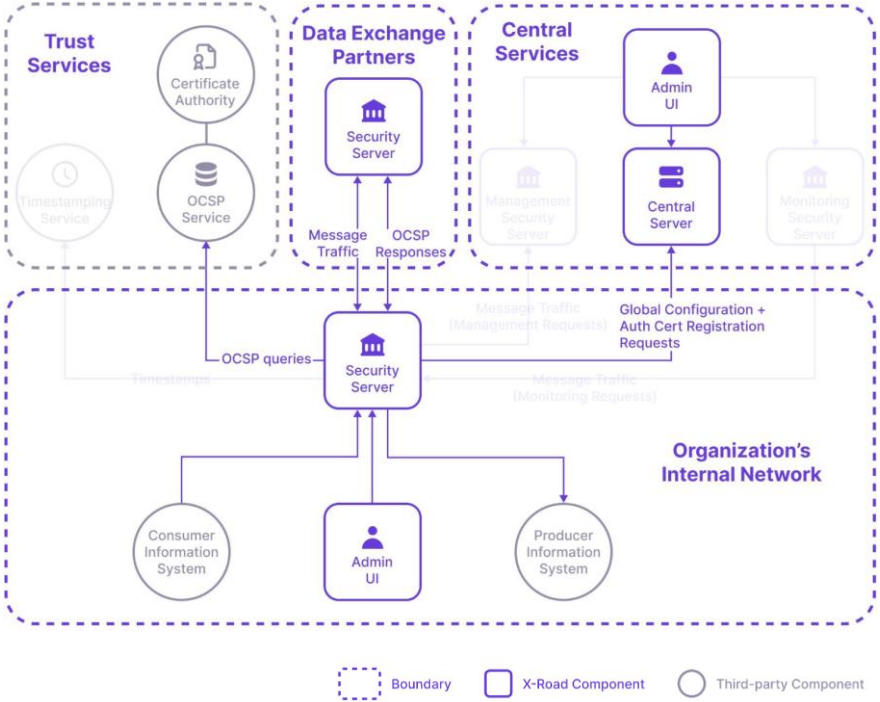
Peffers, Ken, et al. "A design science research methodology for information systems research." *Journal of management information systems* 24.3 (2007): 45-77.

Design

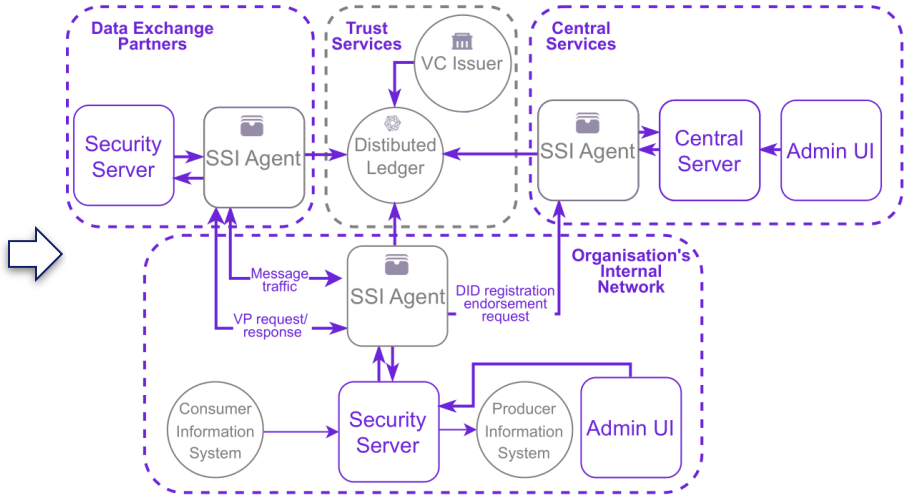
Design goals:

1. Increase the degree of decentralisation
2. Provide a more granular access control mechanism
3. Support automated member onboarding

Design

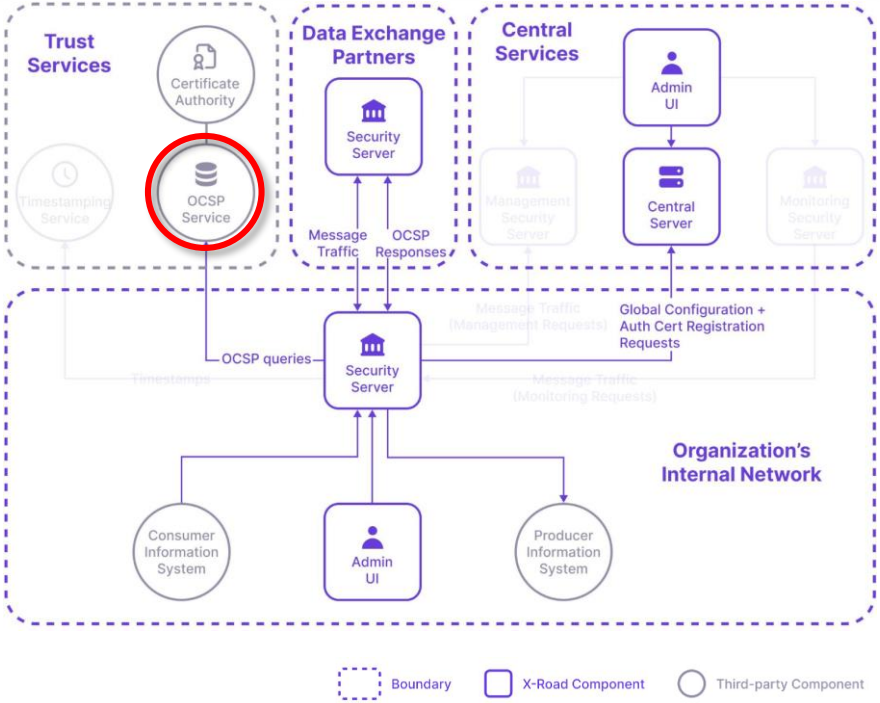


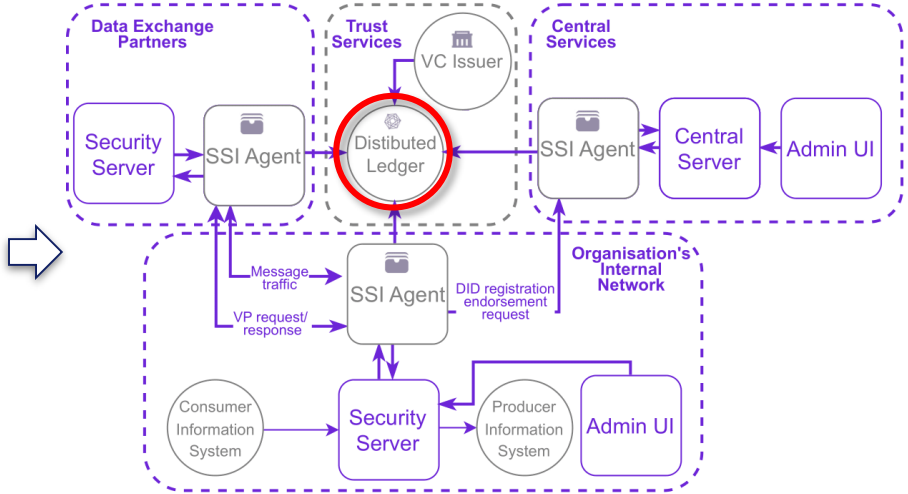
X-Road Original Architecture



X-Road with DPKI PoC Architecture

Design





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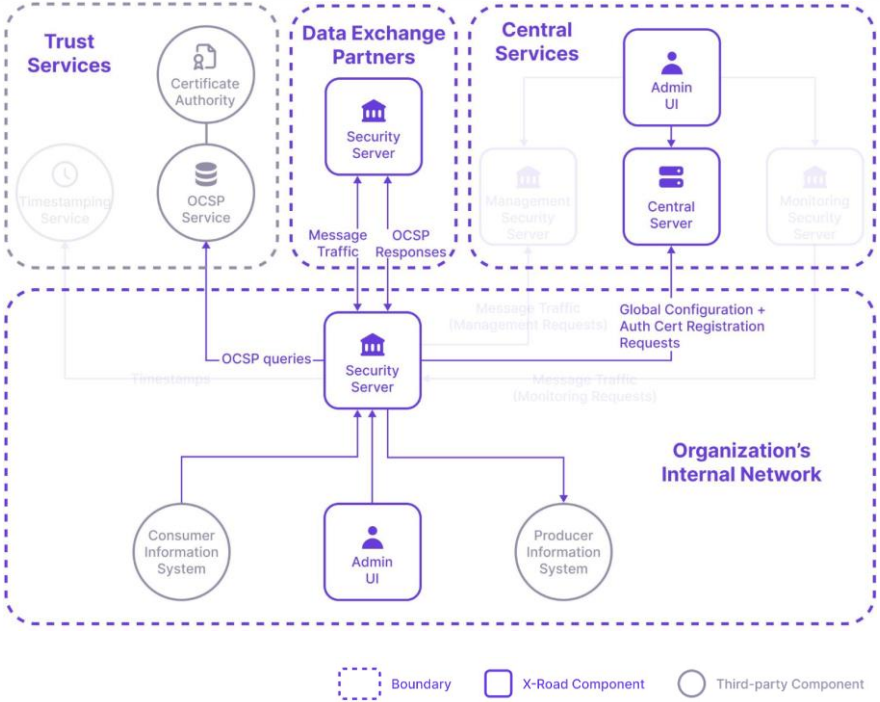
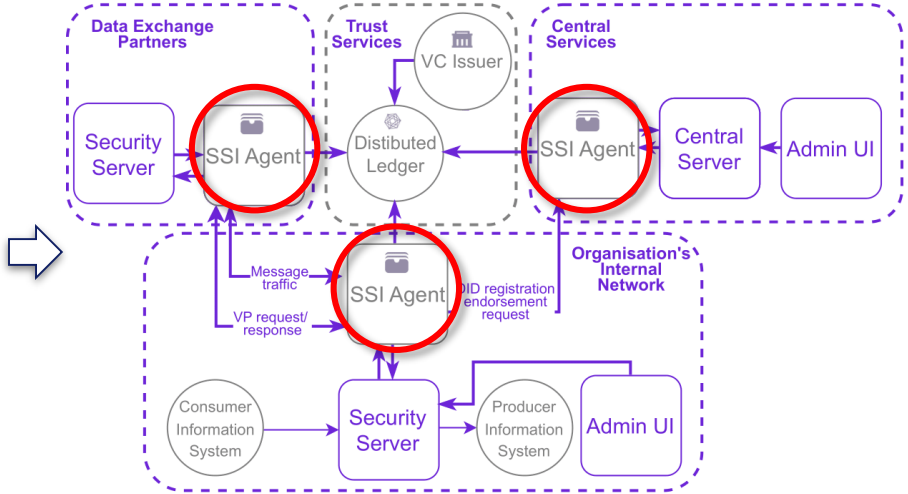




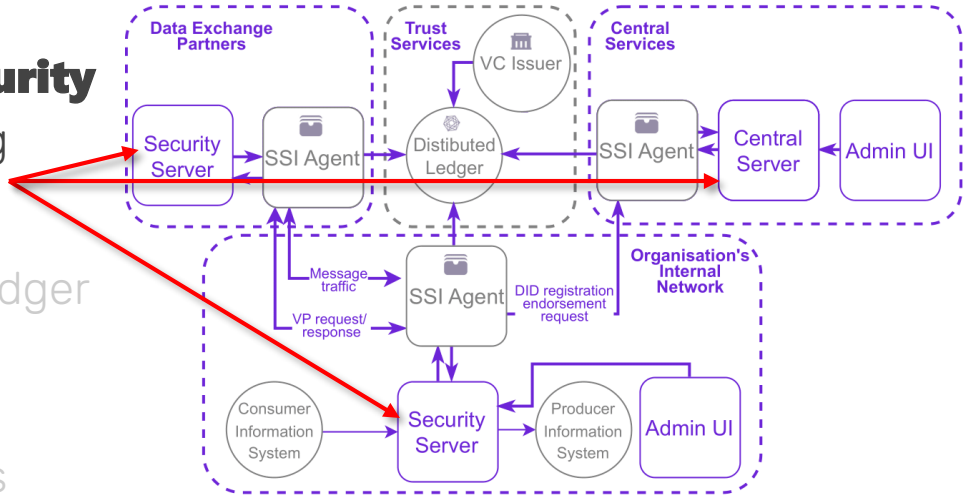
X-Road Original Architecture

X-Road with DPKI PoC Architecture

Implementation

Implemented **instance of X-Road Security Server and Central server,** integrating with:

- **Hyperledger Indy** as distributed ledger
- **Hyperledger Aries Cloud Agent Python** as SSI agent
- **AnonCreds** as verifiable credentials implementation
- **Aries Protocols** for secure connection, credential exchanges



https://gitlab.cs.ut.ee/ssi-xroad/ssi-xroad

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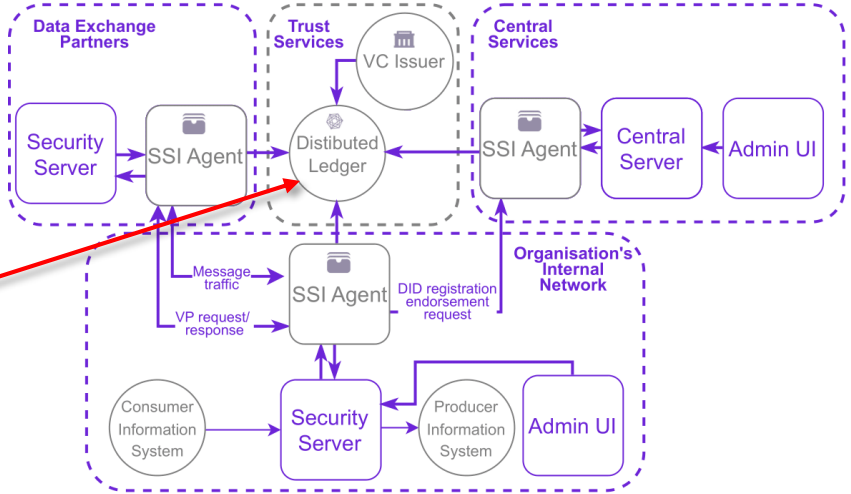

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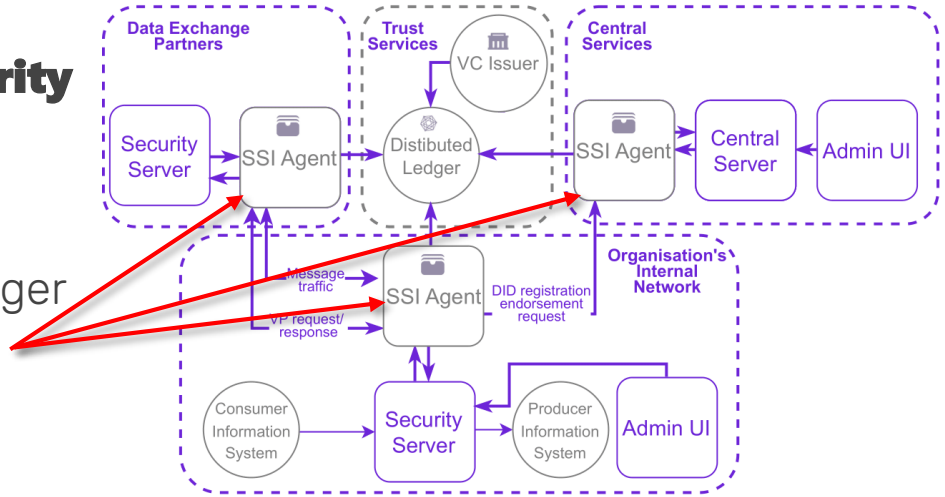

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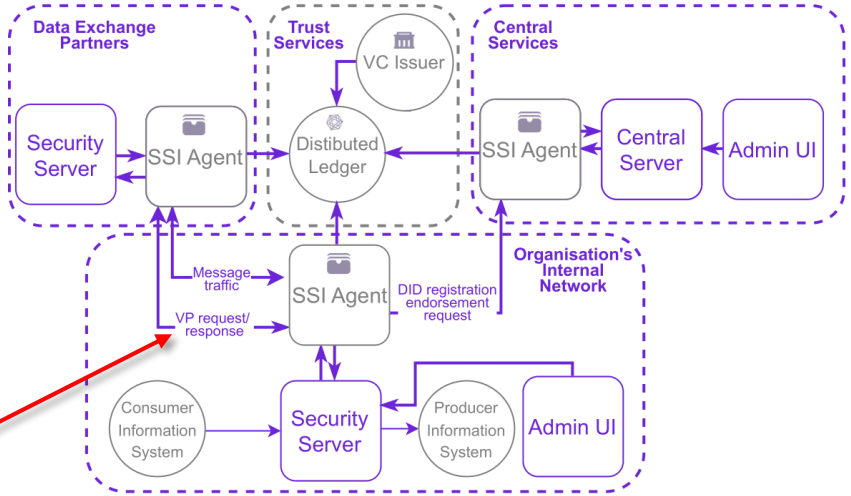

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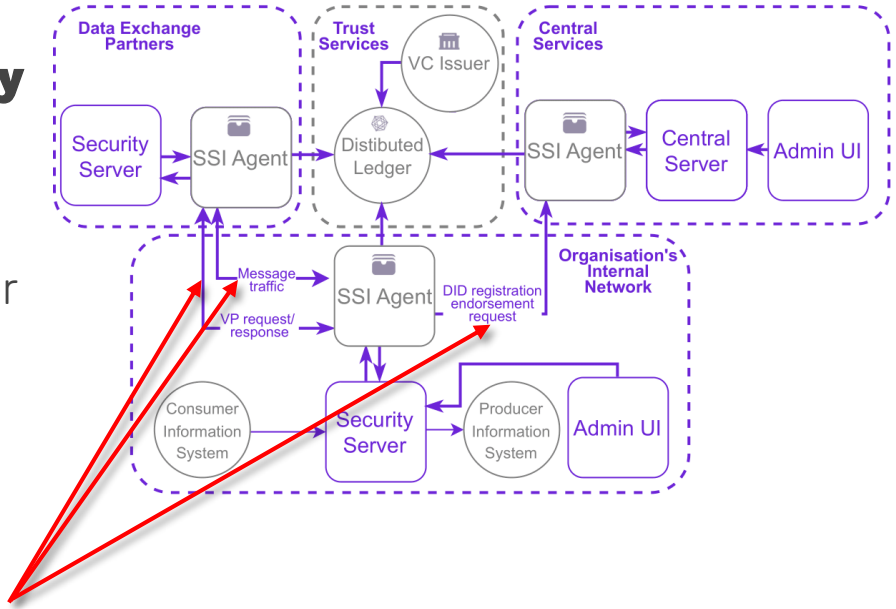

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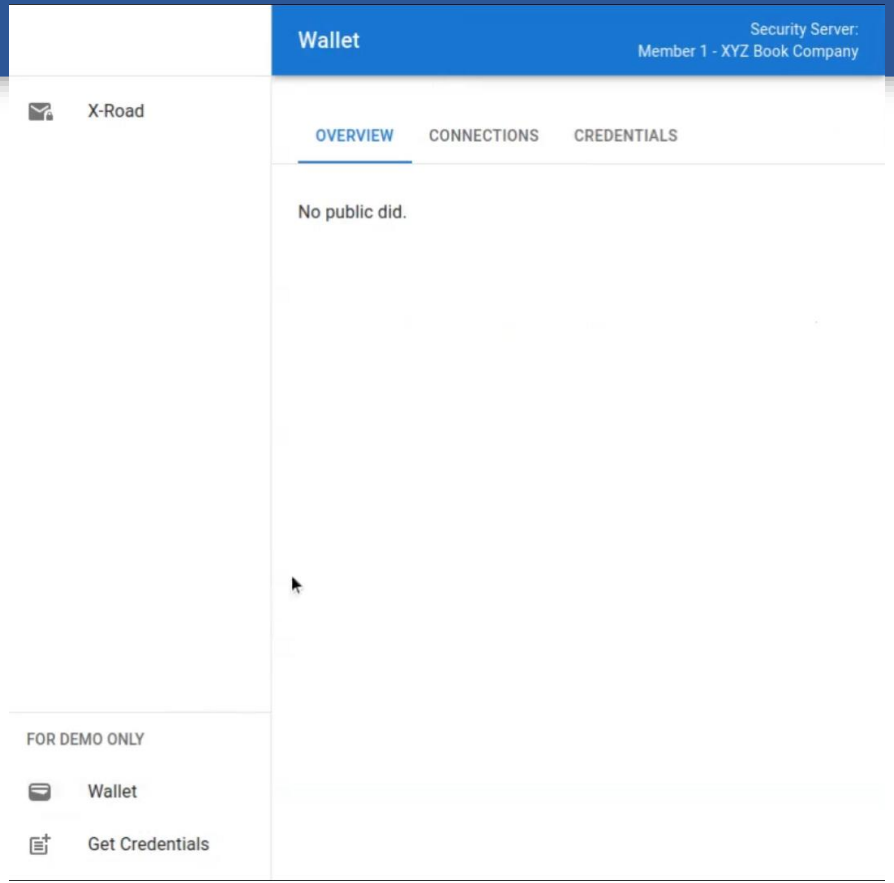
X-Road with DPKI PoC Architecture

Demonstration: Member Onboarding

Central Server requests organisation to present a “Business Registration Credential” for onboarding, i.e. joining an X-Road instance.

DID of new X-Road member is written on ledger for discovery.



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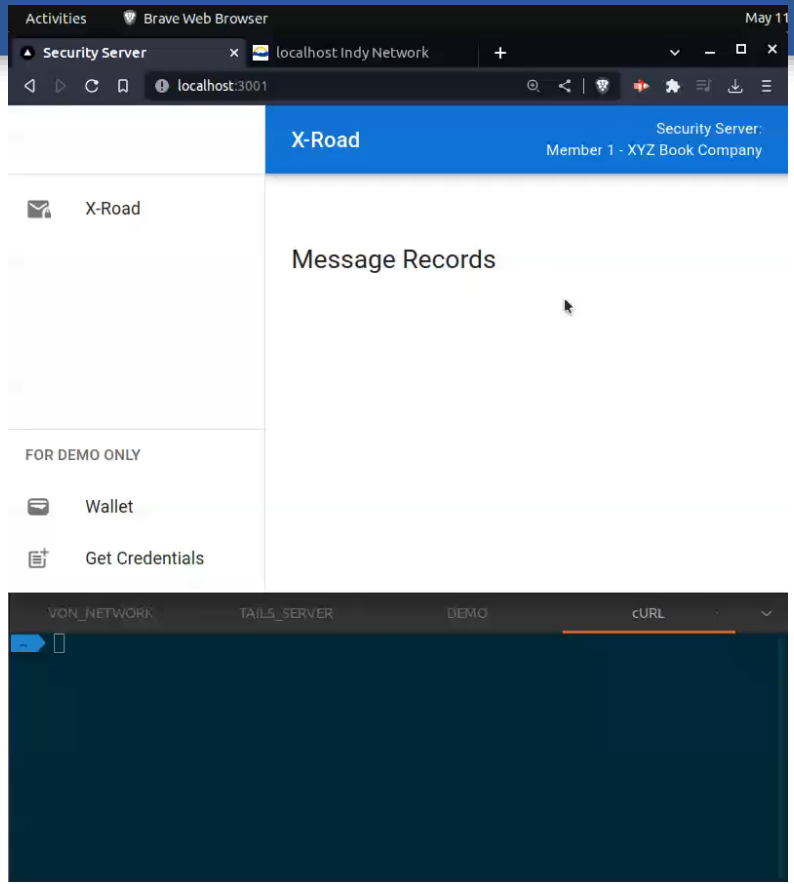
Demonstration: Message Exchange

Information systems of X-Road members exchange credentials before exchanging message.

Message exchange records are signed with authentication keys in members' DID documents.



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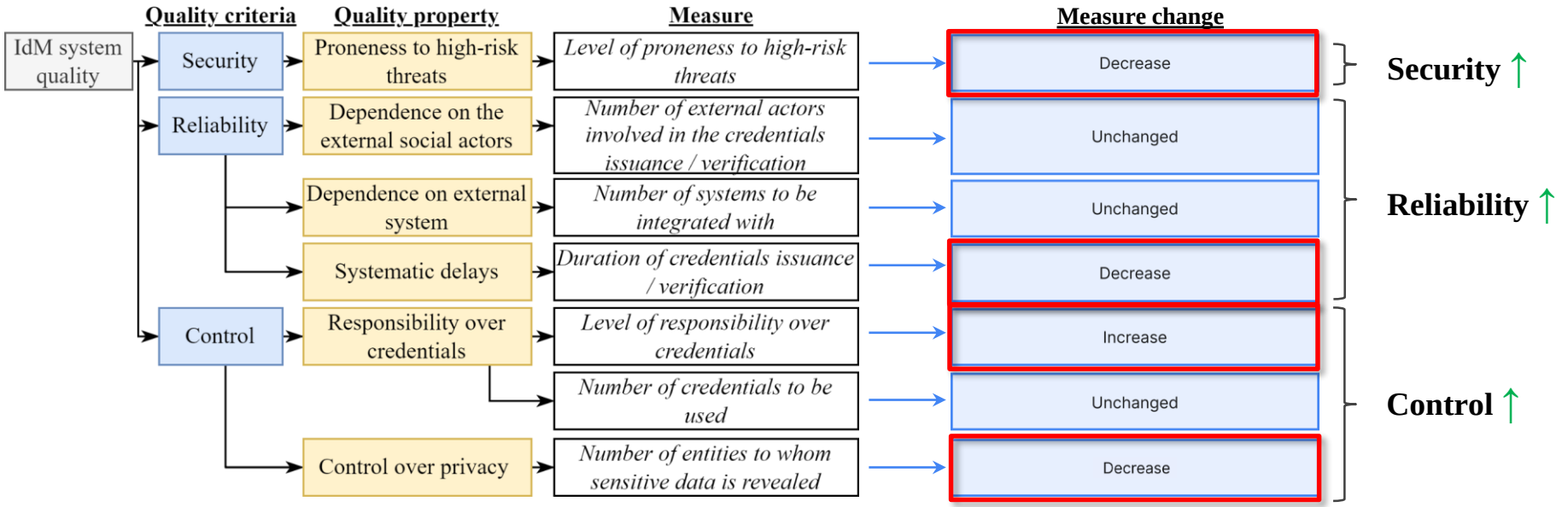
Evaluation: Change in System Quality



Identity Management System Quality Assessment Model

Evaluation

Mariia Bakhtina et al. "On the shift to decentralised identity management in distributed data exchange systems". 2023.

Conclusion

- This paper presents the **first open-access system prototype** for an **organisation's identity management** following **self-sovereign identity** principles
- The presented proof of concept proves that **DPKI helps to address** some of the **scalability issues of PKI**, improve **control over identity** and **mitigate a single point of failure** in the X-Road system

Conclusion

Limitations: The design may be biased towards the Hyperledger Indy ecosystem

Future work:

- Explore the selection of other distributed ledger-based SSI ecosystems
- Enable PKIX certificates to be VCs using the PKIX extension
- Extend the PoC with wallet management measures to strengthen access control over organisational identity

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Thank you for attention!

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