Commit-and-Prove Zero-Knowledge Proof Systems and Extensions

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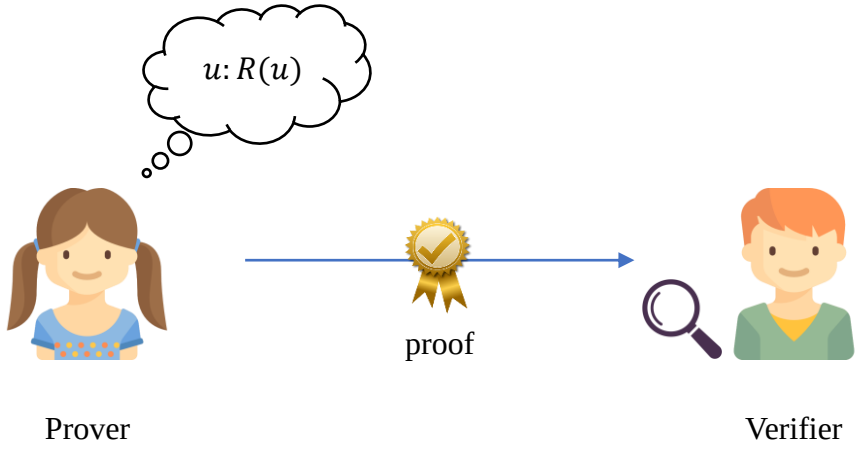
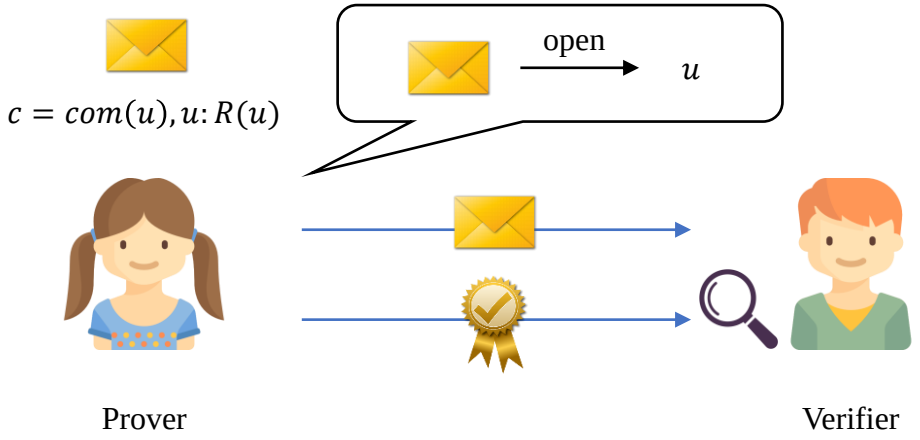
4th ZKProof Workshop

Commit-and-Prove (CP)





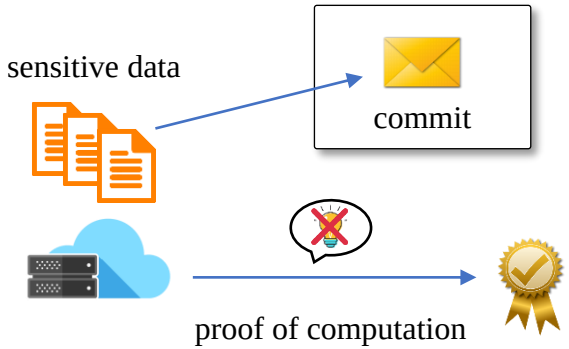
Zero-Knowledge:

"Trusting properties claimed by someone else on data that you have not seen"

Commit-and-Prove Zero-Knowledge:

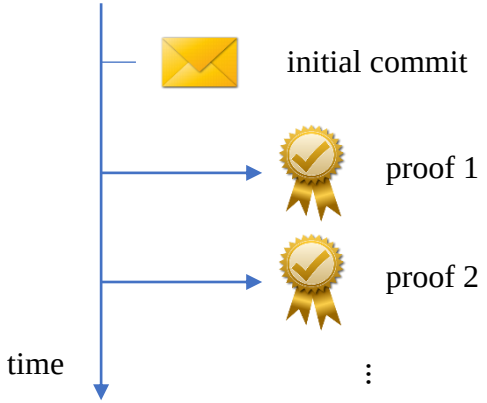
"Trusting properties claimed by someone else on data that you have not seen, **but that can be pointed to**"

Usability



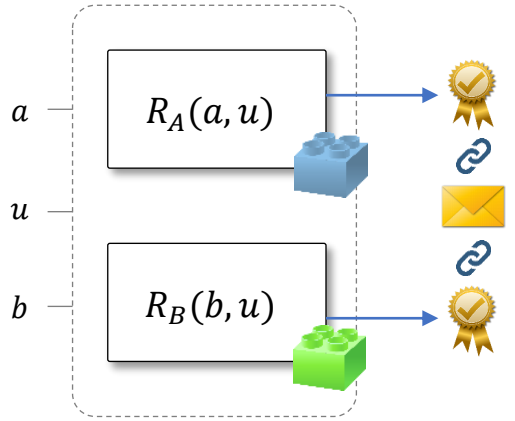
Compressing/Fingerprinting

- Delegate storage and computation
- Verifier keeps the fingerprint
- Prove data-related computation



Commit ahead of time

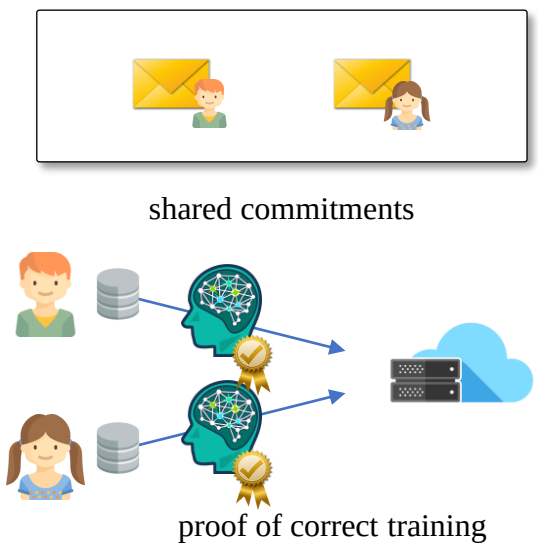
- Commit first, and prove later
- First commit enables multiple arguments
- Useful for stabile data



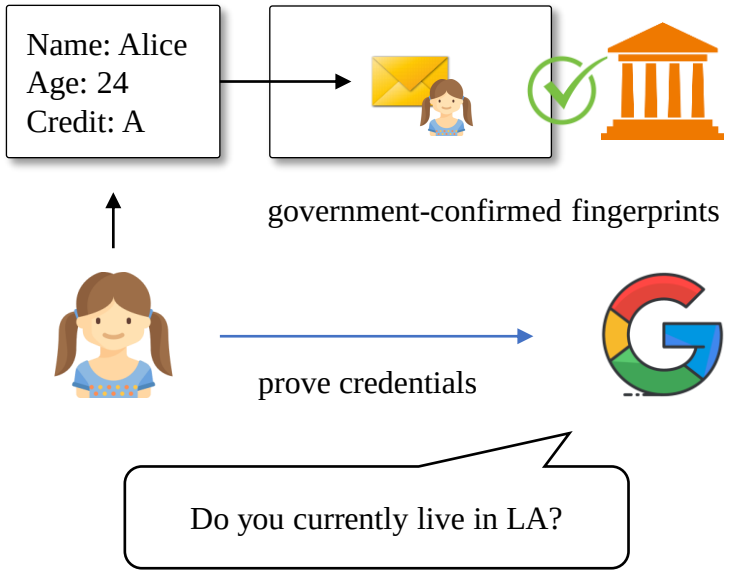
Modular composition

- Modular composition of proofs
- Use different proof systems and connect
- More flexible and efficient structure

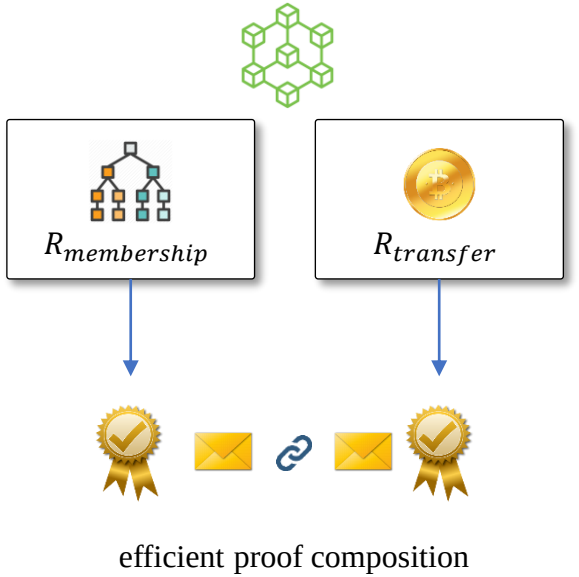
Applications



Federated Learning

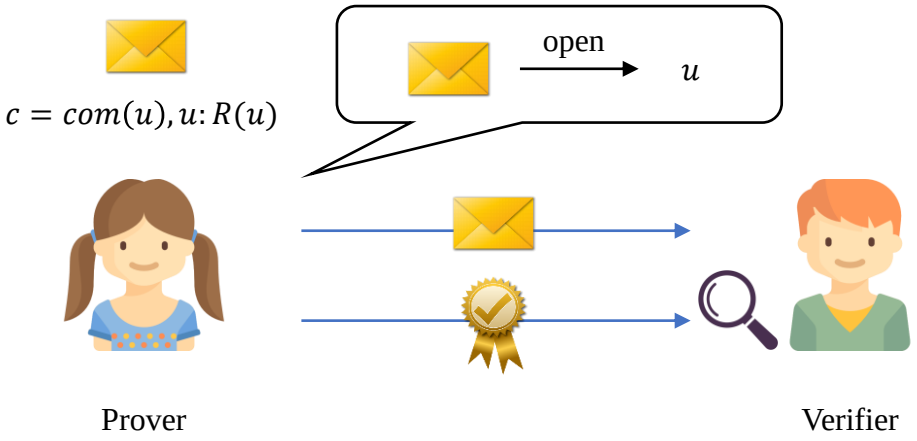


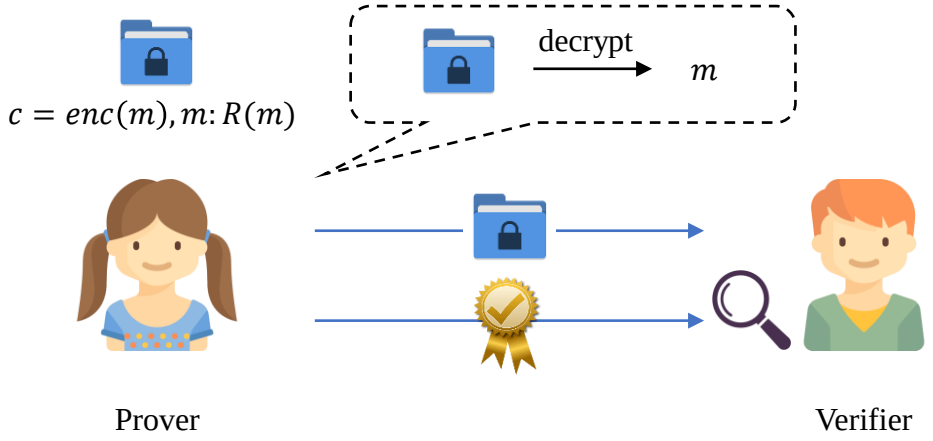
Self Sovereign Identity
(Anonymous credentials)



Blockchains

Extension: Encrypt-and-Prove (EP)





Commit-and-Prove Zero-Knowledge:

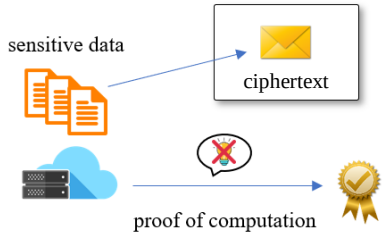
"Trusting properties claimed by someone else on data that you have not seen, **but that can be pointed to**"

Encrypt-and-Prove Zero-Knowledge:

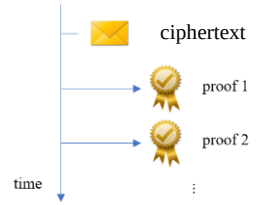
"Trusting properties claimed by someone else on message that you have not seen, **but that can be pointed to a ciphertext**"

Usability

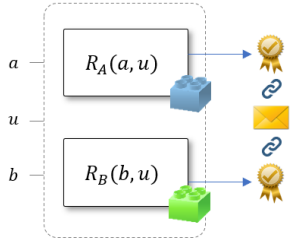
Same as commit-and-prove...



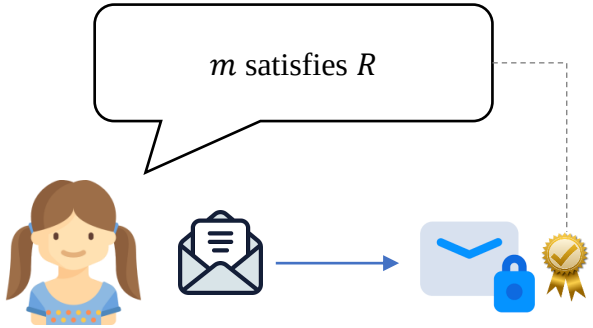
Compressing/Fingerprinting



Commit ahead of time

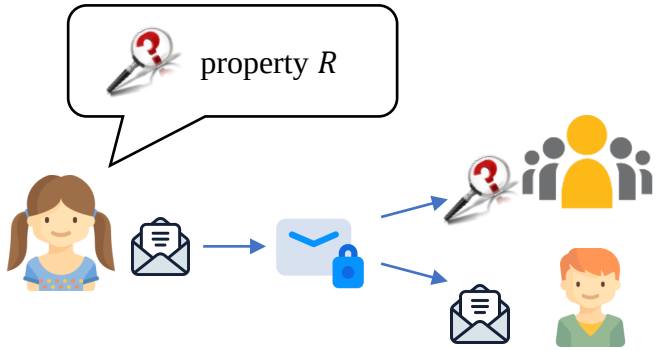


Modular composition



Verifiable encryption

- Proof guarantees the encryption itself
- Encrypt msg while proving its properties



Privacy differentiation

- Encryption reveals different information
- The decryptor gets the whole message
- The public only sees the property holds

Applications

E-commerce

raw product transaction

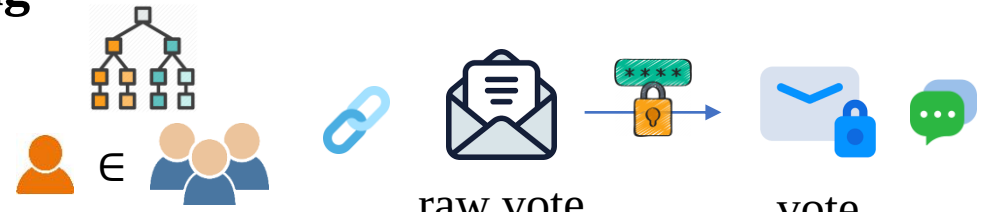
the product satisfies “certain properties”
ex: metadata, copyrights...

Digital contract

raw contract contract

the contract satisfies “certain properties”
ex: contract type, date, deposit...

Voting

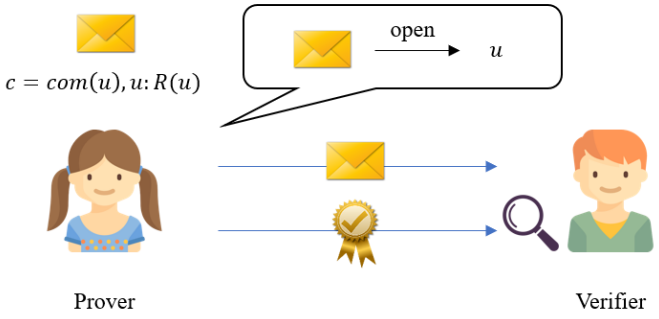


membership test raw vote vote

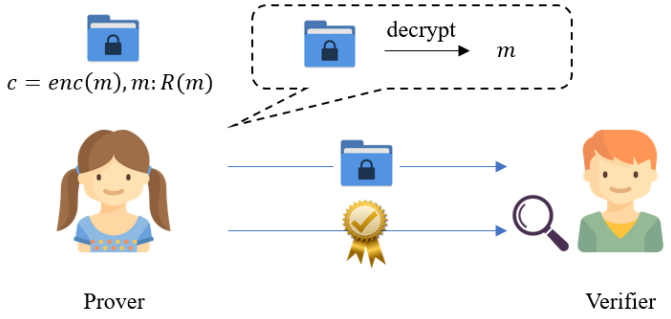
the voter (linked to m) is “within the membership”
the vote is “valid (ex: vote sum is integer 1)”

Construction

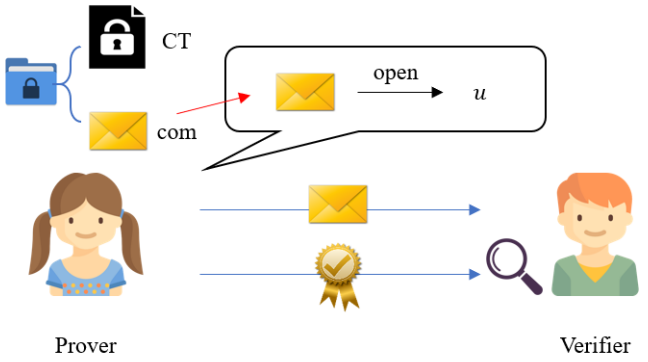
- Exploit cc-SNARK: lifting ElGamal to work with the SNARK
  - If an encryption can output or contain a commitment (commit-carrying encryption), it can be plugged into the CP as a commitment input
  - ex: SAVER; CT in SAVER contains Pedersen commitment of the message for knowledge soundness



Commit-and-Prove

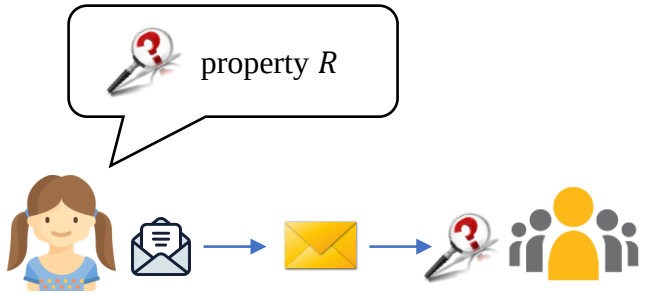


Encrypt-and-Prove



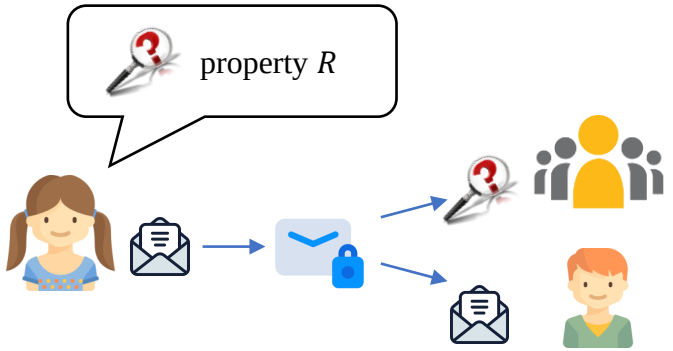
Commit-carrying encryption

Use case: what's different?



Commit-and-Prove

- Commitment (binding, hiding)
- Commitment reacts to the verifier (public)
- For applications where fingerprinting/modularity is enough



Encrypt-and-Prove

- PK Encryption (hiding, no binding in definition)
- Ciphertext reacts to the verifier (public) and the decryptor
- For applications where privacy differentiation is required

Standardization Status

- General commit/encrypt-and-prove syntax
  - both separated and combined version
  - i.e., CP-SNARK, EP-SNARK, CP/EP-SNARK

- Reference document available at
  - https://docs.zkproof.org/pages/standards/accepted-workshop4/proposal-commit.pdf

- Working group available at
  - https://community.zkproof.org/g/WG_COMMIT_PROVE

Next step

- Agree on specific constructions

- Commit-and-prove: ready to proceed
  - commitment scheme
  - commit-and-prove (CP) scheme

- Encrypt-and-prove: gather ideas
  - encryption scheme
  - encrypt-and-prove (EP) scheme

Commitment candidates

- Pedersen commitment
  - Different types of distributions (e.g. uniform, Lagrange polynomials)
  - Possibly required to define preliminaries (e.g. groups, properties)

- SNARK-friendly commitments
  - Ad-hoc scheme-specific commitments (e.g. Pedersen on ZCash JubJub)

- Non-algebraic commitments
  - Collision-resistant hash (e.g. SHA256)
  - Merkle trees and some vector commitments in general

CP candidates

- Sigma protocols
  - Need to agree on syntax (e.g. interaction, random coins, forking lemma)
  - Common reference string vs. Rewinding definition of hiding
- Groth-Sahai
- Groth16 with SNARK-friendly hash/commitments
- LegoGroth16

Encryption candidates

- ElGamal encryption
  - Exponential version ($g^m \cdot h^r$)
  - This may require bunch of definitions on preliminaries

- SAVER [LCKO19]
  - Based on ElGamal, SNARK-linkable encryption (avoid encoding)
  - May want to trim some unnecessary features (e.g. rerandomization)

- SNARK-friendly encryption
  - Algebraic ElGamal
  - RSA from c0c0 (libsnark)

EP candidates

- Basically, similar to the CP candidates
  - Sigma protocols
  - Groth-Sahai
  - Groth16 with SNARK-friendly encryption

- SAVER + LegoGroth16
  - A “working” construction in current status
  - Plugging in the SAVER scheme as a cc-SNARK

Discussion: candidates

Commitment

- Pedersen commitment
  - Different types of distributions (e.g. uniform, Lagrange polynomials)
  - Possibly required to define preliminaries (e.g. groups, properties)
- SNARK-friendly commitments
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Commit-and-prove

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Discussion 1: what are the top two items we want to standardize in the next year from the candidates?

Discussion: applications

- There are some “popular” applications
  - Voting
  - Anonymous credentials

- Providing an official “recipe” for them may help practitioners

Discussion 2: does it make sense to create “recipes” to build/explain usual applications, such as voting or anonymous credentials?

Discussion: encryption

- ElGamal encryption
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- SNARK-friendly encryption
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- Commit-carrying encryption is one way to achieve encrypt-and-prove

Discussion 3: what could be the candidate for the construction of “encryption”? And do we want to standardize “commit-carrying encryption”?

Discussion: extension

- There exists encryption with more functionalities
  - ex: Identity-Based Encryption (IBE), Attribute-Based Encryption (ABE)
- In most applications, practitioners may need more than just an encryption
- It might be helpful to provide more diverse notion of EP for them

Discussion 4: should we extend the notion of EP further, i.e., look at finer-grained notions of encryption (ex: ABE-and-prove)?

Discussion: X-and-prove

- Commitment extended to encryption (CP to EP)
- Similar to above, we may also extend CP to different context
  - Accumulate-and-Prove: for efficient proving of accumulation
  - Sign-and-Prove: for efficient proving of signature verification

Discussion 5: what extensions can we consider for the standard in the future? For example, Sign-and-Prove?

Topics

Candidates: what are the top two items we want to standardize in the next year from the candidates?

Applications: does it make sense to create “recipes” to build/explain usual applications, such as voting or anonymous credentials?

Encryption: what could be the candidate for the construction of “encryption”? And do we want to standardize “commit-carrying encryption”?

Extension: should we extend the notion of EP further, i.e., look at finer-grained notions of encryption (ex: ABE-and-prove)?

X-and-Prove: what extensions can we consider for the standard in the future? For example, Sign-and-Prove?