Using Zero-Knowledge Proofs to Fight Disinformation

Trisha Datta and Dan Boneh

Stanford University

Ukraine conflict: Many misleading images have been shared online

By Alistair Coleman & Shayan Sardarizadeh
BBC Monitoring

24 February 2022

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By Alistair Cole
BBC Monitorin

24 February 202

Fact-checking videos and pictures from Ukraine

Since Russia's attacks on Ukraine began, we have seen several videos and pictures go viral that are actually fake posts.

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THE NEWS / UKRAINE

BBC Breakfast uses old footage of Russian parade rehearsal to show invasion of Ukraine

C2PA: A Content Provenance Standard

Sony Unlocks In-Camera Forgery-Proof Technology

04 Aug, 2022

embedded certified signing key sk_1

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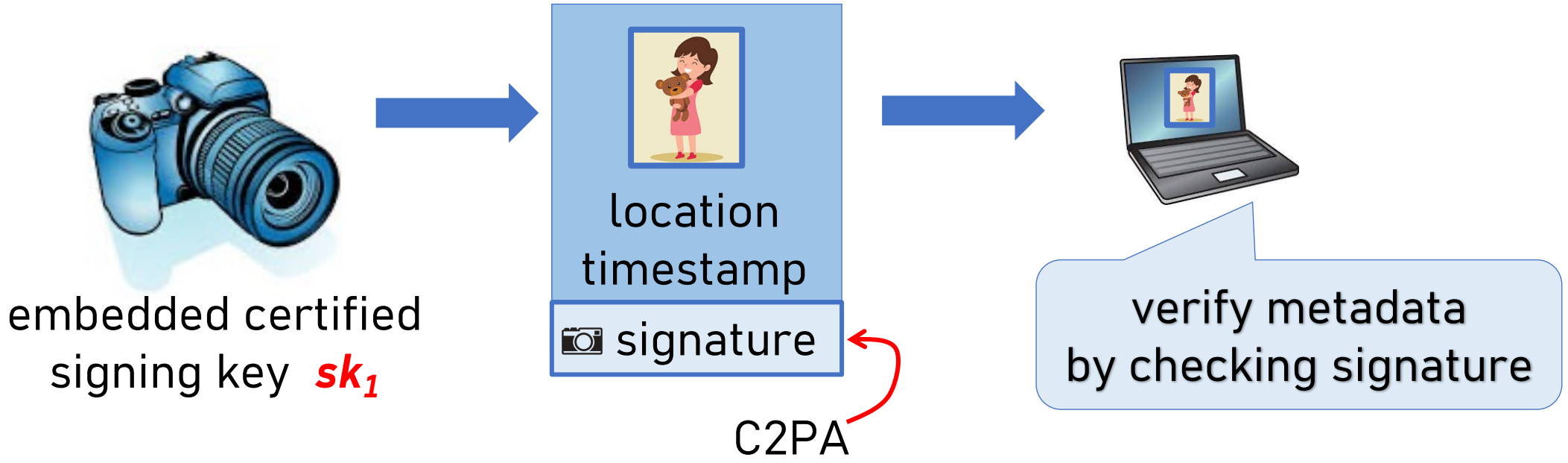

Adobe arm BBC intel Microsoft SONY Truepic

C2PA: A Content Provenance Standard

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See Rivadeneira, "Harms Modelling in the C2PA," 2022 for security analysis of C2PA

embedded certified signing key sk_1

verify metadata by checking signature

Adobe arm BBC intel Microsoft SONY Truepic

A Problem: Post-Processing

- Newspapers often process photos before publication
  - At minimum, need to resize (90 MB → 8 MB)
  - Allowable operations from the *Associated Press:*

    cropping, grayscale, …

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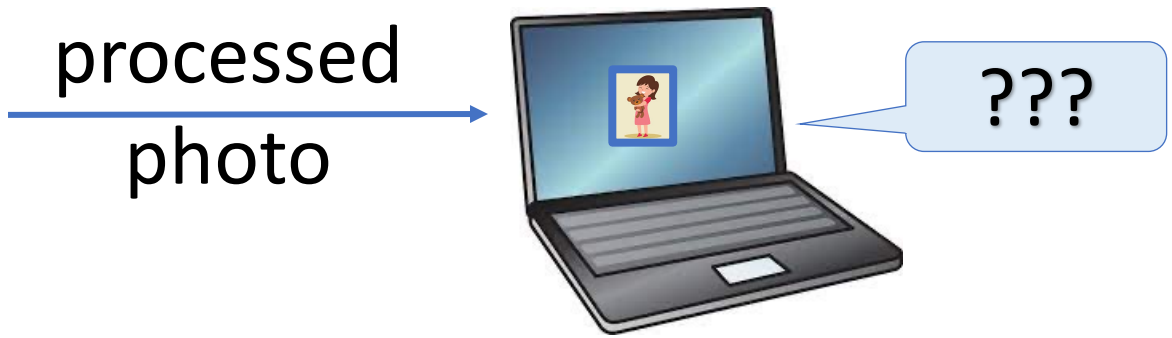

Proposed Solution: ZK-SNARKs!

- ZK-SNARK: efficiently verifiable statement about a secret witness

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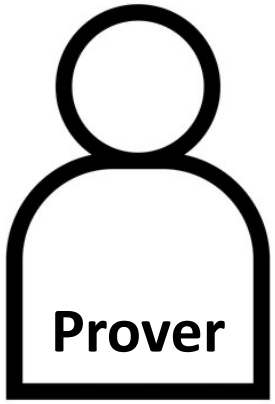

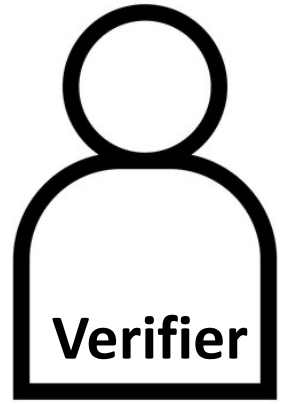

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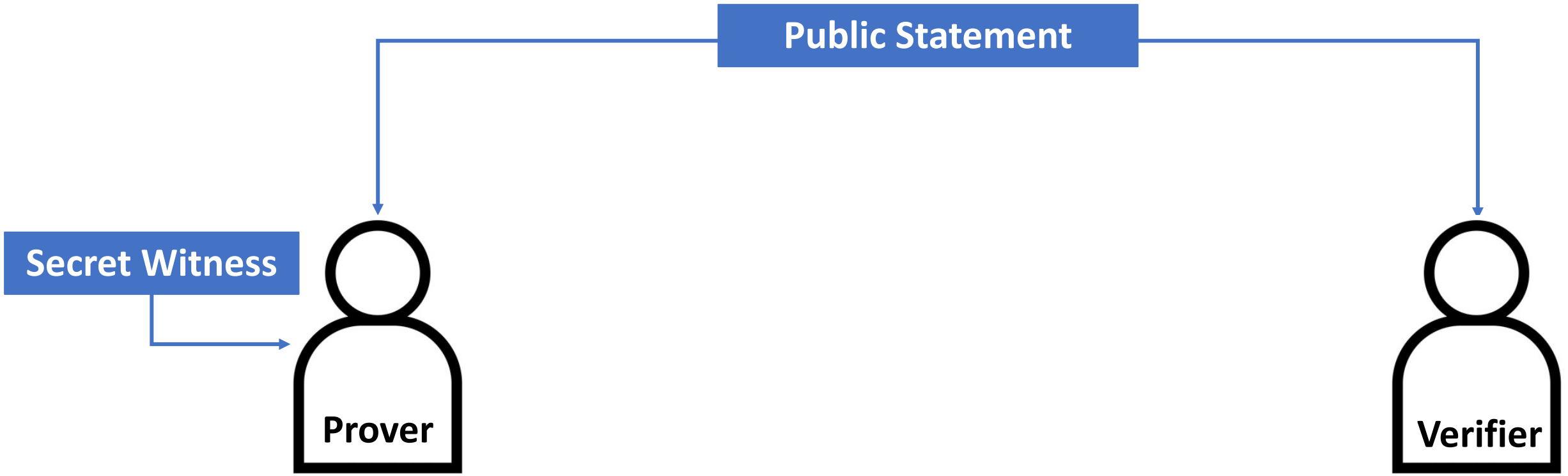

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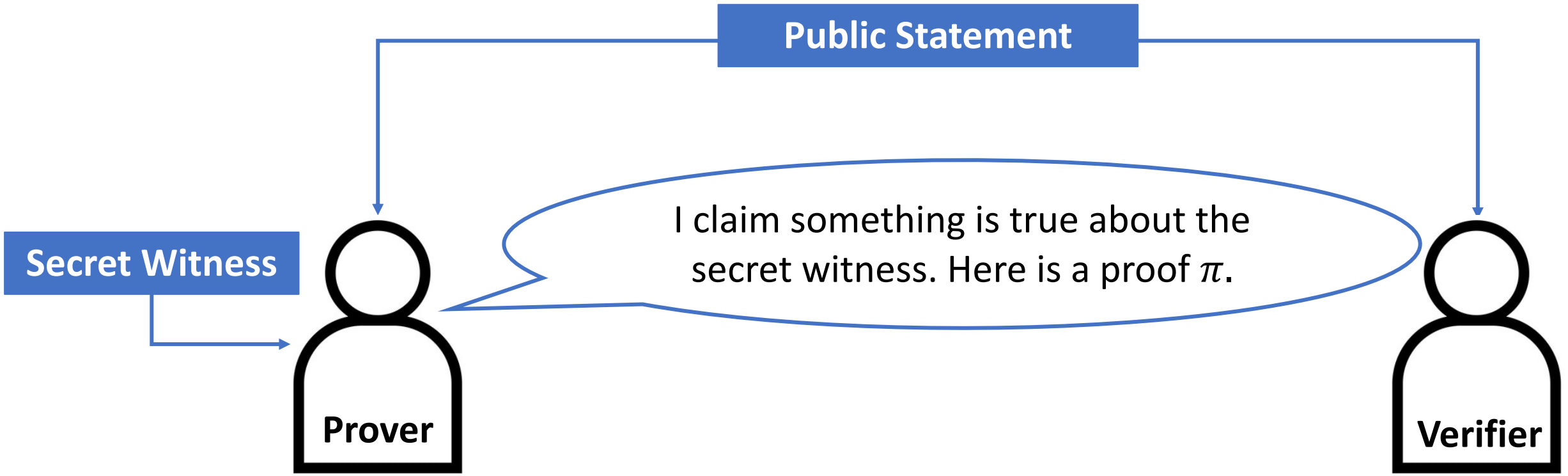

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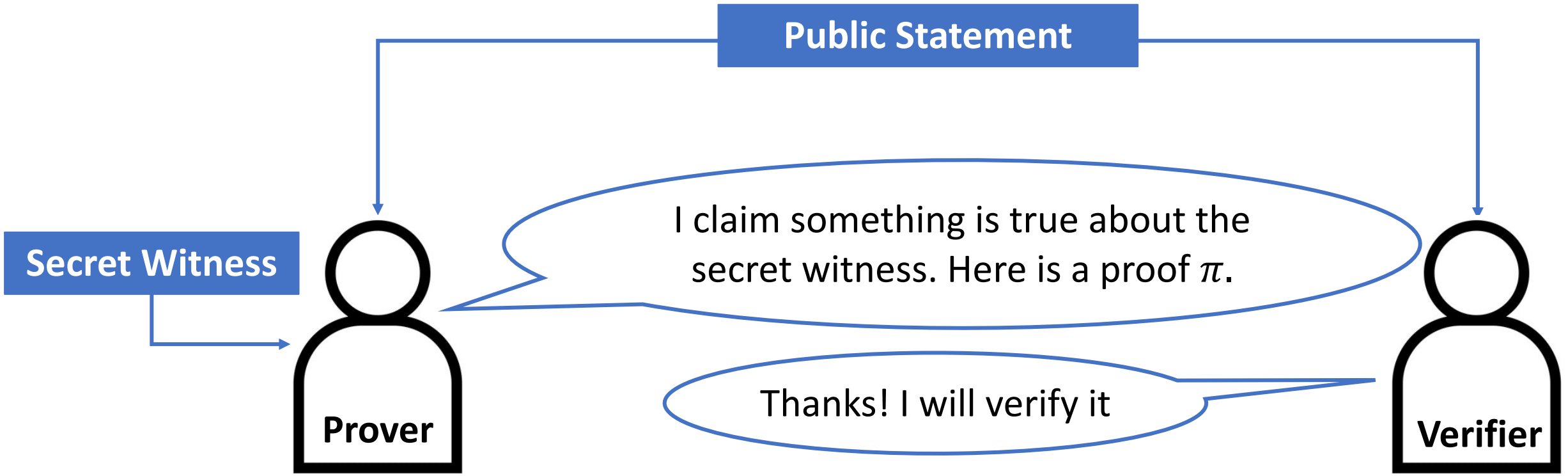
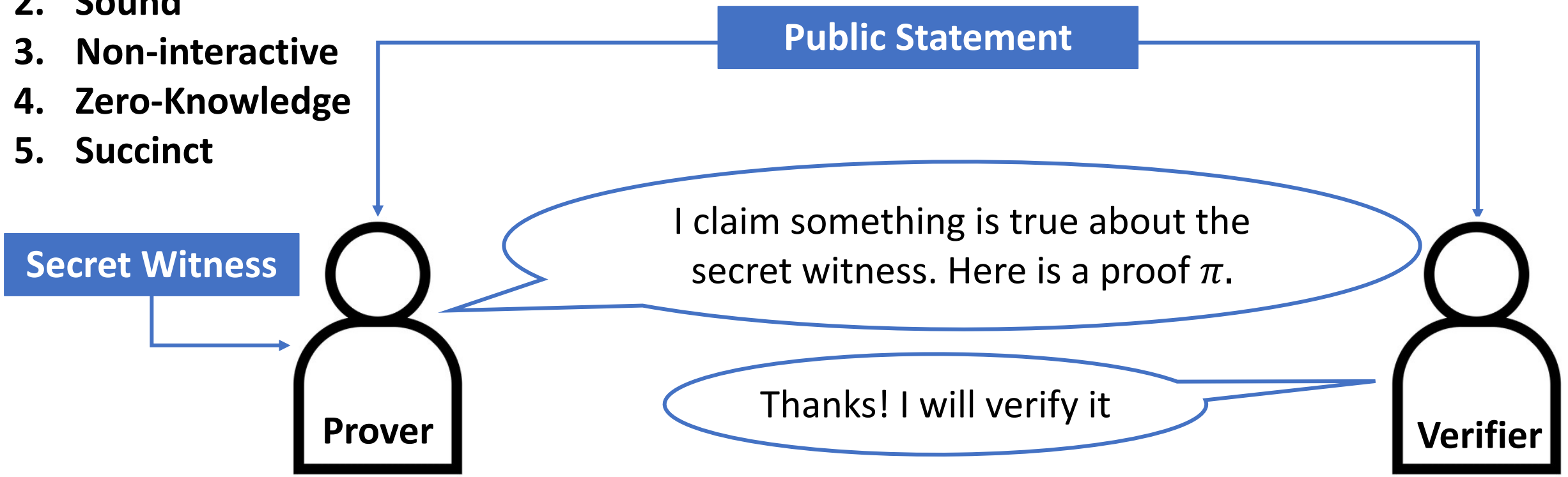


Proposed Solution: ZK-SNARKs!

- ZK-SNARK: efficiently verifiable statement about a secret witness

1. **Complete**
2. **Sound**
3. **Non-interactive**
4. **Zero-Knowledge**
5. **Succinct**



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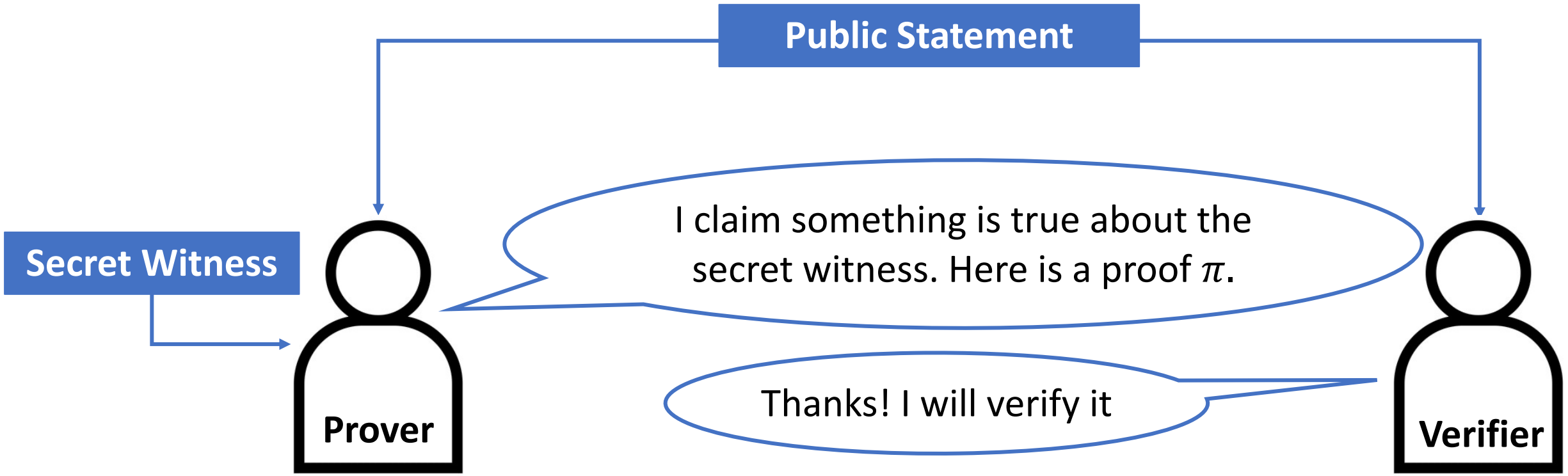

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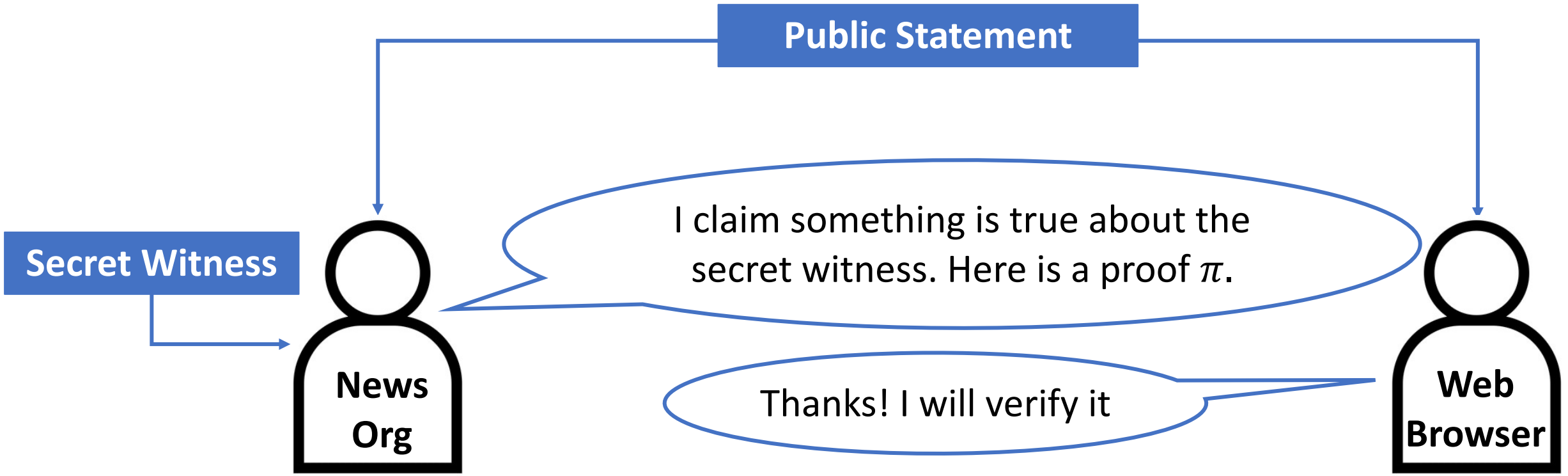

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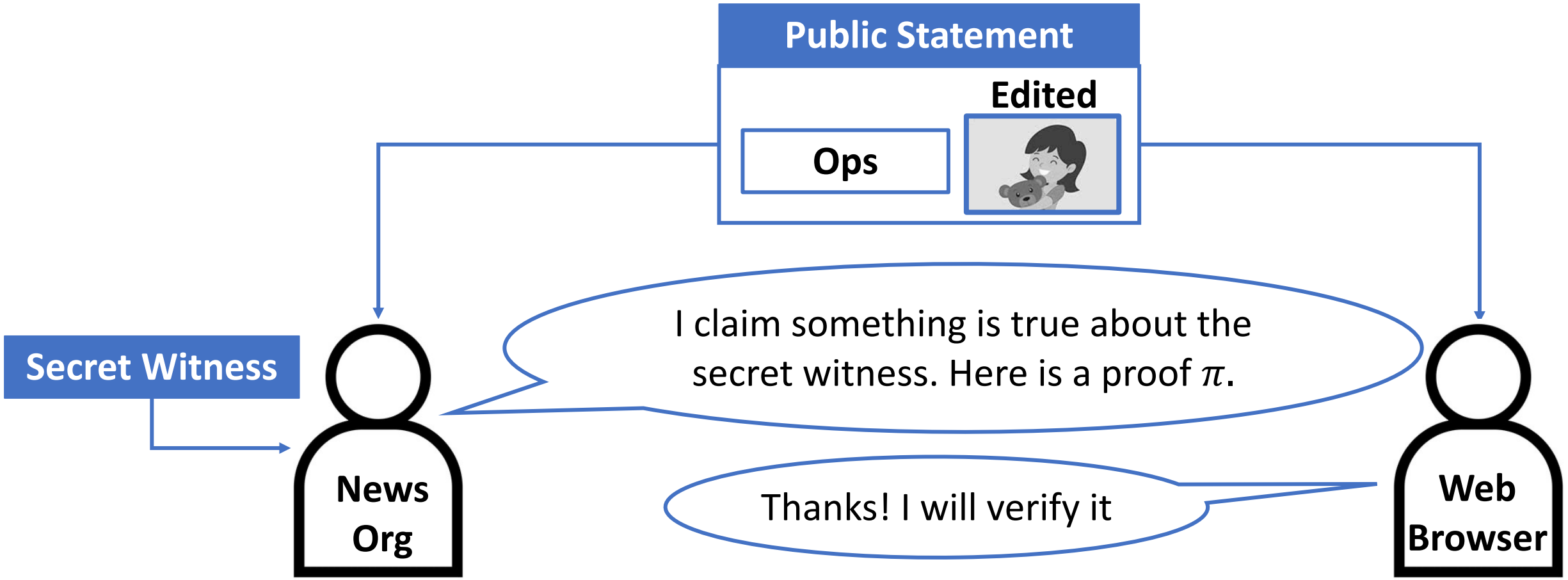

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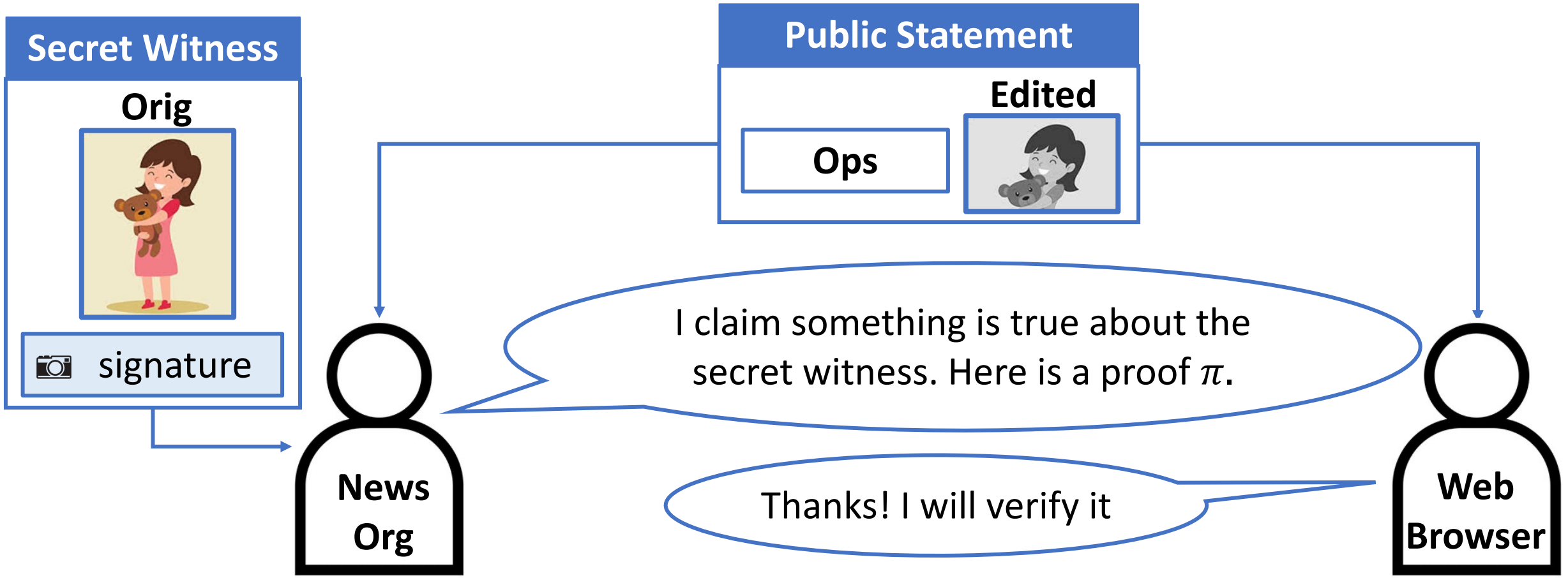

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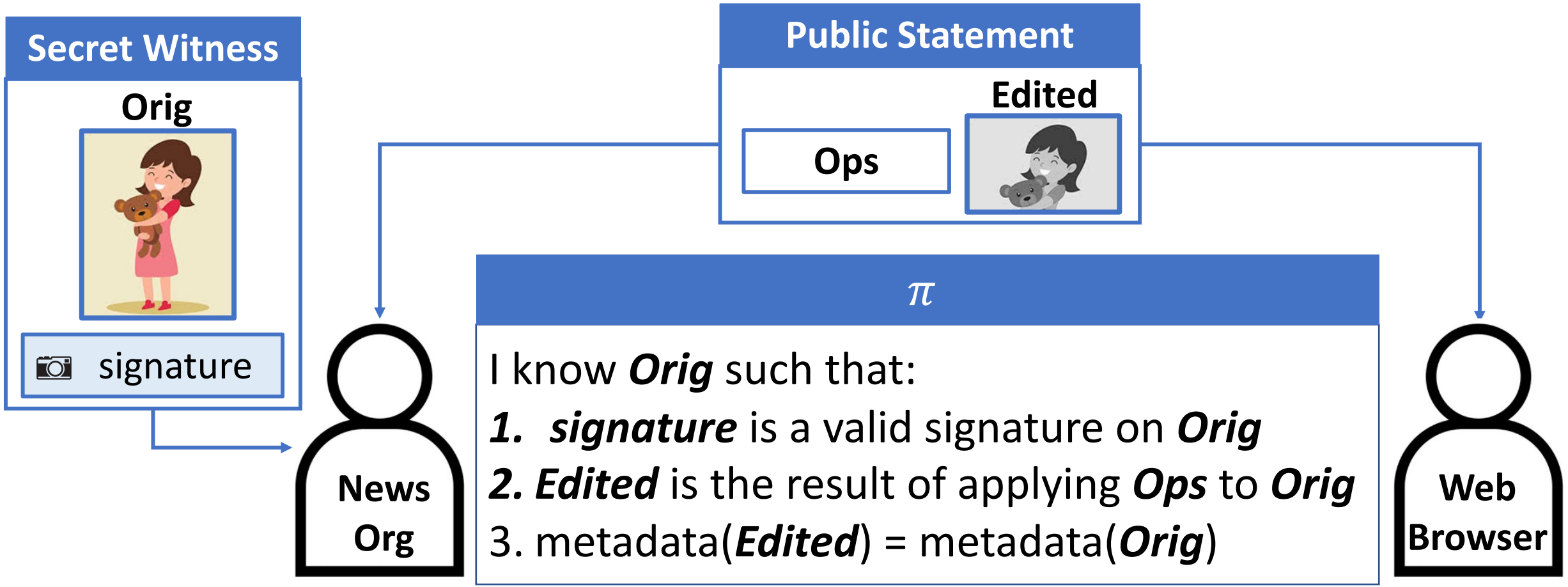


Proposed Solution: ZK-SNARKs!

We rely on all properties of ZK-SNARKs!

Secret Witness

Orig

signature

Public Statement

Edited

Ops

News Org

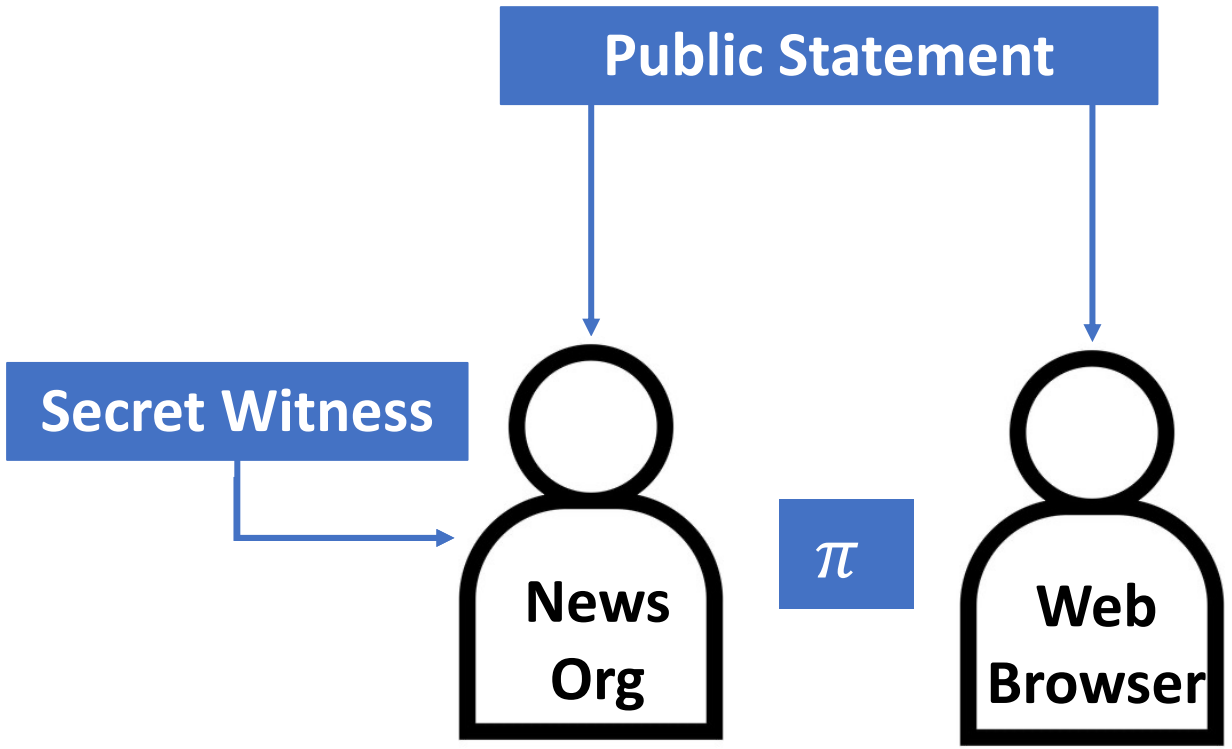
π

I know ***Orig*** such that:

1. ***signature*** is a valid signature on ***Orig***
2. ***Edited*** is the result of applying ***Ops*** to ***Orig***
3. metadata(***Edited***) = metadata(***Orig***)

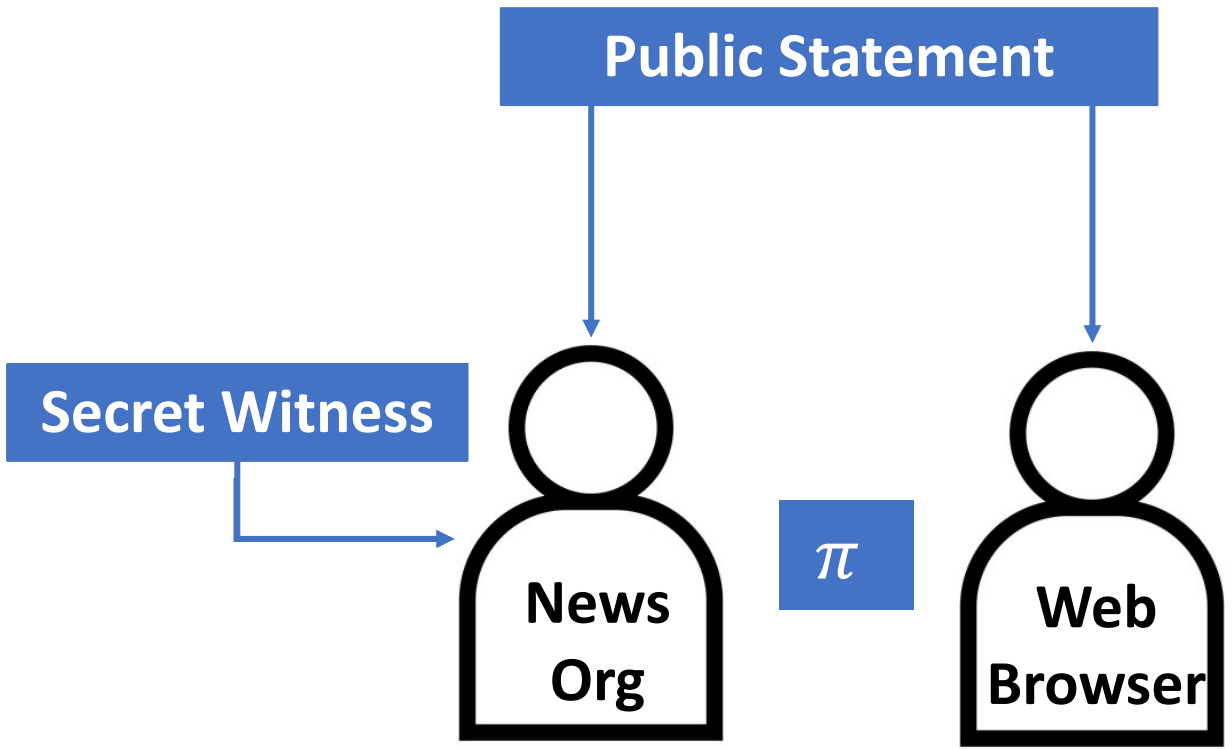
Web Browser

Proposed Solution: ZK-SNARKs!



1. **Complete/Sound:** verifier doesn't need to trust prover

Proposed Solution: ZK-SNARKs!



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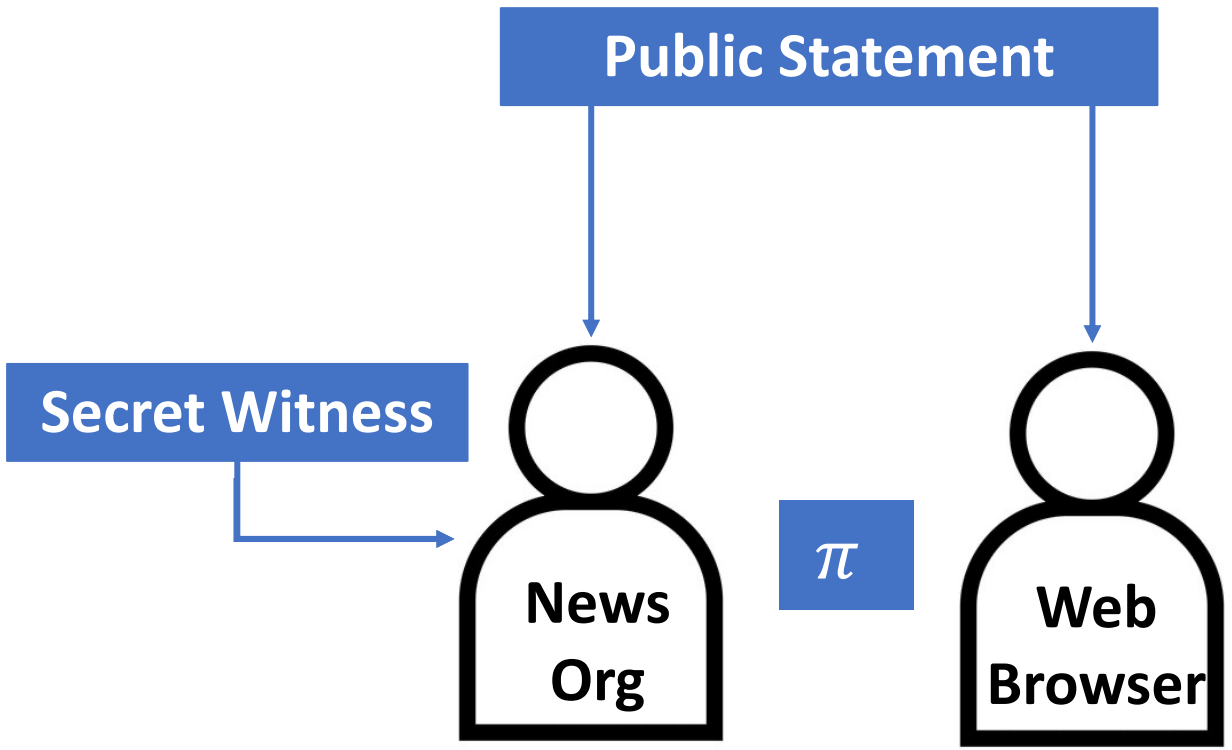

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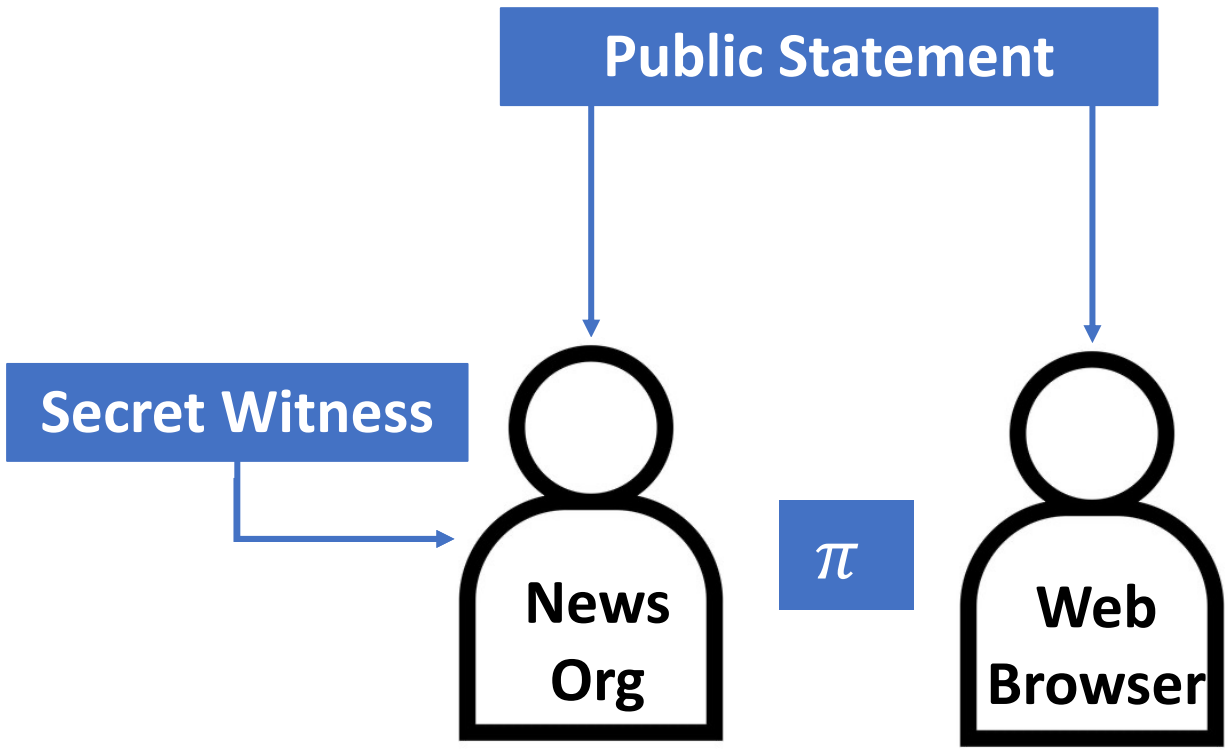

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2. **Non-interactive:** interactivity would entail unique proofs for each browser
3. **Zero-Knowledge:** useful for ops such as cropping
4. **Succinct:** web browser can efficiently verify proof

Proofs for Post-Processing Ops

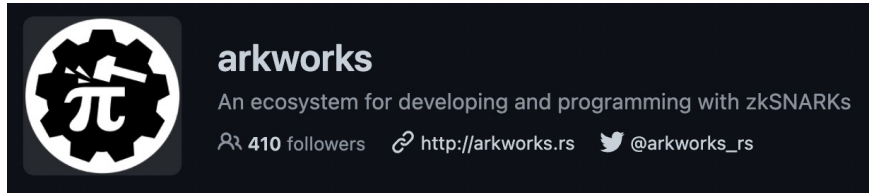
- PhotoProof (Naveh and Tromer, 2016): a few minutes to generate photo editing proofs for 128 x 128 pixel image

Proofs for Post-Processing Ops

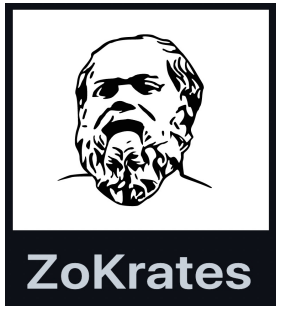
- PhotoProof (Naveh and Tromer, 2016): a few minutes to generate photo editing proofs for 128 x 128 pixel image
- New tools enable faster development!

==> circom
CIRCUIT COMPILER

halo2 crates.io v0.1.0-beta.2



gnark
A fast zk-SNARK library that offers a high-level API to design circuits



The Noir Programming Language

Performance for Post-Processing Ops Proofs

For resizing, cropping, grayscale ops on images of about 6000 x 4000 pixels (~30MP) using Circom:

- Proof generation time: <1 second
- Witness generation time: <4 minutes

by newspaper once per image

- Verification time: 2 ms
- Proof size: <1 KB

by browser

Verifying Signatures in a SNARK Prover

π
I know ***Orig*** such that: ***1. signature*** is a valid signature on ***Orig*** ***2. Edited*** is the result of applying ***Ops*** to ***Orig*** 3. metadata(***Edited***) = metadata(***Orig***)

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Attempt 1

π **(Signature)**
I know (***Orig***, ***hash***) such that: ***hash*** = SHA256(***Orig***)

Verifying Signatures in a SNARK Prover

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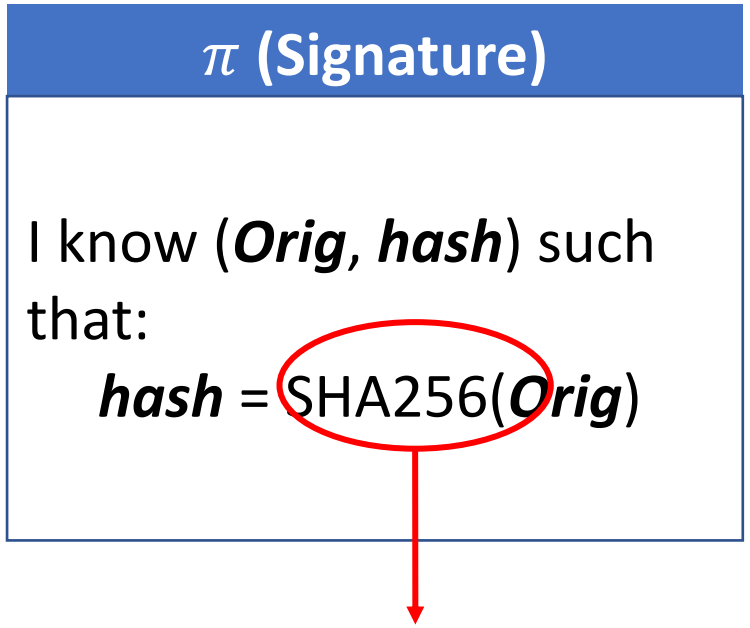

Verifying Signatures in a SNARK Prover

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Too slow for 30 MP!

Attempt 2

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Poseidon hash of lattice hash [GGH'96 , SCMPGLW'08]

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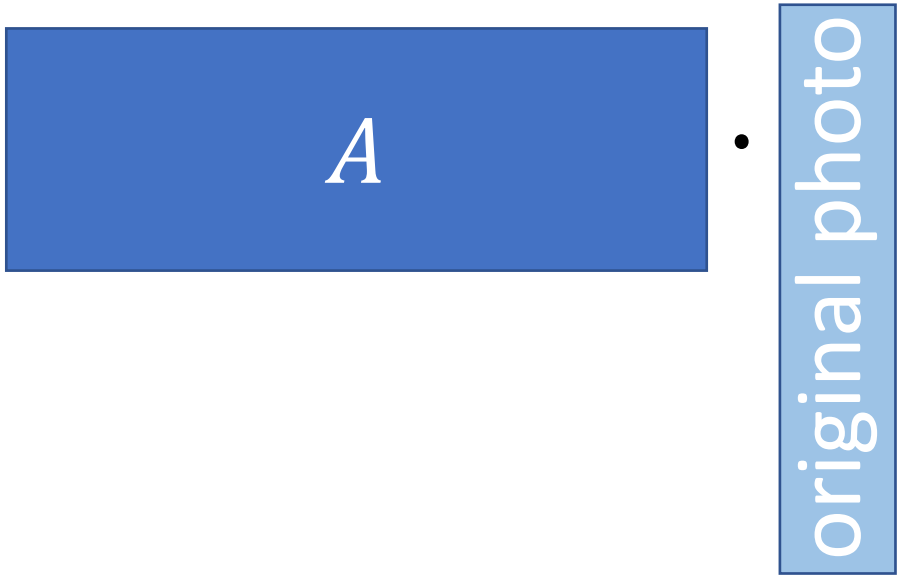

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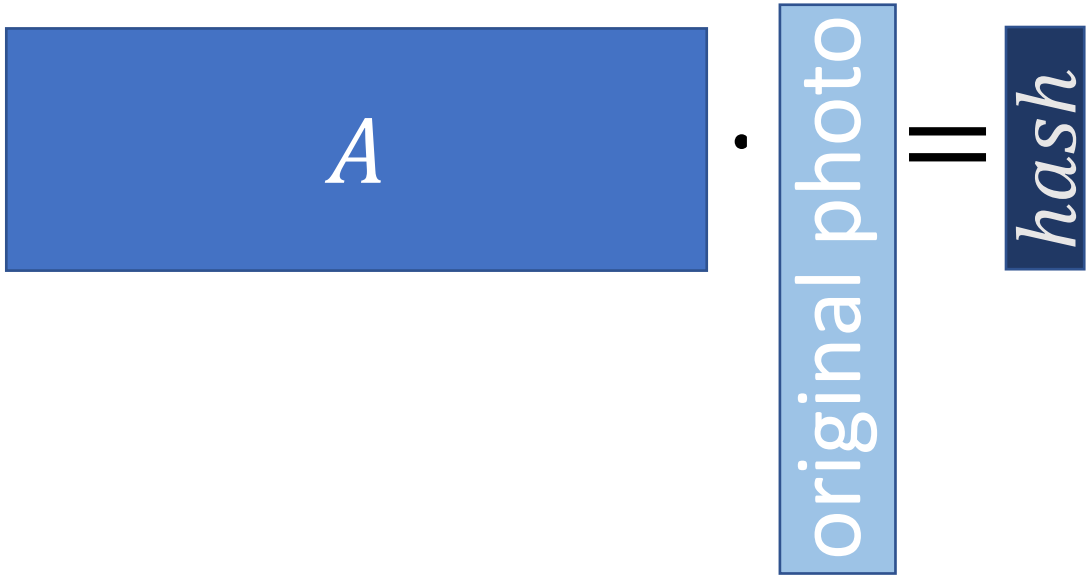

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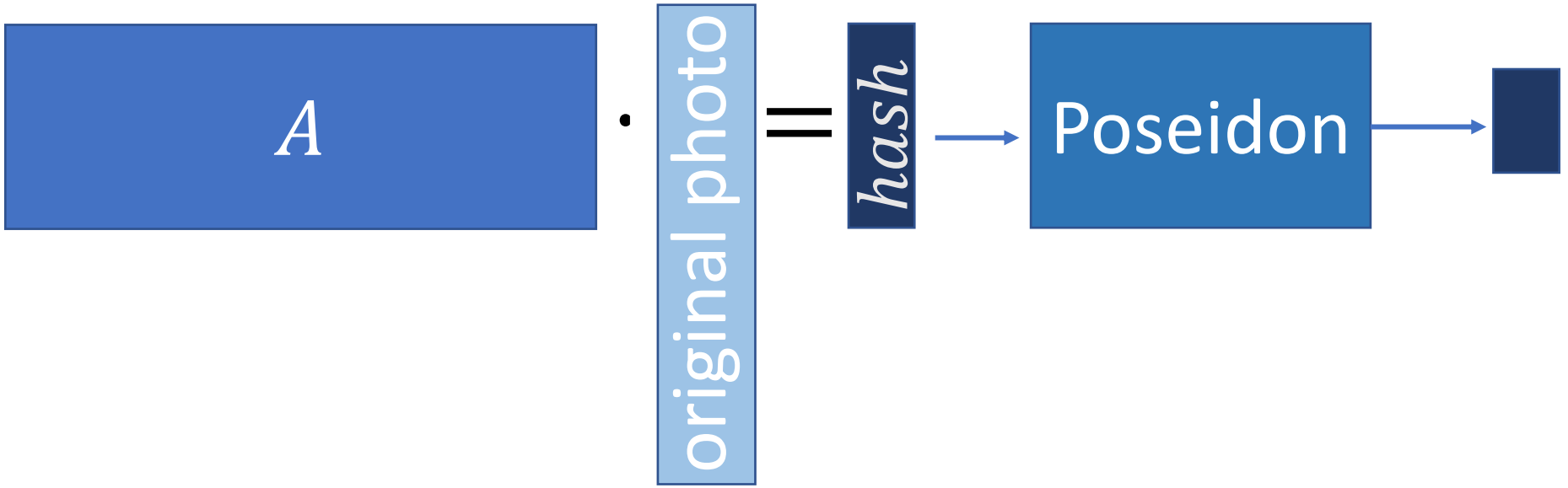

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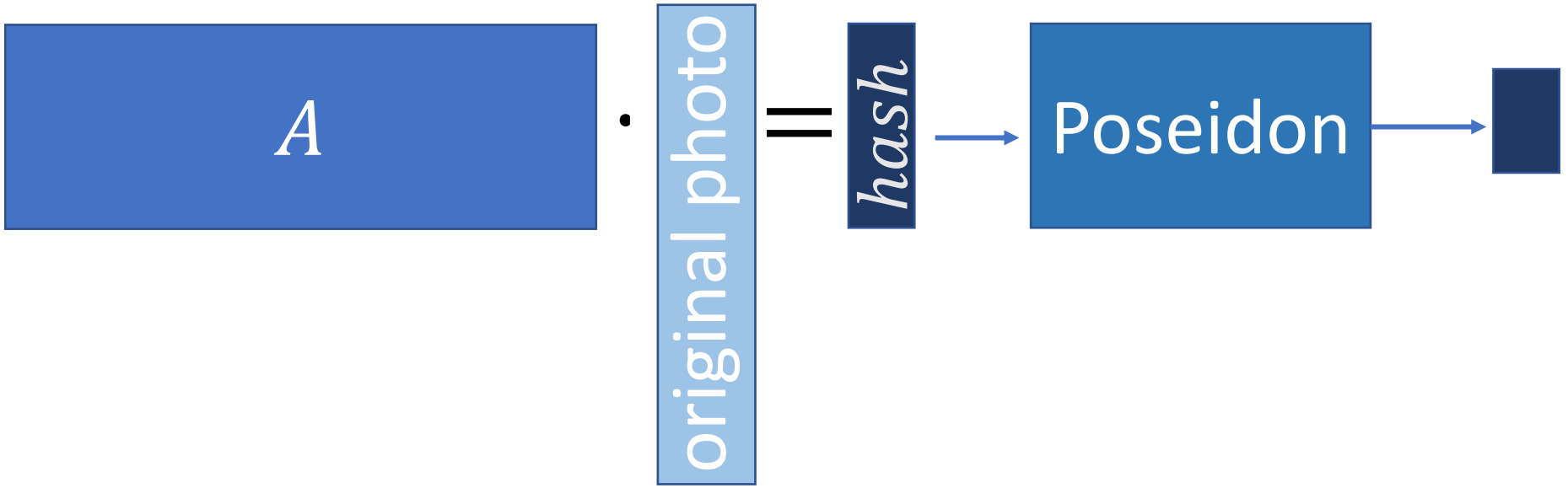

- Collision-resistant assuming SIS → prover must prove original photo representation is low norm

Verifying Signatures in a SNARK Prover

To prove $\vec{x}$ is low norm,

i.e., $\vec{x} \in \{0, 1, \ldots, R-1\}^n$:

***[BCGJM'18, GWC'19, GW'20]

Verifying Signatures in a SNARK Prover

To prove $\vec{x}$ is low norm,

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$R = 3$

$\vec{x}$ | 2 | 0 | 2 |

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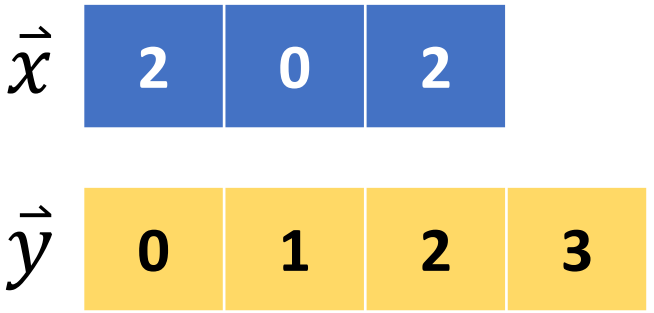

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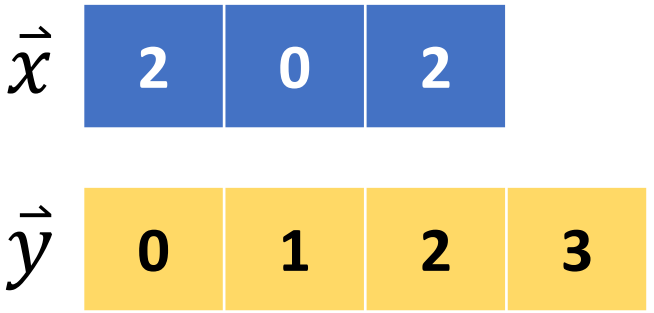

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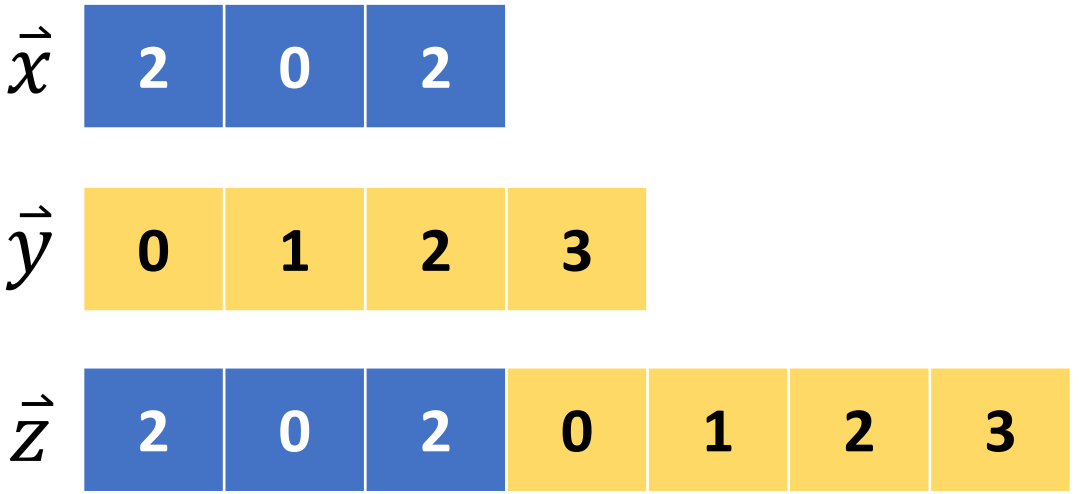

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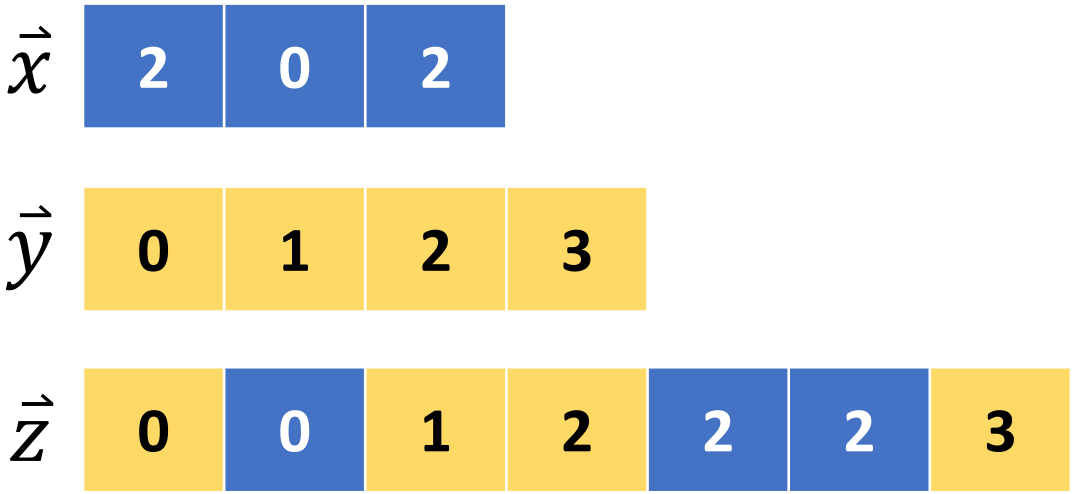

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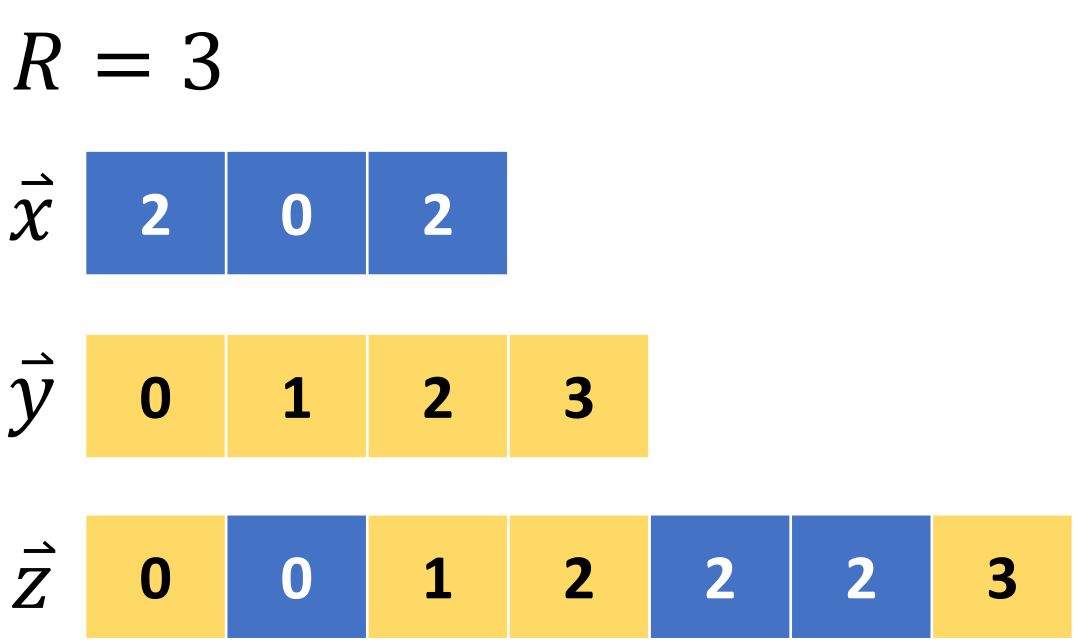
Must show:

- $\vec{z}$ is permutation of $\vec{x}$ and $\vec{y}$
- $\vec{z}[i+1] - \vec{z}[i] \in \{0, 1\}$



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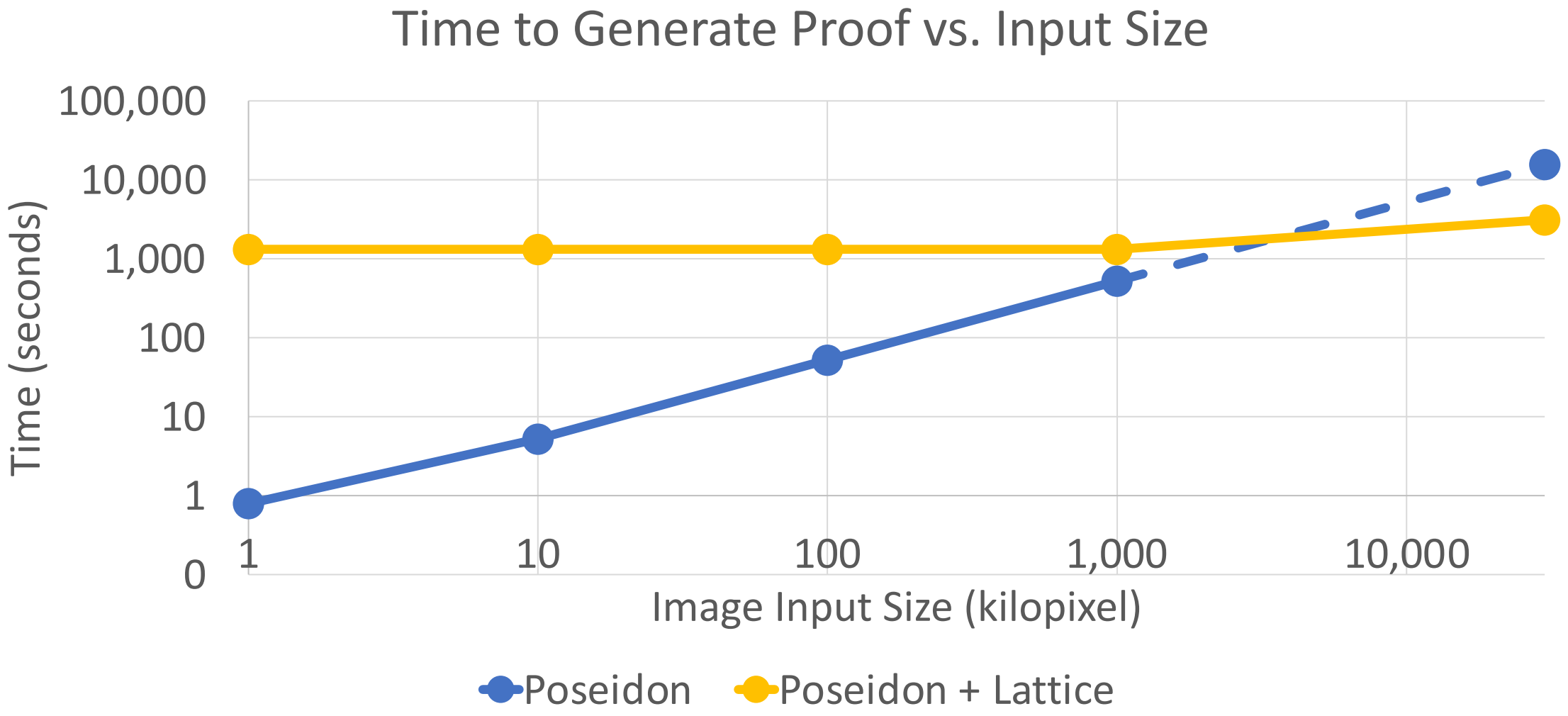
Performance Results for Proving Signatures



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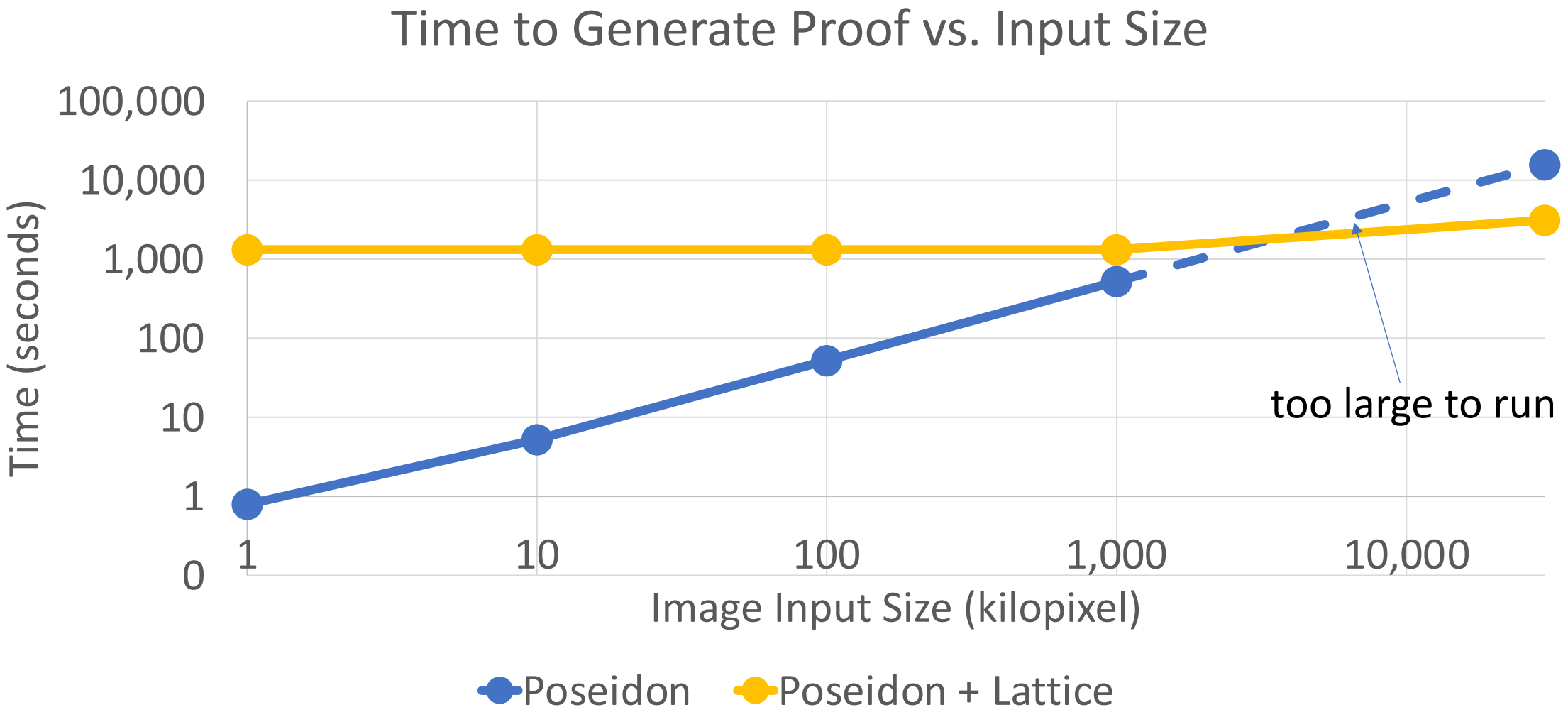

Conclusions

- Proof systems have greatly improved due to their need in blockchains $\Rightarrow$ non-blockchain applications benefit
- Proofs about large images (4000×6000) can be done in reasonable time
- Applicable to C2PA for image authenticity
- Open problem: ZK proofs for videos?