E-ID Hands-on Workshop

Keeping identities safe and sound

Center for
Digital Trust

Program

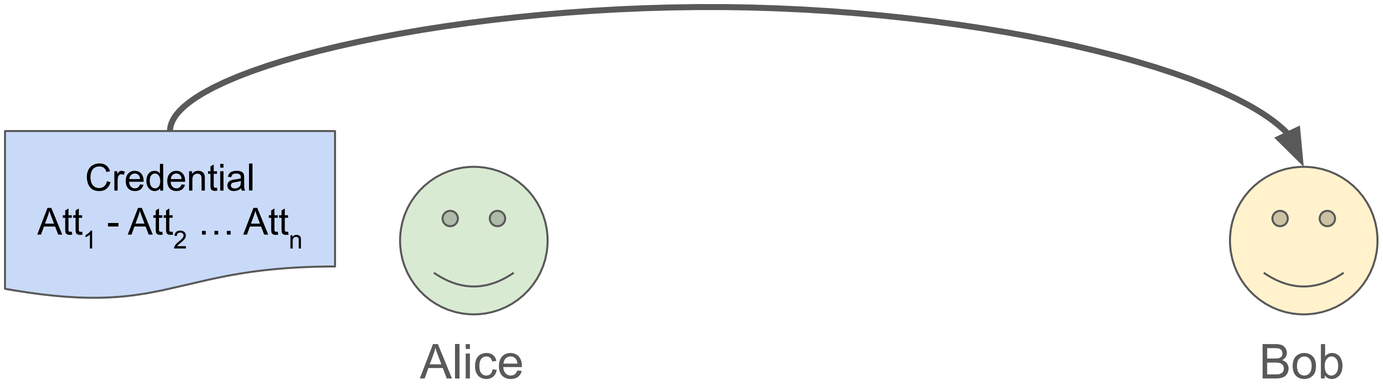
1. Signing simply with RSA
2. Unlinkable proofs using BBS+
3. Predicate proofs with ZKPs
4. ZKP Considerations

For subjects 1-3:

1. Short theory
2. Jupyter exercises
3. Discussion
4. Longer coding exercise

1 - Signing Simply with RSA

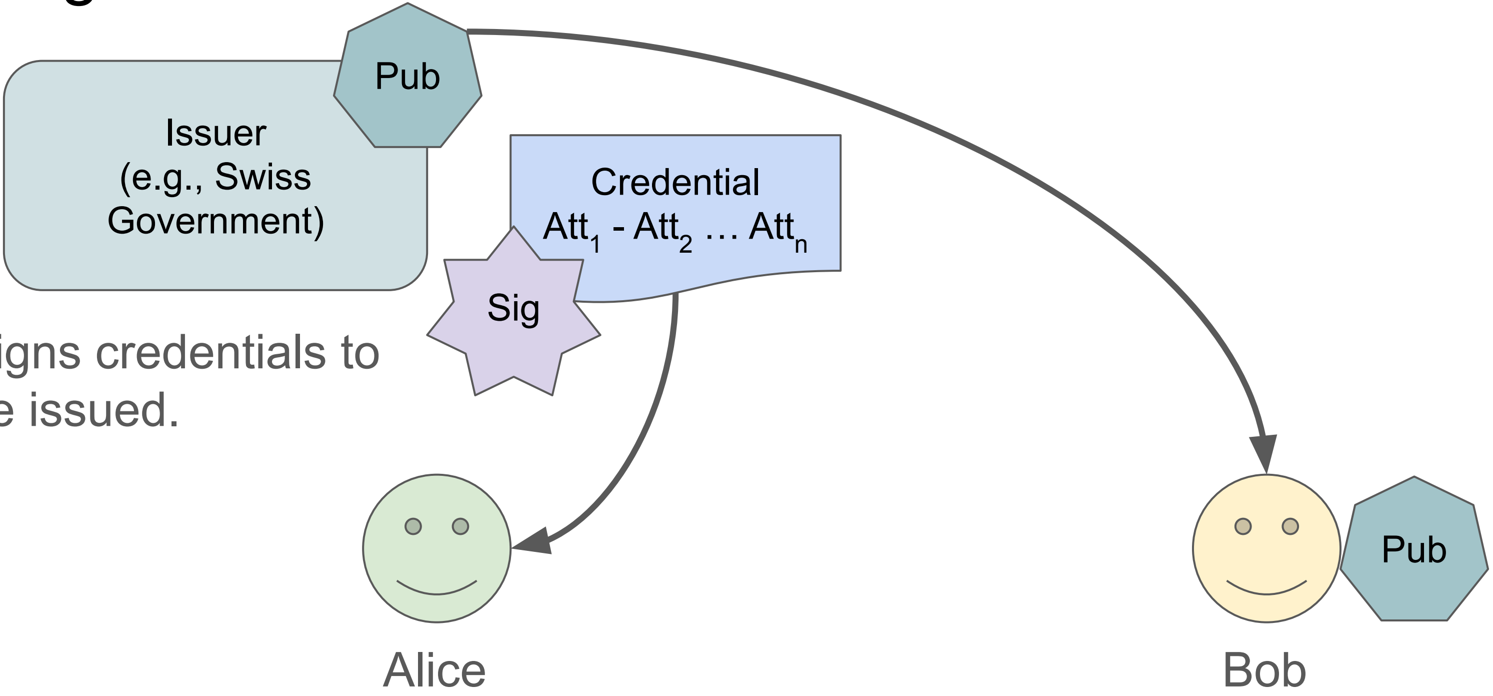
Attribute Sharing



Attribute Sharing - 1st Problem

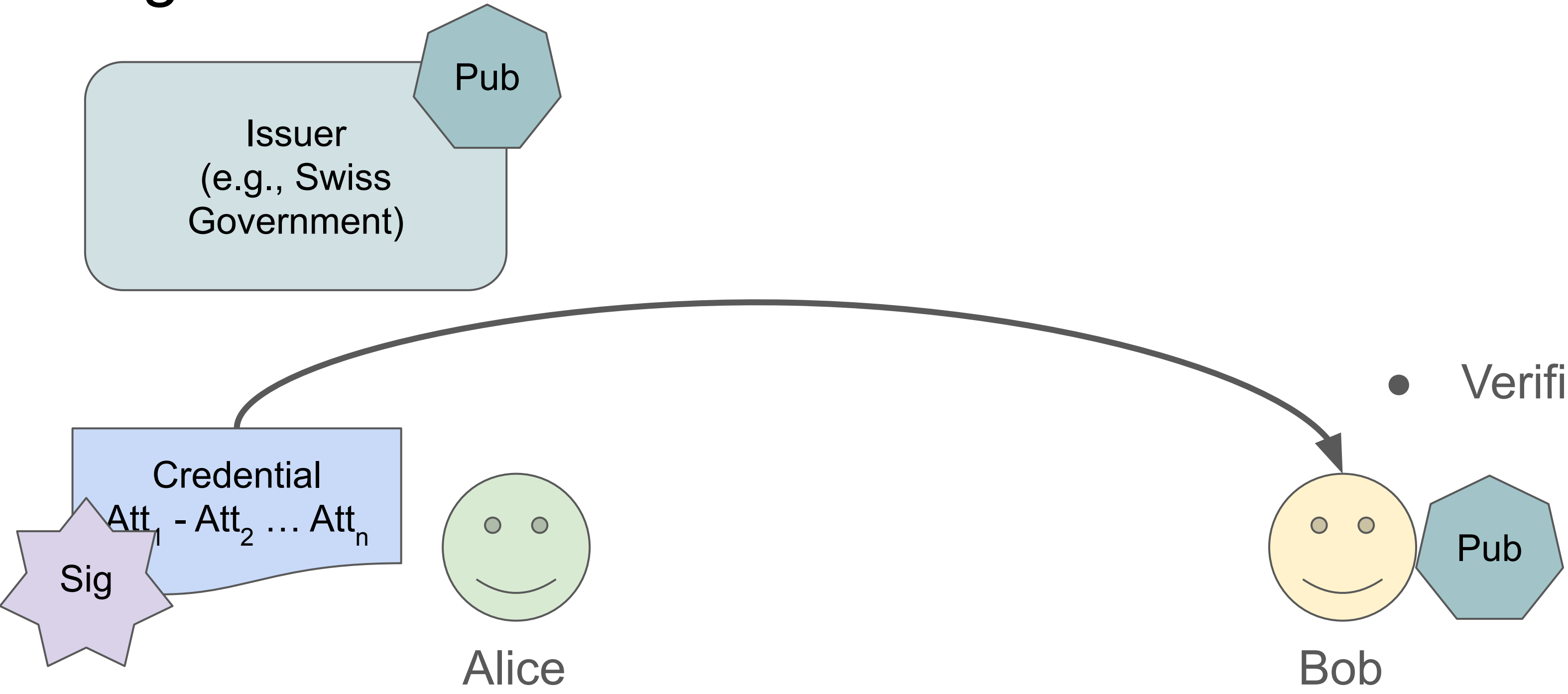
Are the attributes correct?

Signature from Issuer



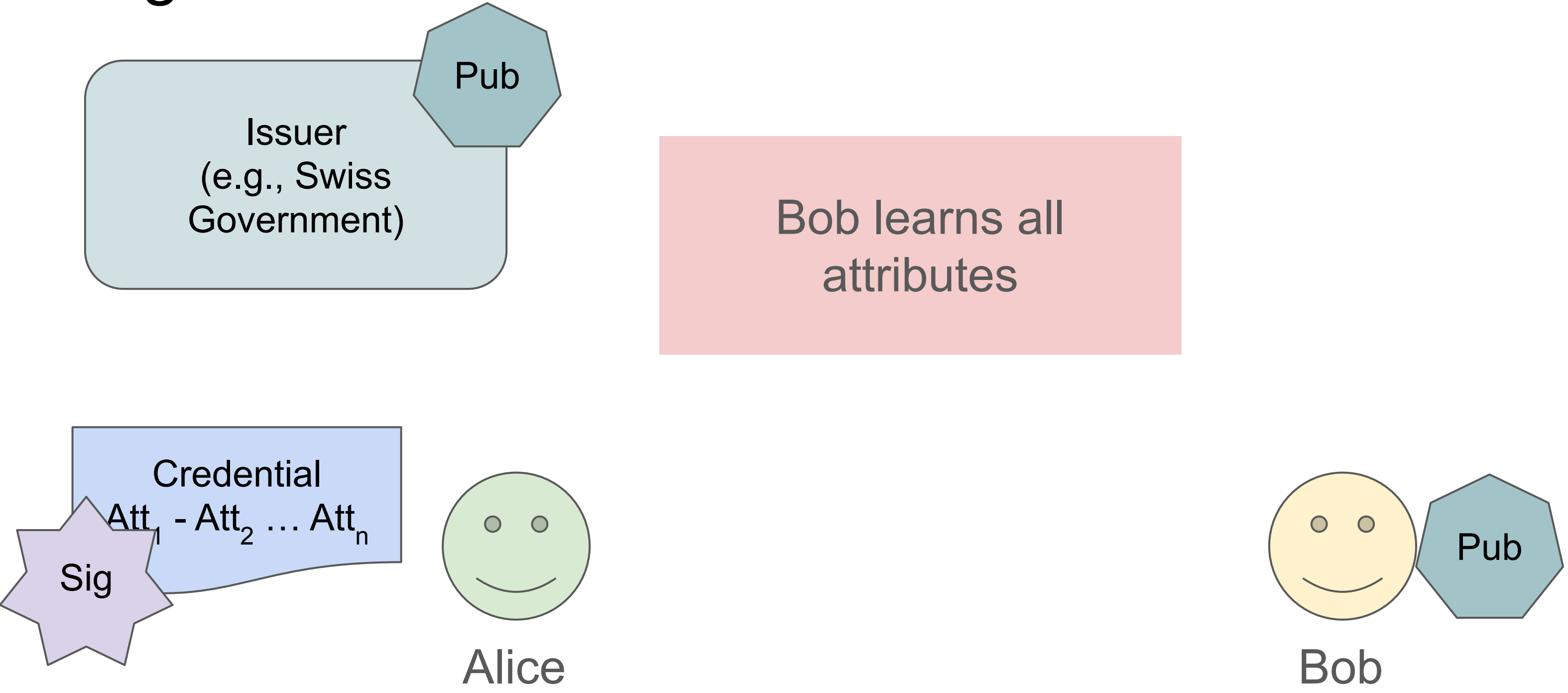
Signs credentials to be issued.

Signature from Issuer

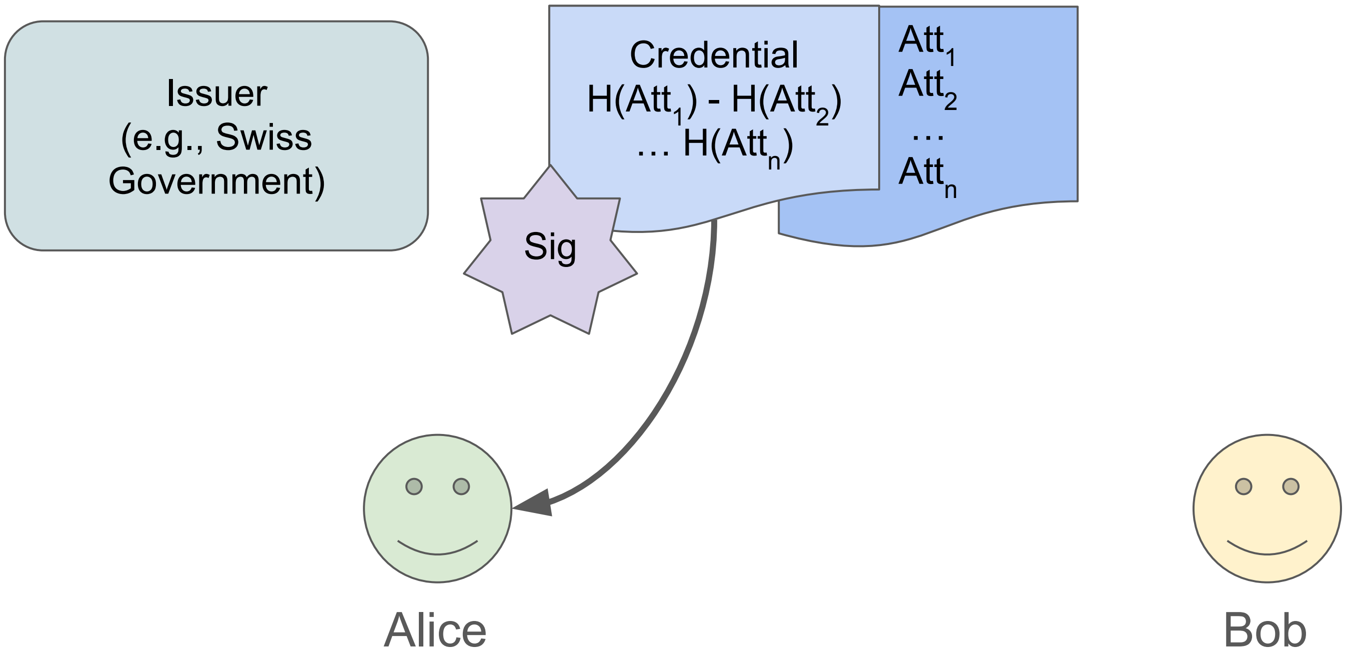


- Verifies signature

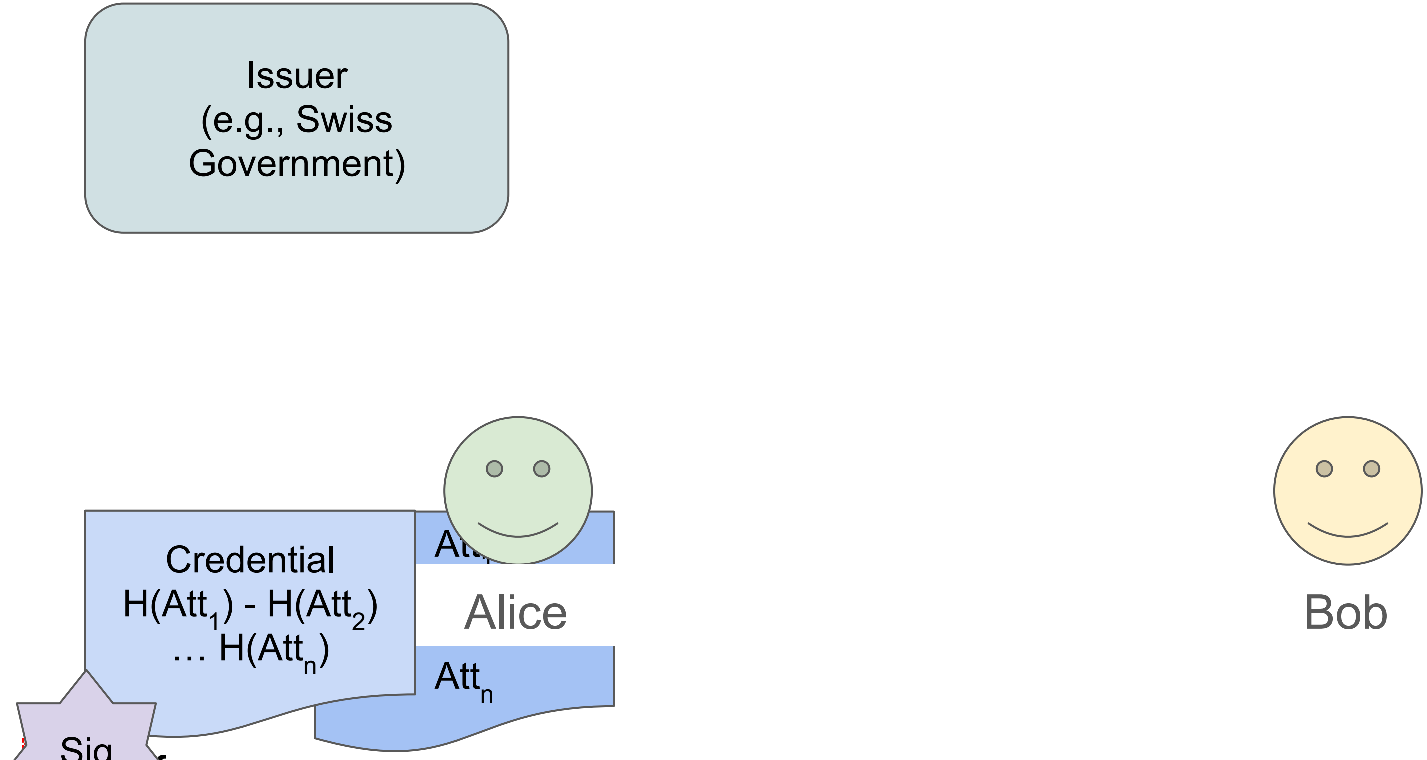
Signature from Issuer - 2nd Problem



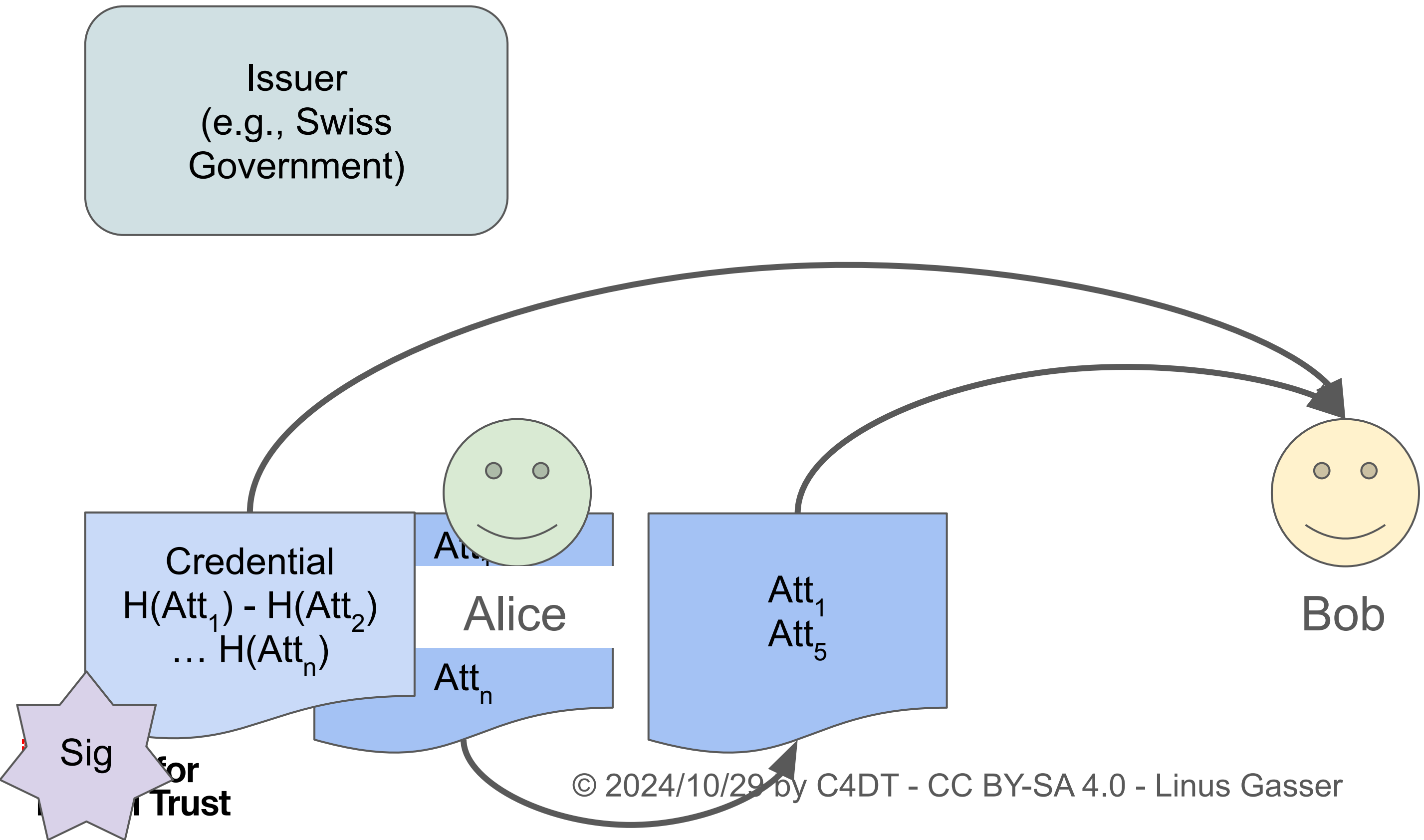
Selective Disclosure



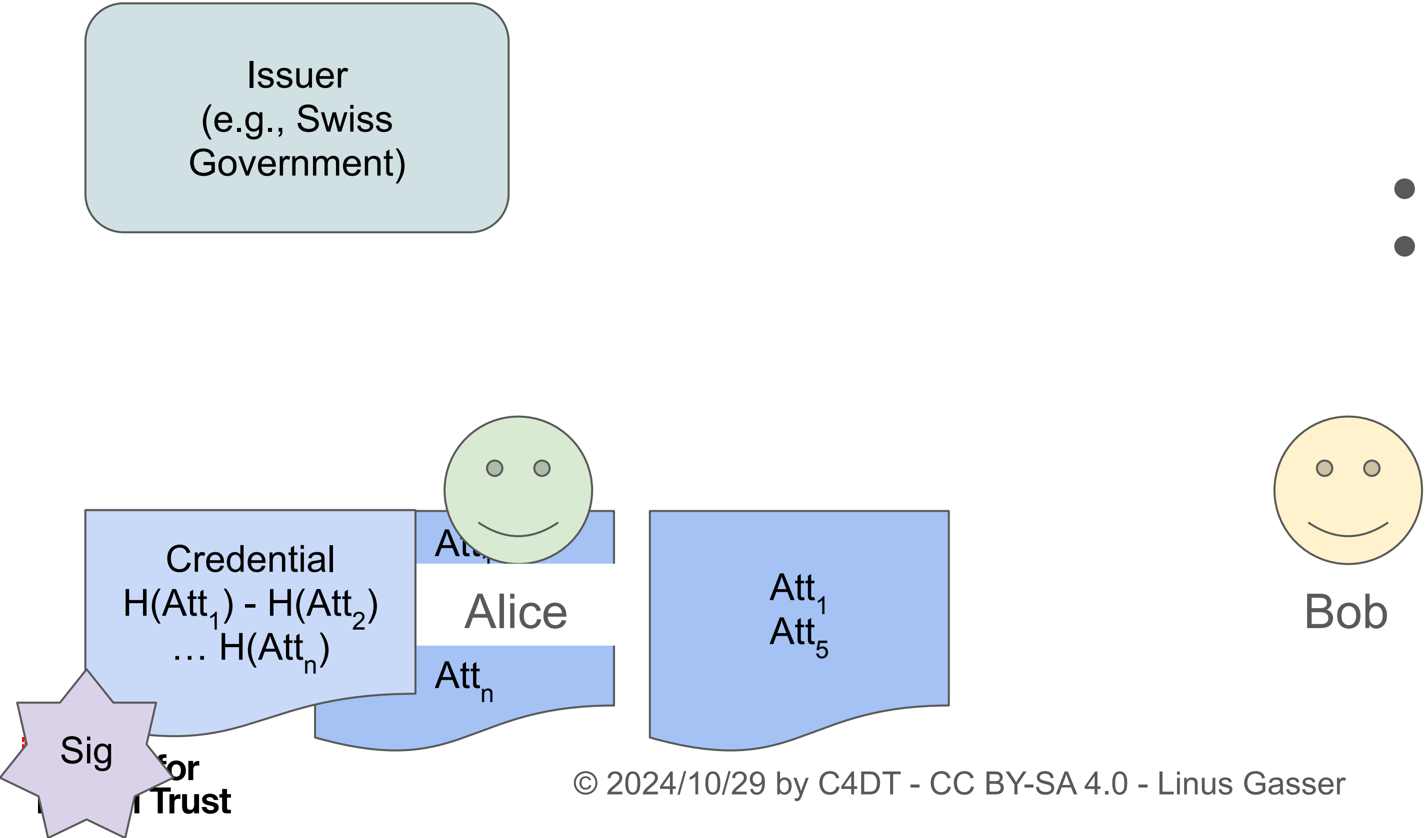
Selective Disclosure



Selective Disclosure

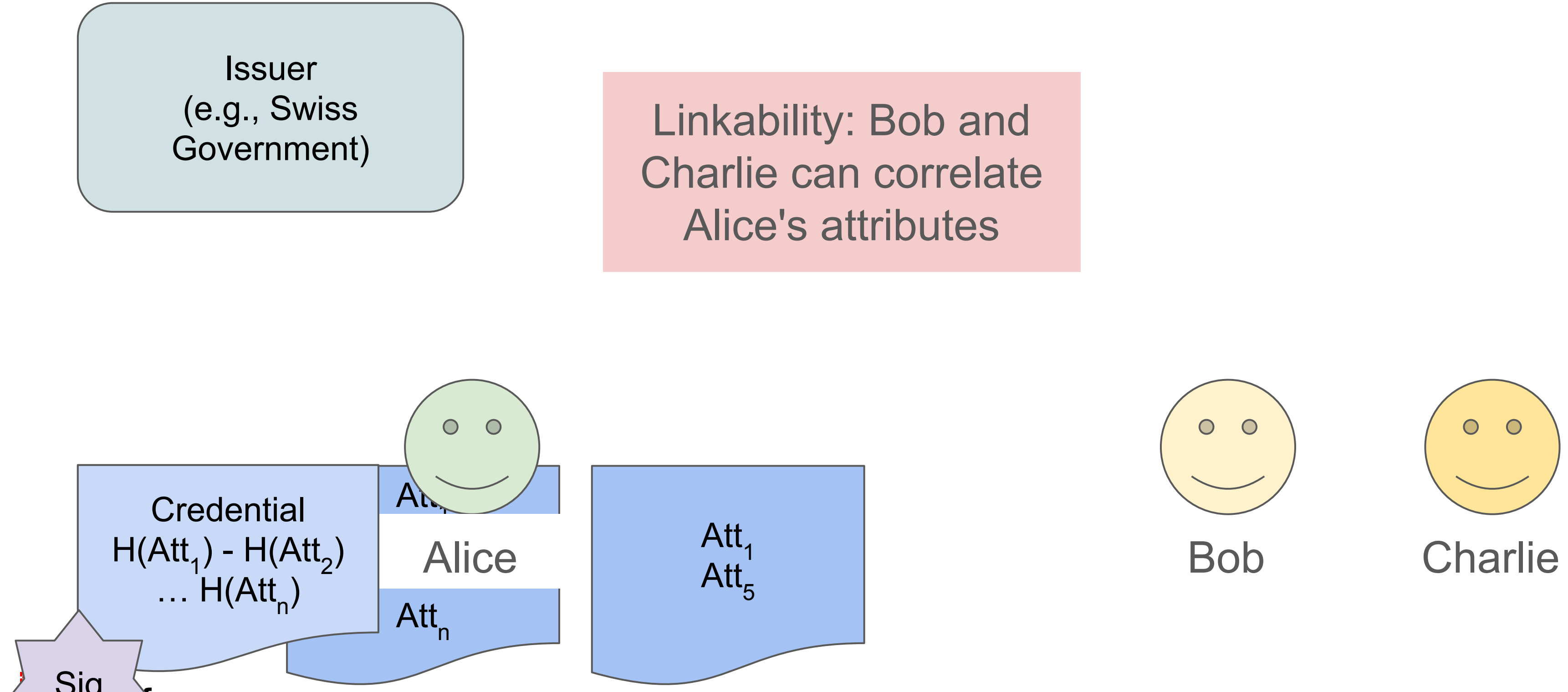


Selective Disclosure



- Verifies signature
- Learns only disclosed attributes 1 and 5

Selective Disclosure - 3rd Problem



Exercise 1 - Signing Simply with RSA

Wrap-up slide

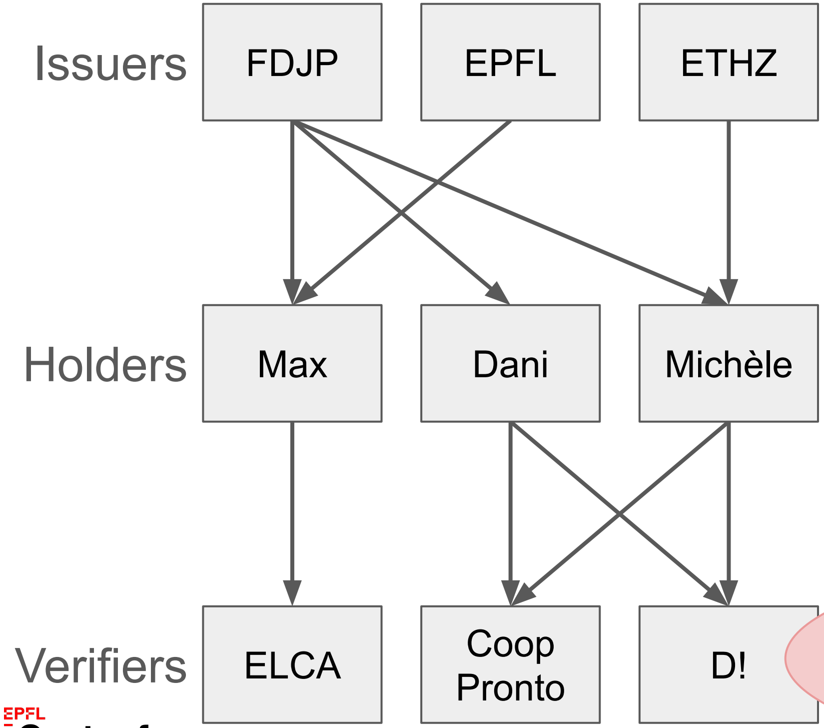
- The issuer allows the verifier to trust the data from the holder
- Selective disclosure can hide personal data to the verifier
- For low-entropy data, even cryptographic hashes do not provide anonymity
- LD-JSON Verified Credentials from EU Digital Wallet are linkable

2 - Unlinkable proofs using BBS+

Why Unlinkability?

- No correlation between visits
- Reduces attack surface if data leaks
- Privacy / Profiling
  - less knowledge about visitors -> less influence
  - no following of holders -> physical security (e.g., stalkers)

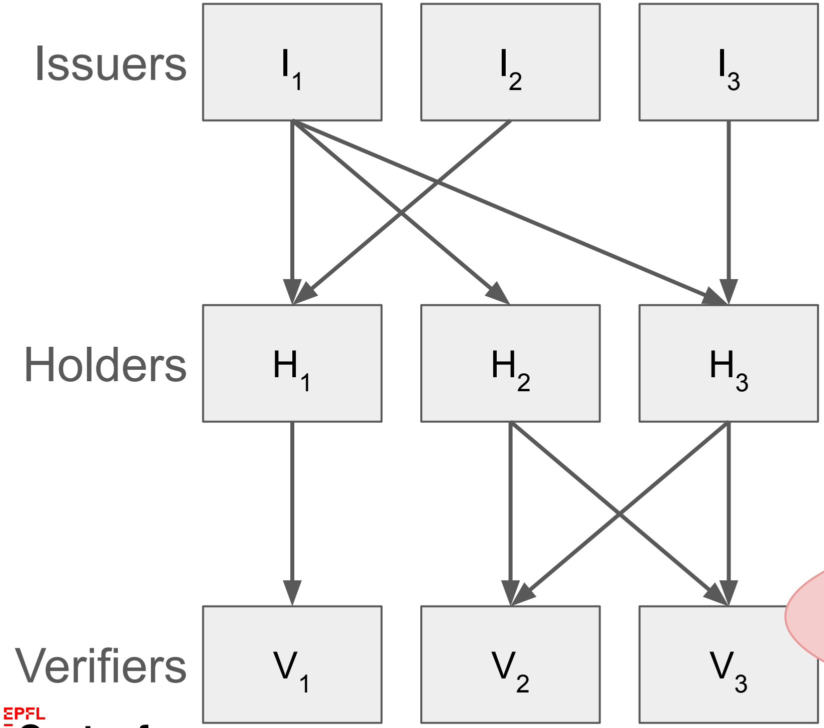
Unlinkability Vows (in addition to anonymity)



1. **Validity check** by Coop and D! on Dani unlinkable by the FDJP
   -> movement tracking
2. **Validity check** by D! on Dani and Michèle unlinkable by the FDJP
   -> counting of usage by a verifier
3. **Has CH Master Degree** check by ELCA unlinkable to EPFL or ETHZ
   -> discrimination against a school
4. **Age** check by Coop and D! on Dani unlinkable by Coop and D!
   -> user profiling

EPFL

Unlinkability Vows (in addition to anonymity)



1. **I** has **Val(V_x(H_1))** and **Val(V_y(H_2))**
   movement tracking: **H_1 =? H_2 ∀ x,y ∈ 1..3**
2. **I** has **Val(V_1(H_x))** and **Val(V_2(H_y))**
   verifier usage counting: **V_1 =? V_2 ∀ x,y ∈ 1..3**
3. **V** has **Attr(H_x(I_a))**
   school discrimination: **a =? 2,3 ∀ x ∈ 1..3**
4. **V_x** has **Attr(H_1)**; **V_y** has **Attr(H_2)**
   user profiling: **H_1 =? H_2 ∀ x,y ∈ 1..3**

How to Make it Unlinkable

1. and 2. - validity or revocation check

- Cryptographic accumulators - slow and potentially huge

3. Issuer hiding

- Create "meta issuer" - issuer of issuers

4. User profiling

- BBS+ signatures

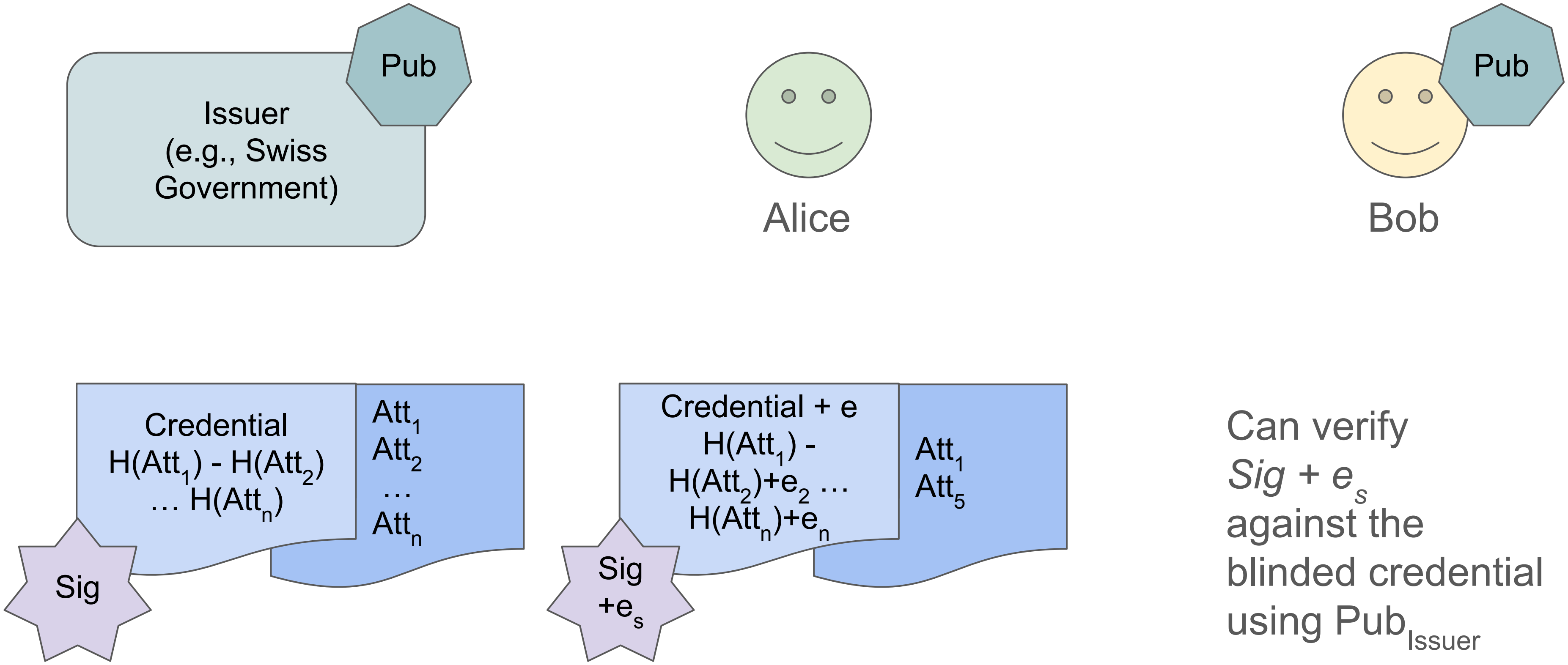
Avoid User Profiling with BBS+

If $\mathbf{V_x}$ has $\mathbf{Attr(H_1)}$; $\mathbf{V_y}$ has $\mathbf{Attr(H_2)}$, it's difficult to verify if $\mathbf{H_1 =? H_2}$, $\boldsymbol{\forall}$ **x,y** $\boldsymbol{\in}$ **1..3**

- Issuer signature needs to be blinded (valid but different each time)
- Hashes of the non-disclosed fields need to be blinded
- BBS(+) to the rescue
  - Zero-knowledge proof:
    Here is a proof that I know a signature of the following hash(es)
  - BBS: original paper, security proof only later
  - BBS+: added a random factor to create a security proof
  - BBS#: extension proposed by Orange to do holder binding
  - Short BBS: not using pairing-based cryptography

Blinding disclosed fields -> Predicate Zero Knowledge Proofs, not in BBS+!

BBS+ in One Slide



Can verify
Sig + *e$_s$*
against the
blinded credential
using Pub$_{Issuer}$

Exercise 2 - Unlinkable proofs using BBS+

What we Learnt

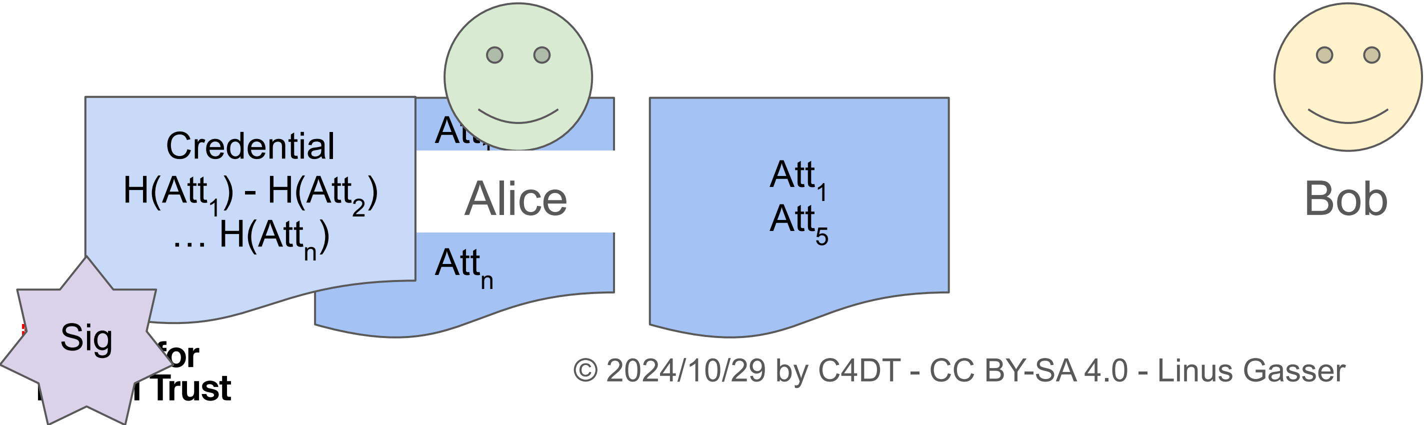
- BBS+ creates unlinkable proofs
- It can selectively disclose fields chosen by the holder
- Hover, the disclosed fields might still be used to link proofs

Selective Disclosure - 4th Problem

Issuer
(e.g., Swiss
Government)

Too Much Information:
Bob learns more than
necessary.

- Verifies signature
- Learns only disclosed attributes 1 and 5



Unlinkability - and Now?

Disclosed values are fully visible, for example

- Birthdate (when you only want to prove you're > 65)
- Salary (instead of proving you earn less than 30k)
- Address (reduction for a ticket bc you live in VD)

This is not desirable because of:

- Privacy: you don't want to give away that data
- De-anonymization: when combining fields, you can get a very small anonymity set (male, 1.1.1978, 1015)

3 - Predicate Proofs with ZKPs

Zero Knowledge Proofs 101

Setup	All agree on the statement **x** which should be fulfilled	Common reference string (**CRS**)		
Prover			Creates proof **p** for private data **w** fulfilling **x**	
Verifier				Can verify that **p** fulfills **x** w/o knowing **w**

An Example of a Statement

Wanting to buy a ticket with a reduction for retired people:

Proving the issuer signed a verified credential which includes an age >= 65:

- All agree on the condition **x**:
  - I know a signature $\mathbf{Sig_{issuer}+e_{sig}}$ to a hash $\mathbf{H_A+e_A}$ verifiable by $\mathbf{Pub_{issuer}}$ AND
  - I know a number $\mathbf{N_A}$ which hashes to $\mathbf{H_A+e_A}$ AND
  - $\mathbf{N_A}$ is above or equal to 65
- The holder creates a proof **p** for **x** using their **w**
- The verifier can check **p** fulfills **x**, knowing only $\mathbf{Pub_{issuer}}$

Biggest Zero Knowledge Proof Families in 2024

Name	Foundation	Setup	Proof creation	Verification
SNARK	Bilinear pairings, elliptic curves PQ: No	Yes Time: long	Size: constant Time: fast (w/o setup)	Time: fast
STARK	Hash functions PQ: Yes	No	Size: large Time: slow	Time: fast
Bulletproofs	Elliptic curves PQ: No	No	Size: medium Time: slow	Time: medium

2024/10 - depends also on complexity of statement **x**

Some Zero Knowledge Terms

- **Completeness**: If the statement is true, an honest prover will be able to convince an honest verifier of this fact.
- **Soundness**: If the statement is false, no dishonest prover can convince an honest verifier that it is true, except with a very small probability.
- **Zero-Knowledge**: If the statement is true, the verifier learns nothing other than the fact that the statement is true.
- **Interactive**: the verifier interacts over many rounds with the prover, until they are convinced of the statement. Sigma protocols are interactive ZKPs.
- **Succinctness**: the proof size should be small, and the verification time should be fast

Exercise 3 - Predicate proofs with ZKPs

Wrap-up slide

The good:

- Zero Knowledge Proofs allow to minimize the data leakage from the credentials
- The docknetwork/crypto library has a very powerful mechanism to set up a ZKP statement

The bad:

- There are no standards yet - it is very new
- Some statements are still very complicated to express

4 - ZKP Considerations

Difference Between ZKP Systems

- Setup: either with (zkSNARK) or without (zkSTARK, Bulletproofs)
  - with: smaller and faster proofs and verifications, but need to trust the setup
  - without: no trust needed
  - as seen in the exercises, fast advancing research turns the tables
- Statement complexity
- Setup: time and size ms to seconds; 1-100kB
- Proof creation: time and size - ms to minutes; 100B to xMB
- Verification: time - ms to seconds

(Lego)Groth16 <-> Bulletproofs++

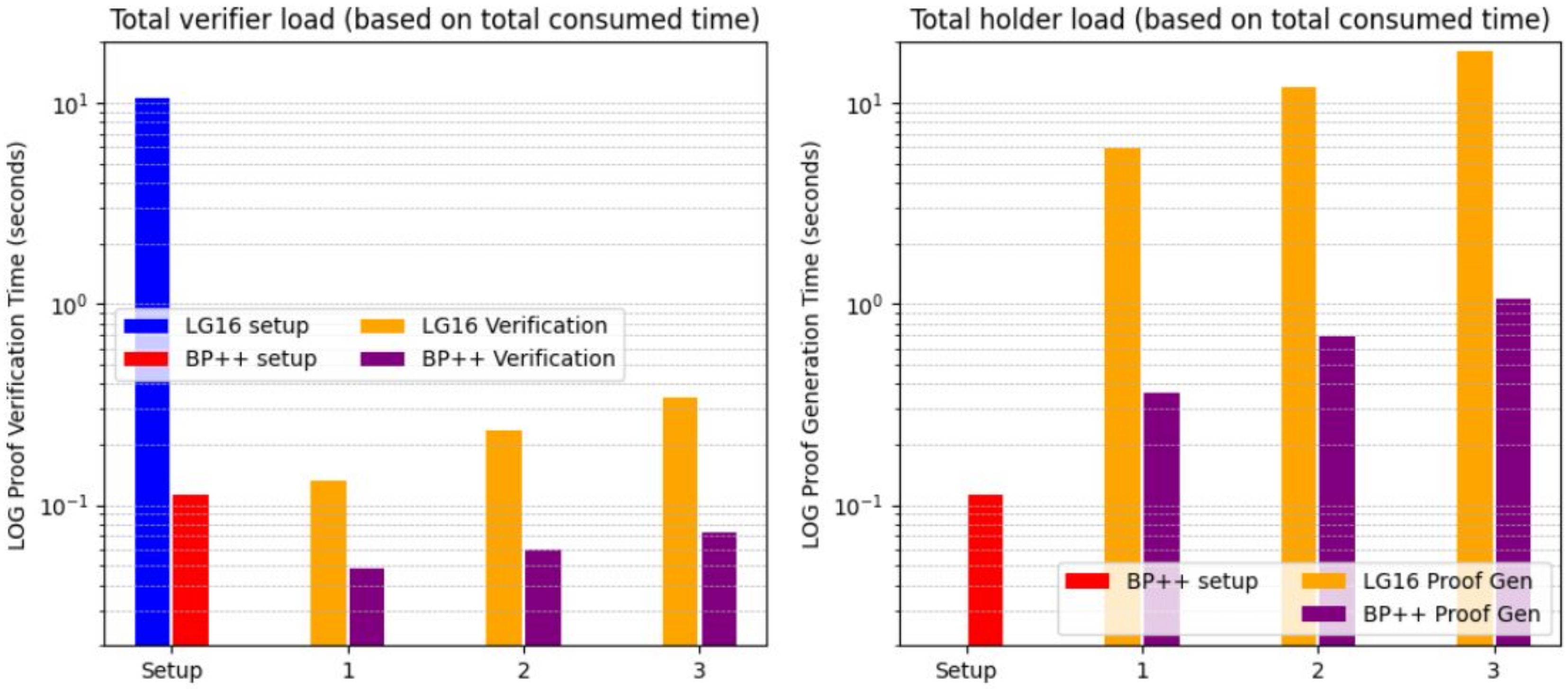
- Groth16 is an "old" algorithm which is well understood
- Bulletproofs(++) is more advanced, and looks like it could replace Lego16
- LegoGroth16 is an example of combining various ZKP algorithms
- The docknetwork/crypto library adds yet another layer

Comparison in exercise:

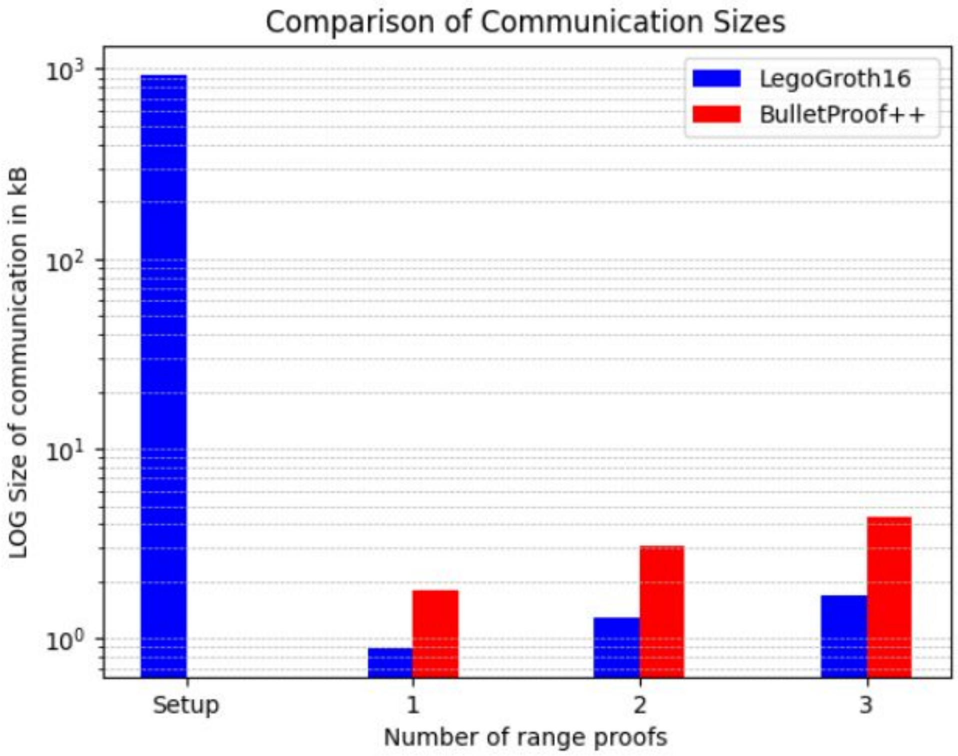
- Computation cost:
  - Server: setup and verify
  - Client: setup and create proof
- Communication cost:
  - Server -> client: setup material
  - Client -> server: proof

Exercise 4 - ZKP Considerations

Setup and Proof Generation - Logarithmic y-scale!



Communication Sizes



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Interpretation

This is very specific to the *docknetwork/crypto* library:

- Special setup to create composed proofs
- Not optimized for 'simple' range proofs

Generally:

- The setup for the LegoGroth16 can be re-used by the verifier
- The setup for Bulletproofs++ must be done every time
- The communication size for LegoGroth16 is very high

Conclusions

Setting up a Trustworthy E-ID

- What is important?
  - Convince Swiss citizens that E-ID is trustworthy
  - Use Cases for the E-ID
- Questions for the Swiss E-ID
  - ZKP for ECDSA signatures for holder binding
  - Which basic signatures scheme to use
- Standardizations
  - BBS+ has an IETF draft
  - Nothing yet for ZKPs