Enabling Decentralised Identifiers and Verifiable Credentials for Constrained Internet-of-Things Devices using OAuth-based Delegation

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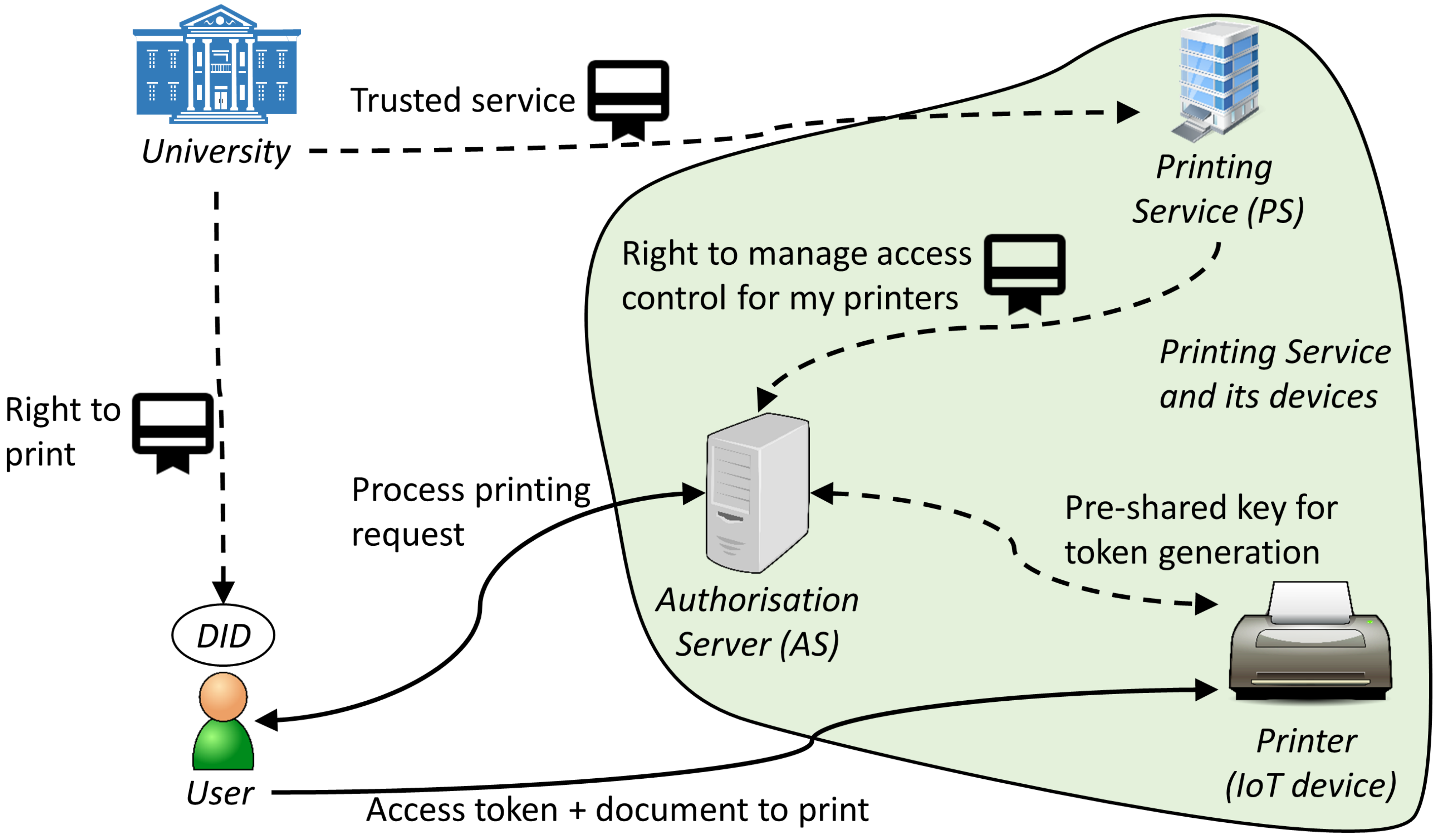
Motivation: Identifiers and IoT

- It should be possible to use services and devices while preserving privacy and preventing tracking
- Current identifier and certificate solutions have several problems
  - Different identifier for each service, lack of interoperability
  - Social logins: lack of privacy and control by the user
  - Very complicated to provide privacy-preserving proofs online
- From privacy's point of view, digital identifiers should provide:
  - Self-sovereignty (owner controls the identifier)
  - Ability to change identifiers at will
  - Anonymity

Use Case: Printing at University



Requirements of Use Case

- User (visiting lecturer) wants to print a document before the lecture in a secure way
  - User does not have a university user account
  - Printers are managed by a third-party printing service, which collaborates with the university
- User should stay anonymous as much as possible
  - Printing Service (PS), Authorisation Server (AS), or Printer will never learn user's real identity or able to track user
- User and printing service need mutually authenticate each other:
  - Printing Service is trusted by University
  - Authorisation Server is trusted by Printing Service
  - User has right to print from University

Decentralised Identifiers and Verifiable Credentials

- Decentralised Identifiers (DIDs) aim to provide *self-sovereignty*
  - DIDs can be created by the user without dependence on any third party, hence a large number of DIDs can be used (even different one for each transaction)
  - Often derived from key pair, e.g.: *did:sov:3k9dg356wdcj5gf2k9bw8kfg7a*
- With *verifiable credentials* (VCs), owner of identifier can “prove” something (e.g. date of birth, degree) about themselves
  - Selective disclosure: disclose only part of the information present in credential
  - Zero-knowledge Proofs (ZKP) allow one to prove of, e.g., being over certain age without revealing real age
- IoT devices may not be able to use public-key cryptography (resource constrains, lack of entropy, cost of upgrading, etc.)
- **How to use privacy-enabling properties of DIDs and VCs with existing constrained IoT devices?**

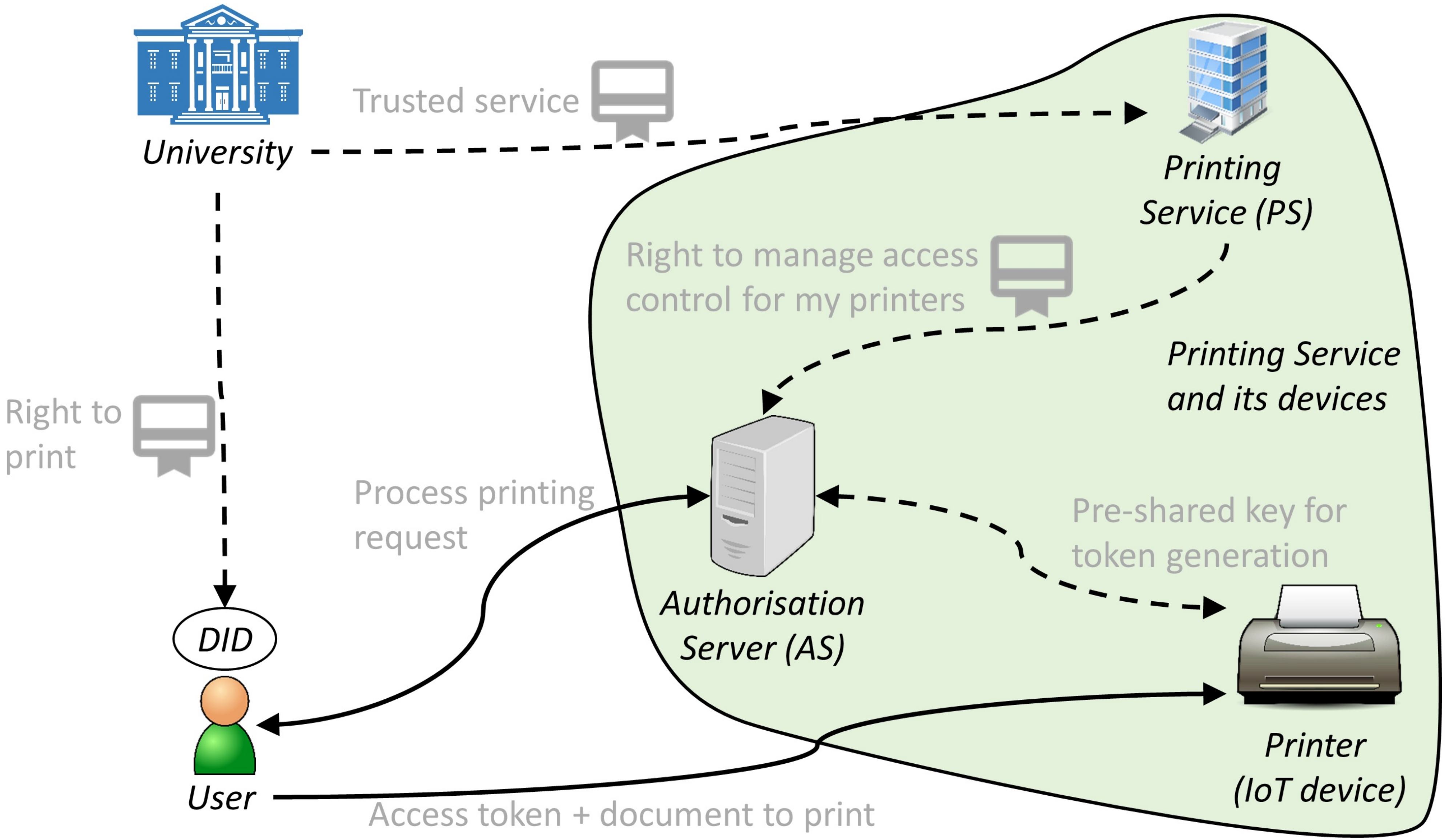
Existing Solutions for IoT Authentication and Authorisation

- OAuth 2.0 allows a client to obtain access to protected resource, residing on resource server (RS)
  - Access control is managed by authorisation server (AS), which issues access tokens
  - OAuth does not define used authentication solution
  - ACE extension for constrained IoT devices: allows usage of proof-of-possesion tokens that are based on pre-shared key
- Some technologies are not relevant for this use case
  - OpenID Connect: functionality is provided by DIDs and VCs
  - User Managed Access (UMA) 2.0: not always suitable for constrained devices

Delegating DID processing with OAuth

- Authorisation Server (AS) can act as a bridge between OAuth and DIDs
  - All actors except the device (printer) utilize DIDs and VCs for mutual authentication
  - Printer delegates DID processing to AS
- AS issues proof-of-possesion access tokens to client (Lecturer), after authentication has been performed (ACE-OAuth)
  - Lecturer uses the access token to access the printer

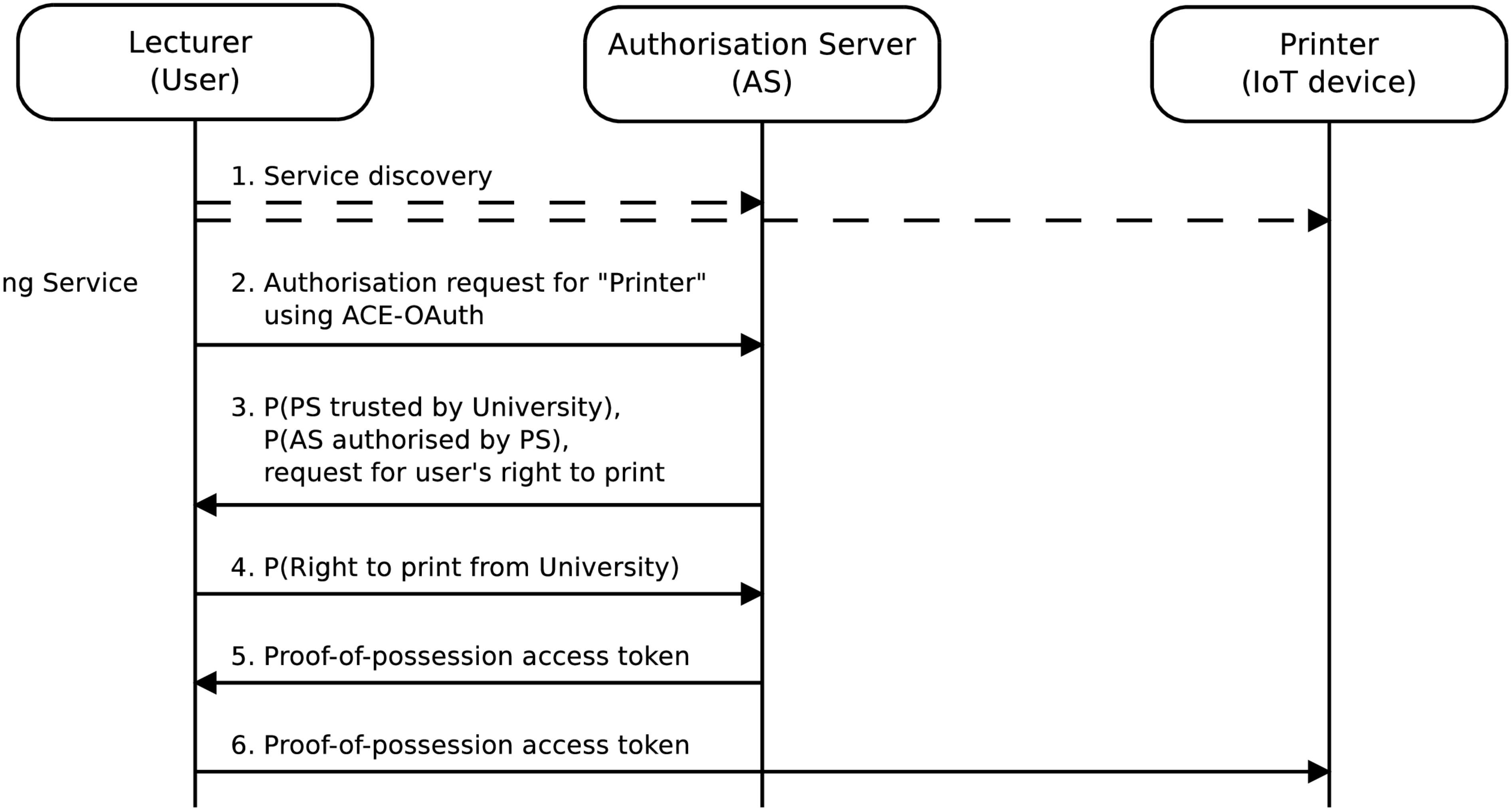
Printing at University: Actors



Message Flow

PS - Printing Service

P - Proof



Implementation

- The described solution has been implemented using Sovrin DID scheme (Hyperledger Indy) and OAuth2 server
  - User receives credentials from a Hyperledger Indy instance
  - User contacts OAuth server as usual
  - OAuth server generates a proof request containing a nonce
  - User generates a proof based on credentials using the nonce
  - Communication continues using standard OAuth protocol
- The source code will be made available before the publication of the paper

Comparison with Existing Solutions

- Using decentralised identifiers improves privacy

	X.509 Certificates	***DID + VC***
Granularity	Coarse	Fine-grained
Duration	Usually long	Short or long
Processing	By humans	Machine-readable

- Printing service or the printer will never learn real identify of user
  - User can change DIDs frequently to protect against correlations attacks
- Proposed solution is compatible with and complementary to OAuth and its extensions
  - Provides mutual authentication, decouples resource server from AS, can provide trusted AS discovery
  - No modification to the actual device (printer) necessary

Conclusions

- Decentralised identifiers and verifiable credentials improve privacy in several situations
  - Open standards, allowing easy deployment and adoption across organisations and industries
- Delegation allows constrained OAuth-capable devices to take advantage of DIDs and VCs
  - Without any modifications to existing devices
- We have implemented a proof-of-concept solution which will be released as open source

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Backup slide: Message Flow

- User and printing service mutually authenticate each other using proofs:
  - Printing Service is trusted by University
  - Authorisation Server is trusted by Printing Service
  - User has right to print from University
- Afterwards, proof-of-possesion access token, derived from pre-shared key, is issued using standard ACE-Oauth
- Message flow can be optimised by transmitting proofs during TLS handshake, utilising Encrypted Server Name Indication extension (TLS 1.3)

Verifiable Credential Example


```
{
  "@context": [
    "https://www.w3.org/2018/credentials/v1",
    "https://example.com/examples/v1"
  ],
  "id": "http://example.gov/credentials/3732",
  "type": ["VerifiableCredential", "UniversityDegreeCredential"],
  "issuer": "https://example.edu",
  "issuanceDate": "2010-01-01",
  "credentialSubject": {
    "id": "did:example:ebfeb1f712ebc6f1c276e12ec21",
    "degree": {
      "type": "BachelorDegree",
      "name": "Bachelor of Science in Mechanical Engineering"
    }
  },
  "proof": {
    "type": "RsaSignature2018",
    "created": "2018-06-18T21:19:10Z",
    "verificationMethod": "https://example.com/jdoe/keys/1",
    "nonce": "c0ae1c8e-c7e7-469f-b252-86e6a0e7387e",
    "signatureValue": "BavEll0/I1zpYw8XNi1bgVg/sCneO4Jugez8RwDg/+
MCRVpjOboDoe4SxxKjkCOvKiCHGDvc4krqi6Z1n0UfqzxGfmatCuFibcC1wps
      PRdW+gGsutPTLzvueMWmFhwYmfIFpbBu95t501+rSLHIEuujM/+PXr9Cky6Ed+W3JT24="
  }
}
```

ACE-OAuth Token Response

Header: Created (Code=2.01)

Content-Format: "application/ace+cbor"

Payload:


```
{
  "access_token" : b64'SlAV32hkKG ...
  (remainder of CWT omitted for brevity;
  CWT contains COSE_Key in the "cnf" claim)',
  "profile" : "coap_dtls",
  "expires_in" : "3600",
  "cnf" : {
    "COSE_Key" : {
      "kty" : "Symmetric",
      "kid" : b64'39Gqlw',
      "k" : b64'hJtXhkV8FJG+Onbc6mxCcQh'
    }
  }
}
```

Backup slide: Implementation

- Used software
  - https://github.com/hyperledger/indy-sdk/
  - https://github.com/bshaffer/oauth2-server-php
- Proofs are processed in JSON using Base64 encoding
- Implementation is written using Python, other bindings are also available for Indy SDK