VeriTAS

Verifying Image Provenance at Scale

Trisha Datta **Binyi Chen** Dan Boneh

Stanford University

Image Provenance Verification

Verify Image Metadata

- Who
- When
- Where

Image Provenance Verification

Verify Image Metadata

- Who
- When
- Where

Why Important?

- Fight disinformation
- Copyright protection
- Regulation compliance

These look like prizewinning photos. They're AI fakes.

Artificially generated images of real-world news events proliferate on stock image sites, blurring truth and fiction

November 23, 2023

By Will Oremus and Pranshu Verma

C2PA Standard (Simplified)

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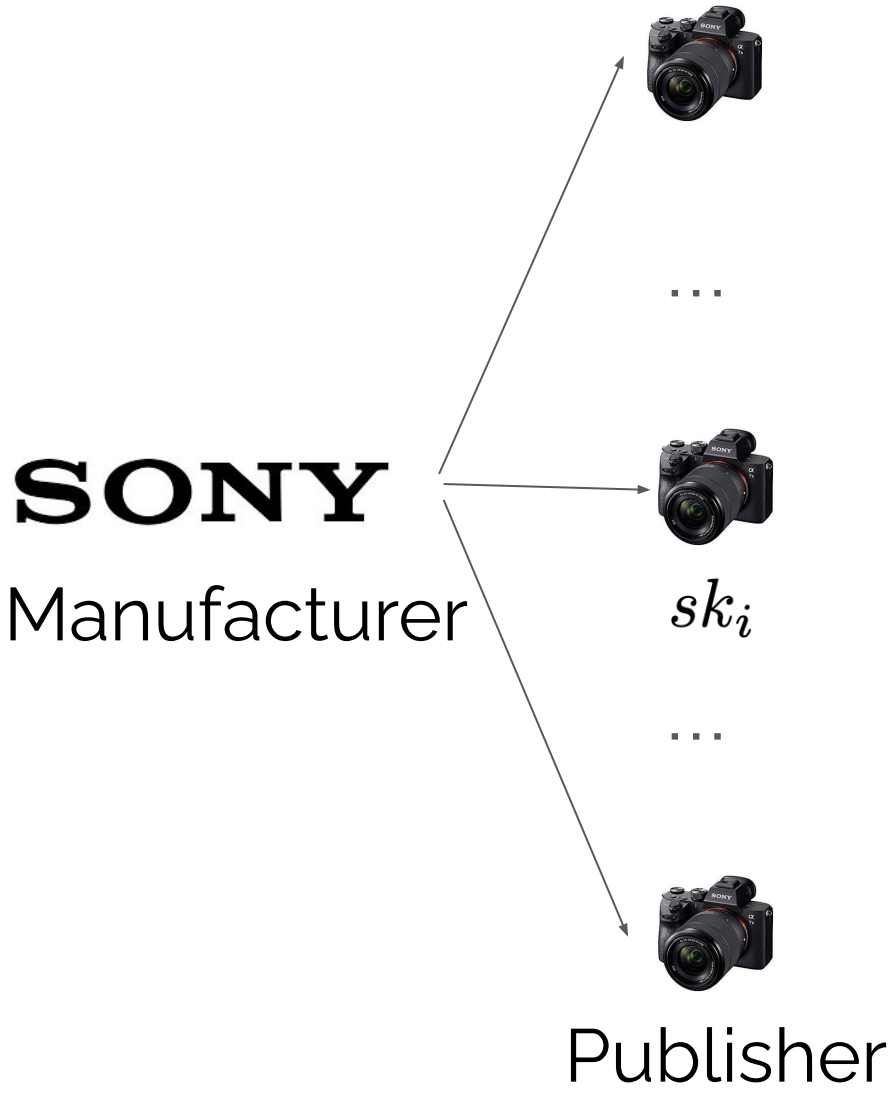

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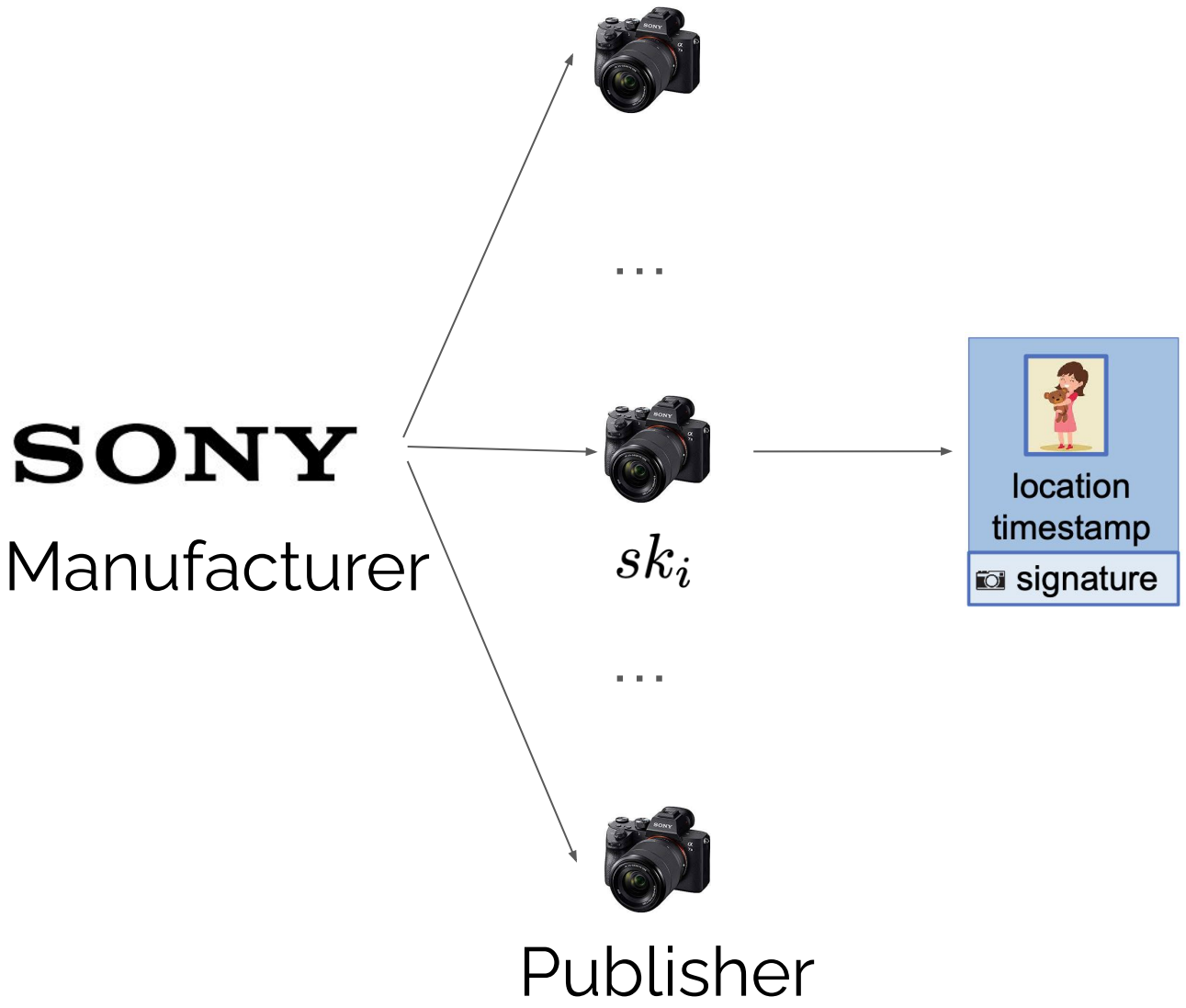

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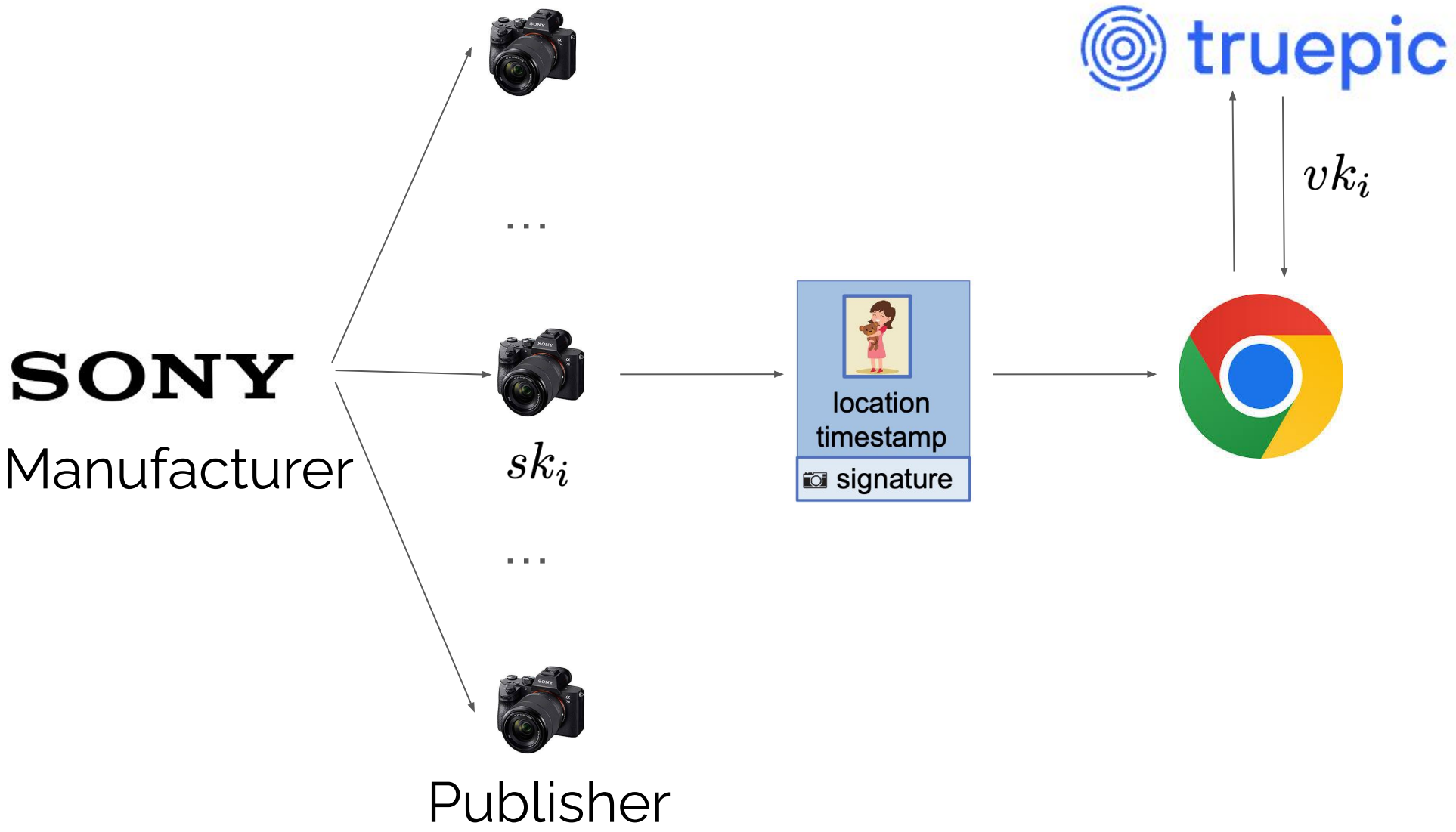

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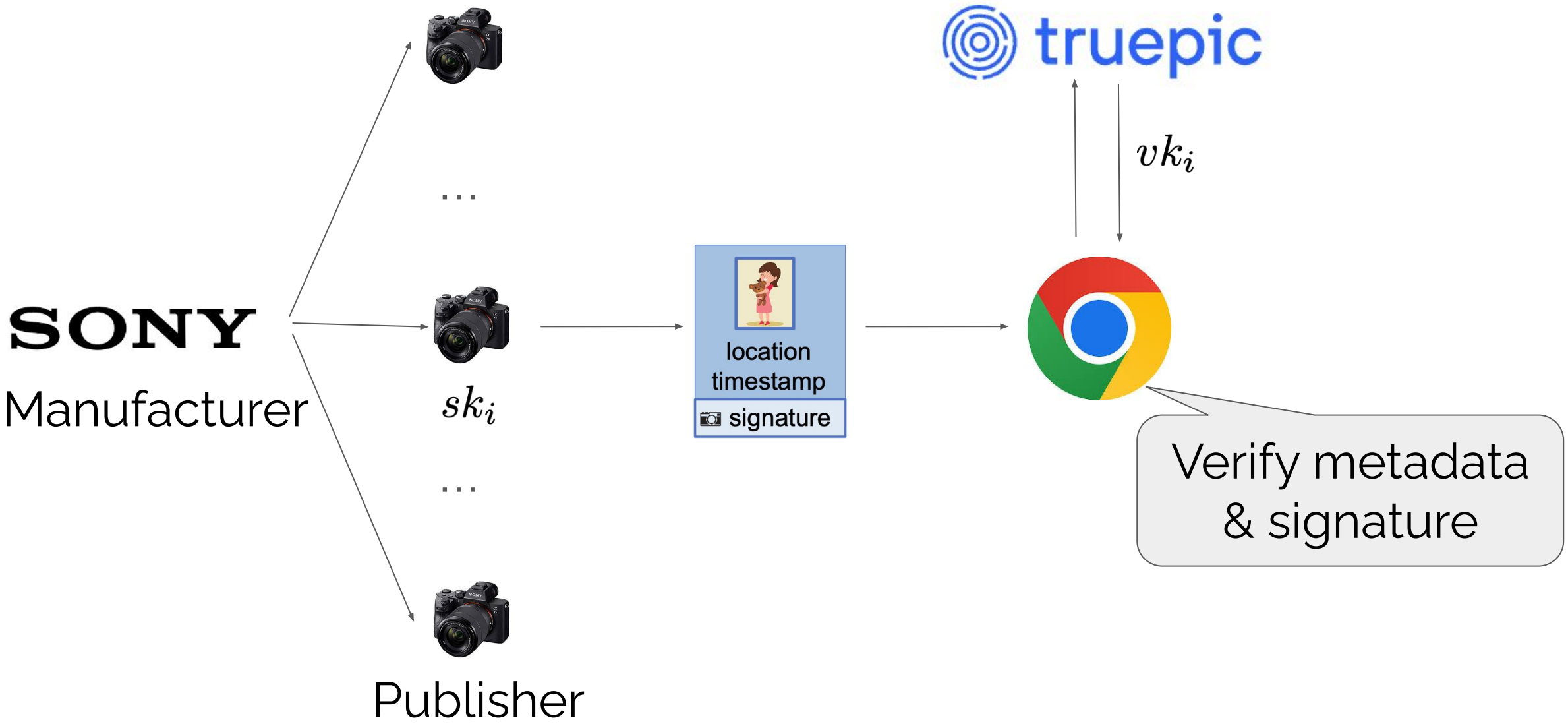
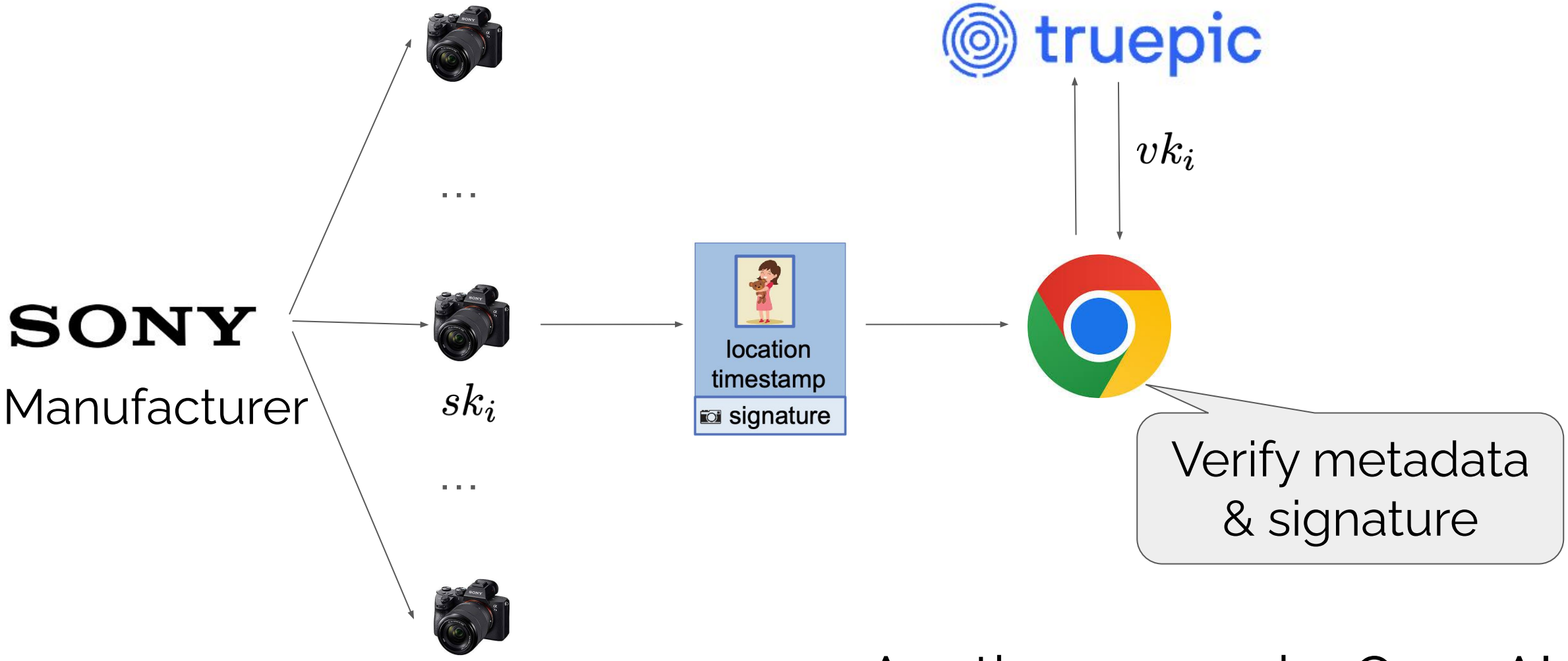


C2PA Standard

Leica camera has built-in defense against misleading AI, costs $9,125



Another example: OpenAI

[https://help.openai.com/en/articles/8912793-c2pa-in-dall-e-3]

Challenge: Verifying Edited Images

Issue: Publishers process photos before publication

(e.g. cropping, blurring, etc.)

Publisher has no signature for it

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C2PA's solution:

Publisher

C2PA-approved
Editing App

sk

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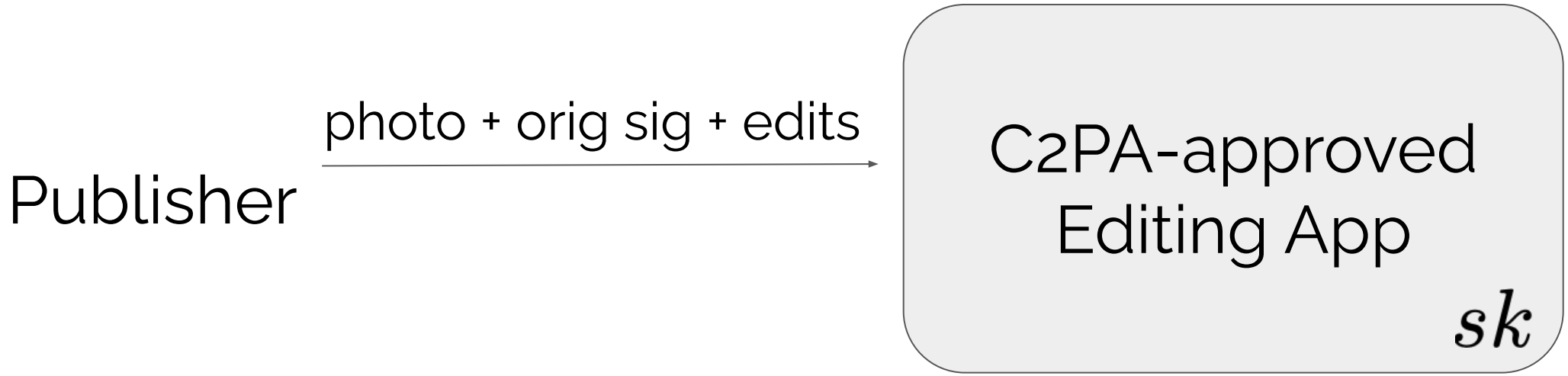

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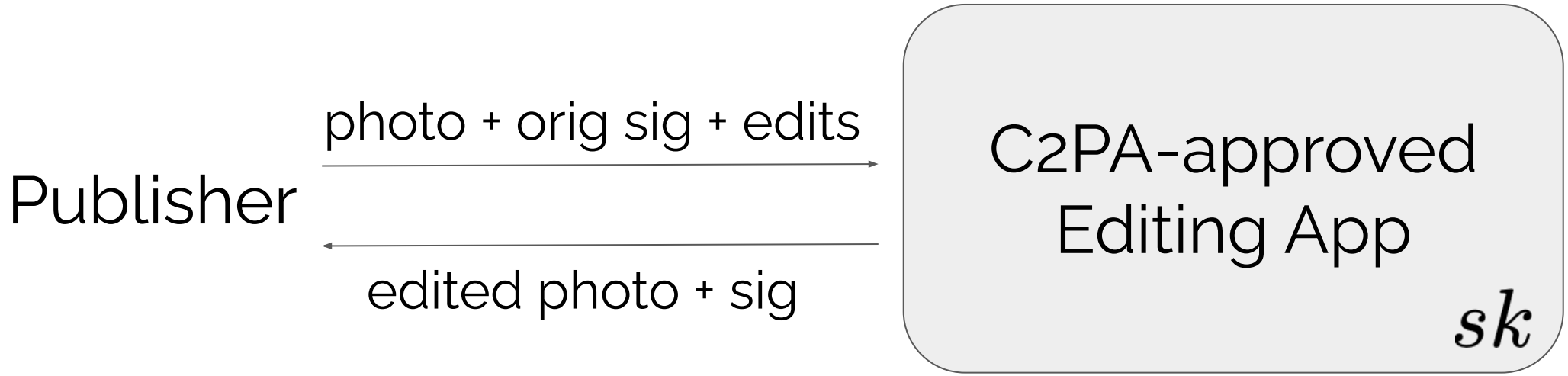

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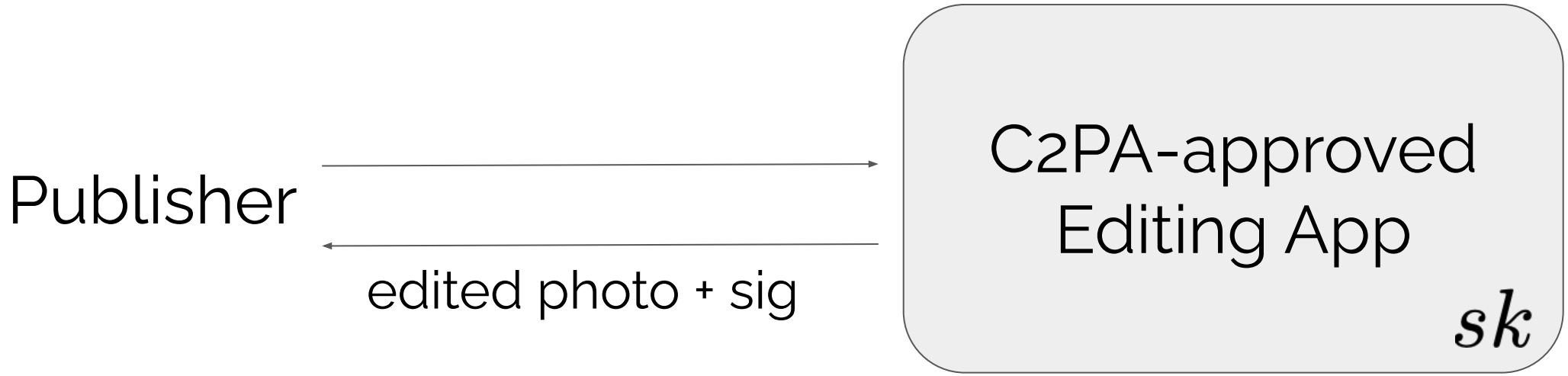

Issue: Must trust the editing application

Our Goals

- Original photos properly signed

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Glass-to-glass security:

- No intermediate trust from camera to user screen

Our Results

- A zkSNARK-based image provenance system
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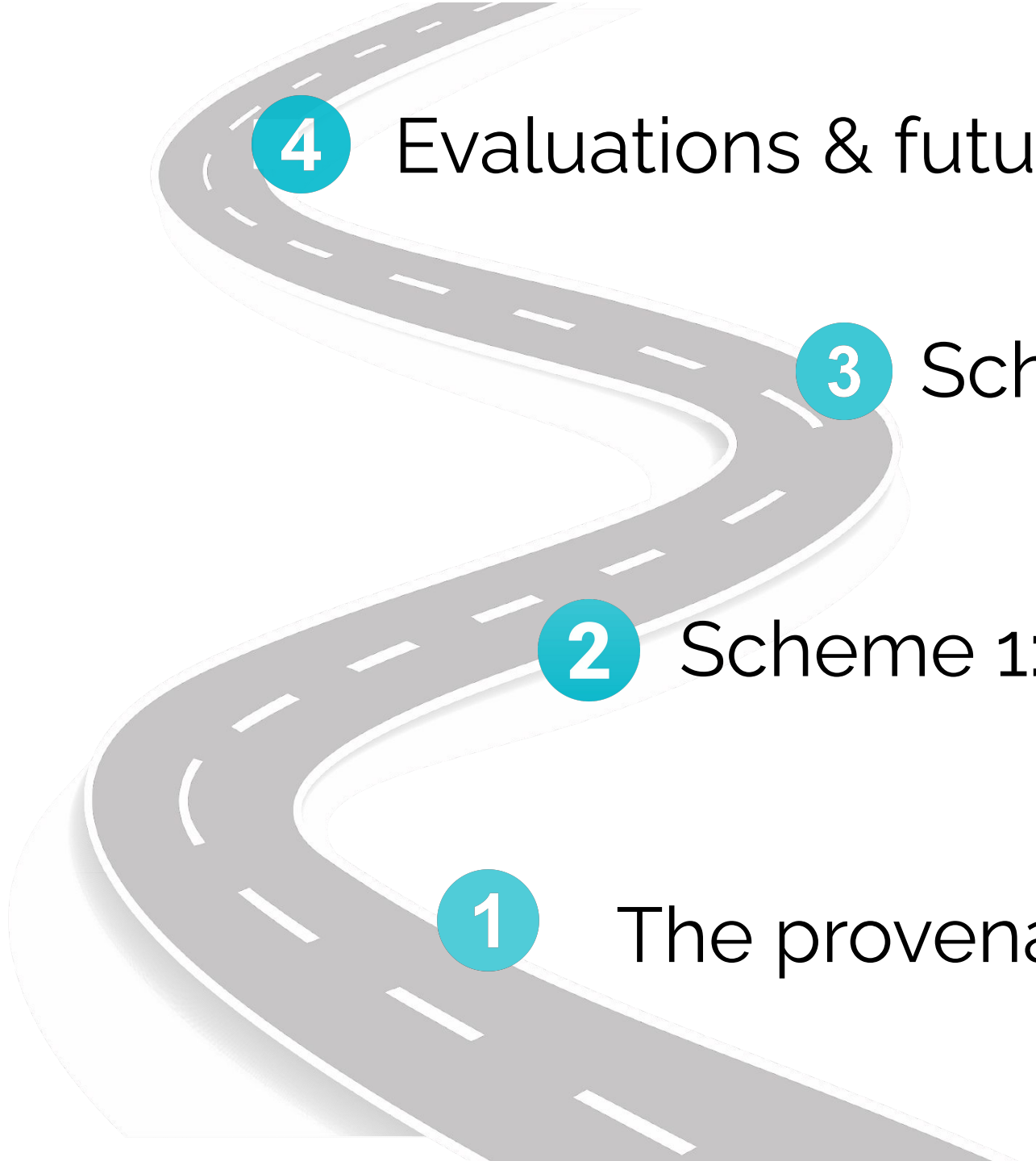
- The 1st system that supports >90MB images



4 Evaluations & future directions

3 Scheme 2: Faster proving

2 Scheme 1: Lightweight signing

1 The provenance framework

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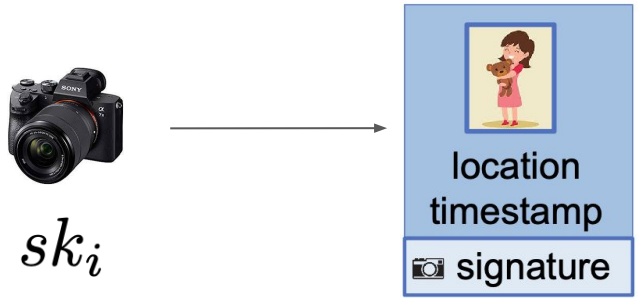
The Provenance Framework



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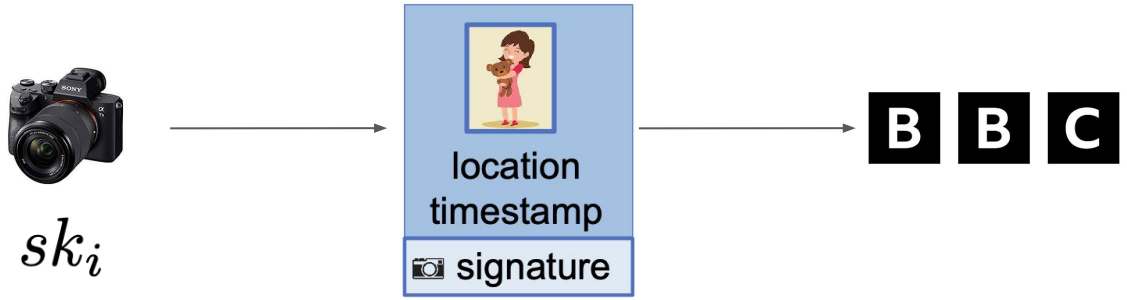

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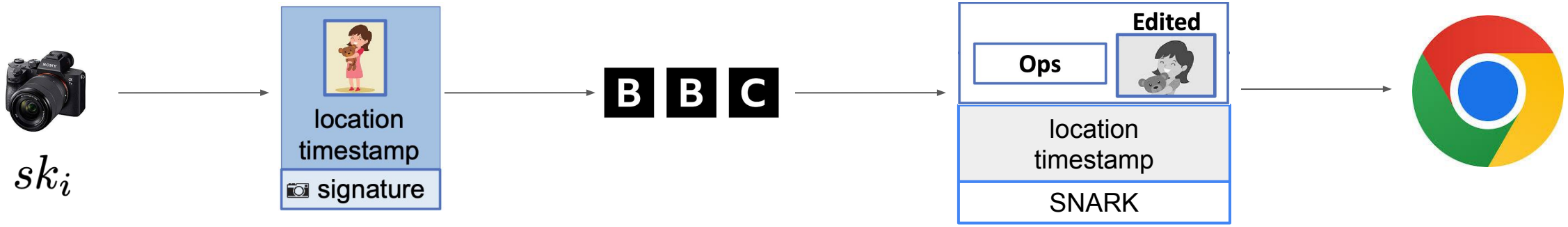

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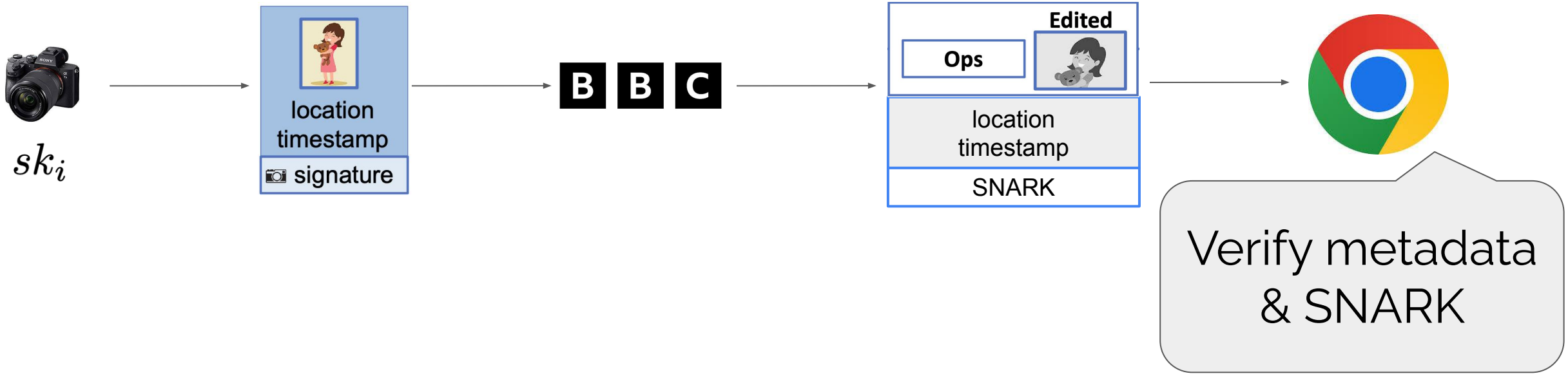

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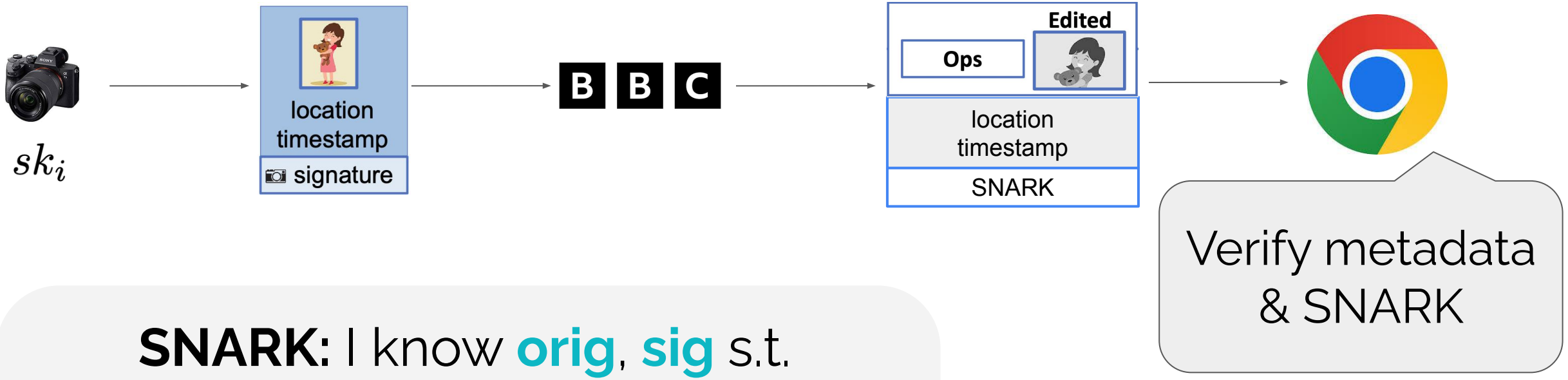

SNARK: I know **orig**, **sig** s.t.

- **sig** is valid on hash(**orig**) w.r.t. **vk**
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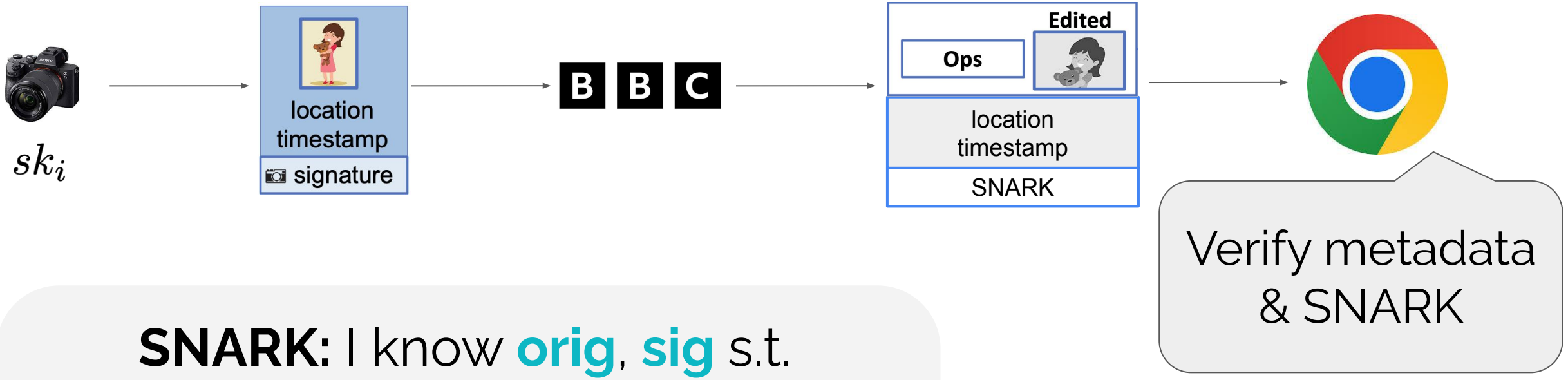

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Hash proving is hard

orig > 90MB

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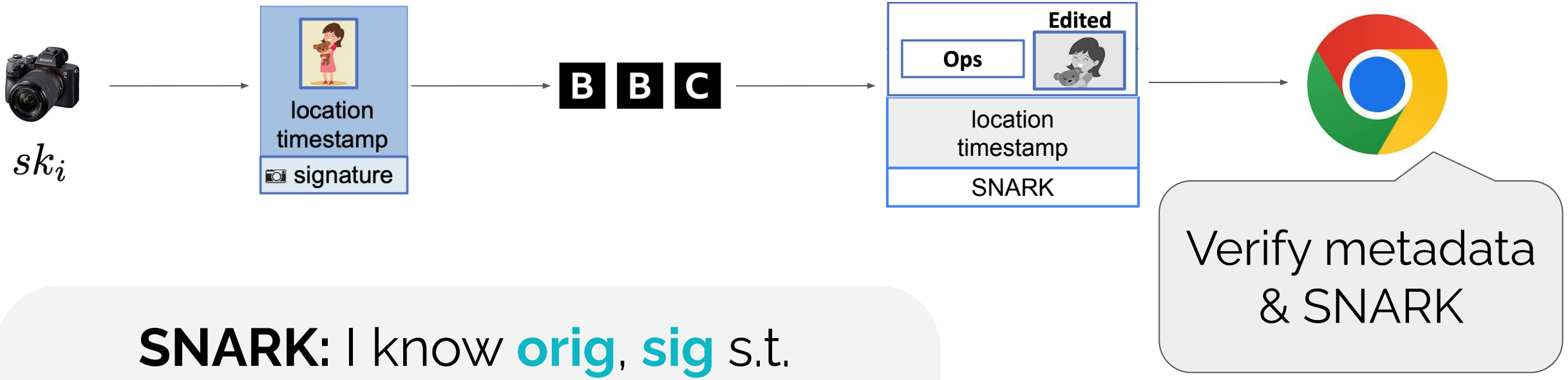

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PhotoProof (2016):
a few mins for 128 x 128 pixel image

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Hash Proving for Weak Signers

Scheme 1: Lightweight signing + ZK-friendly hash

	Speed	ZK-friendly	Output length
SHA-256			
Poseidon			
Ajtai			

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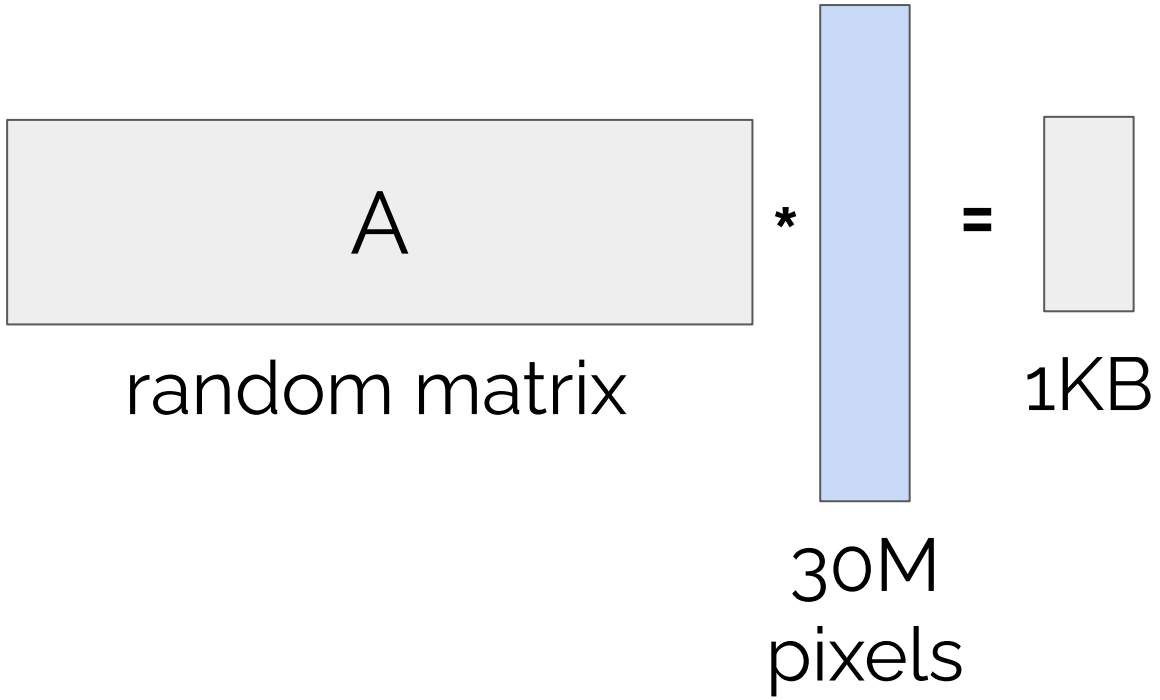
Our choice: Compose Ajtai with Poseidon

Hash Proving for Weak Signers

30M
pixels

Hash Proving for Weak Signers



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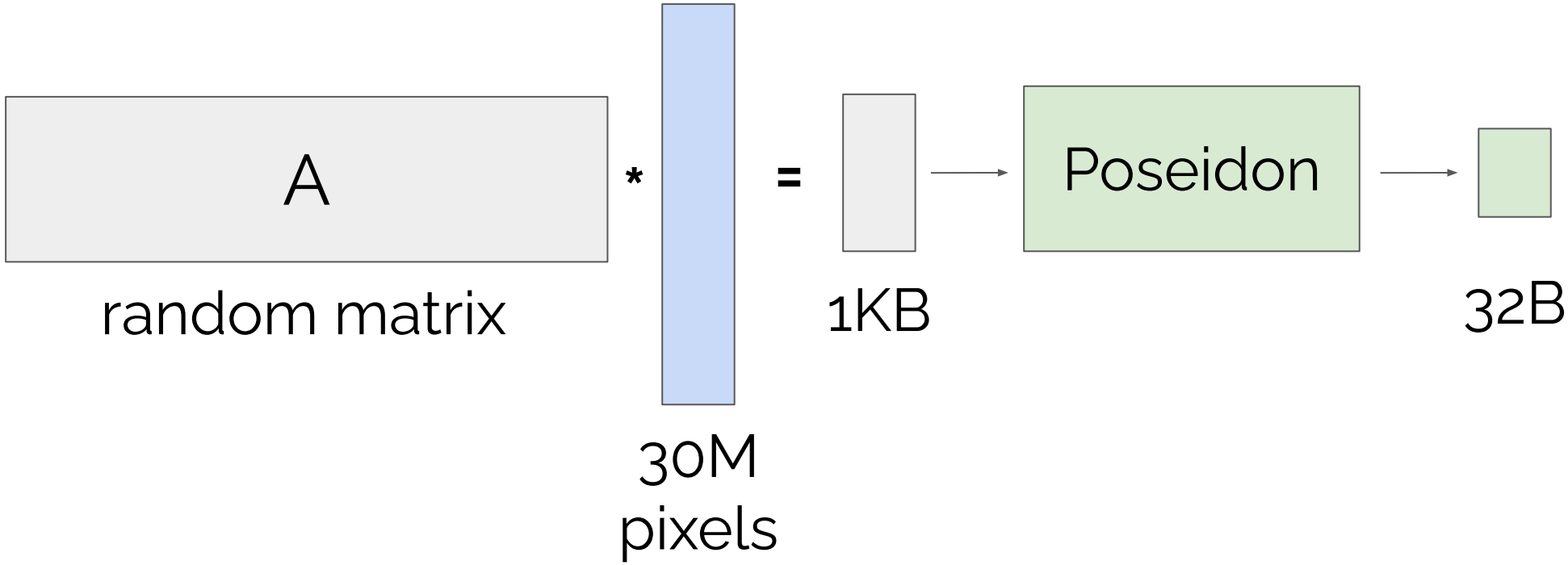

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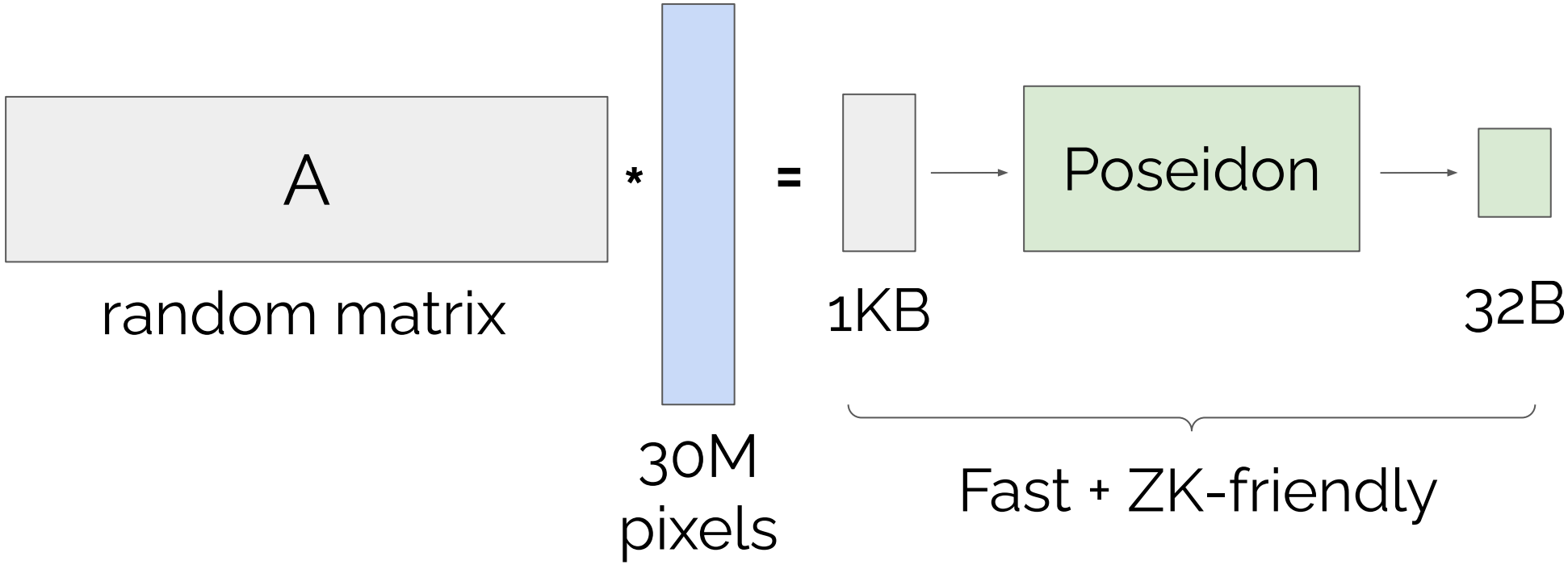

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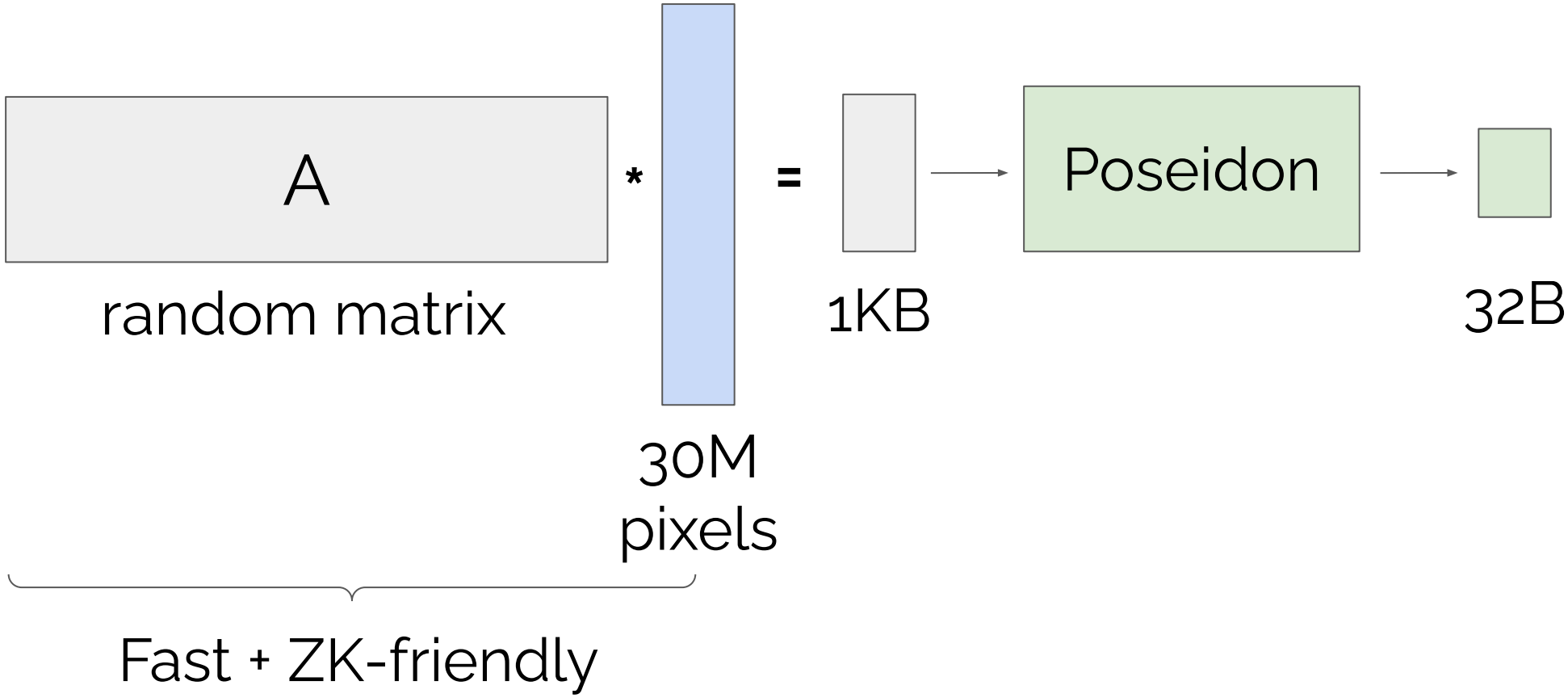
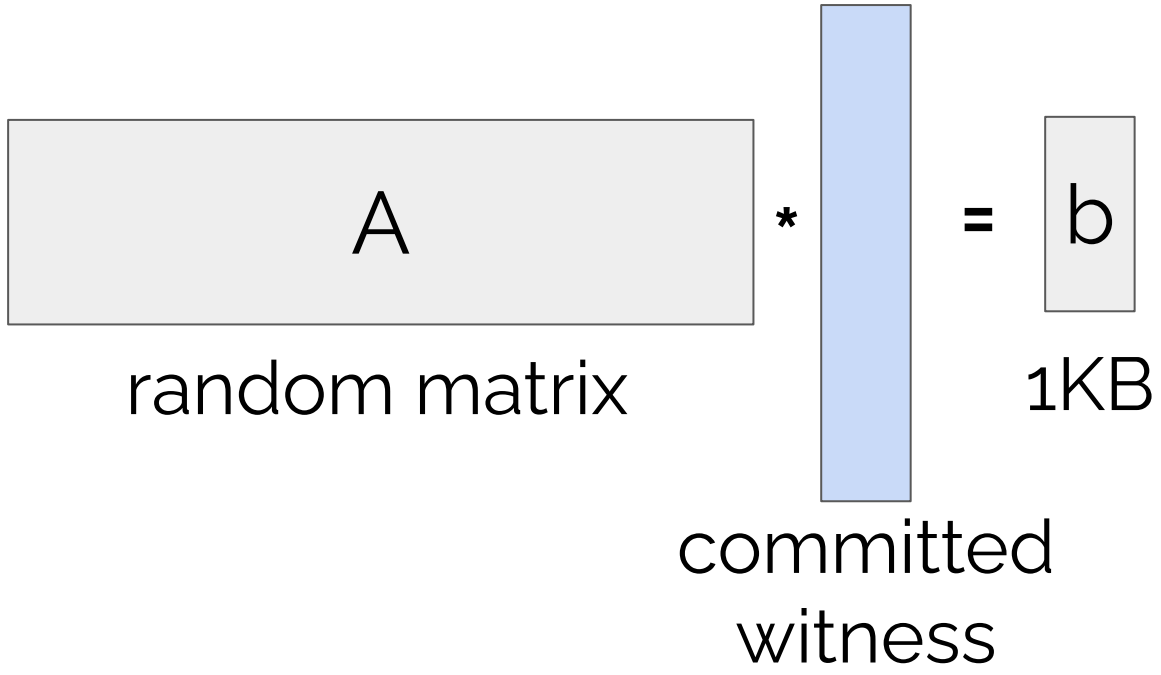


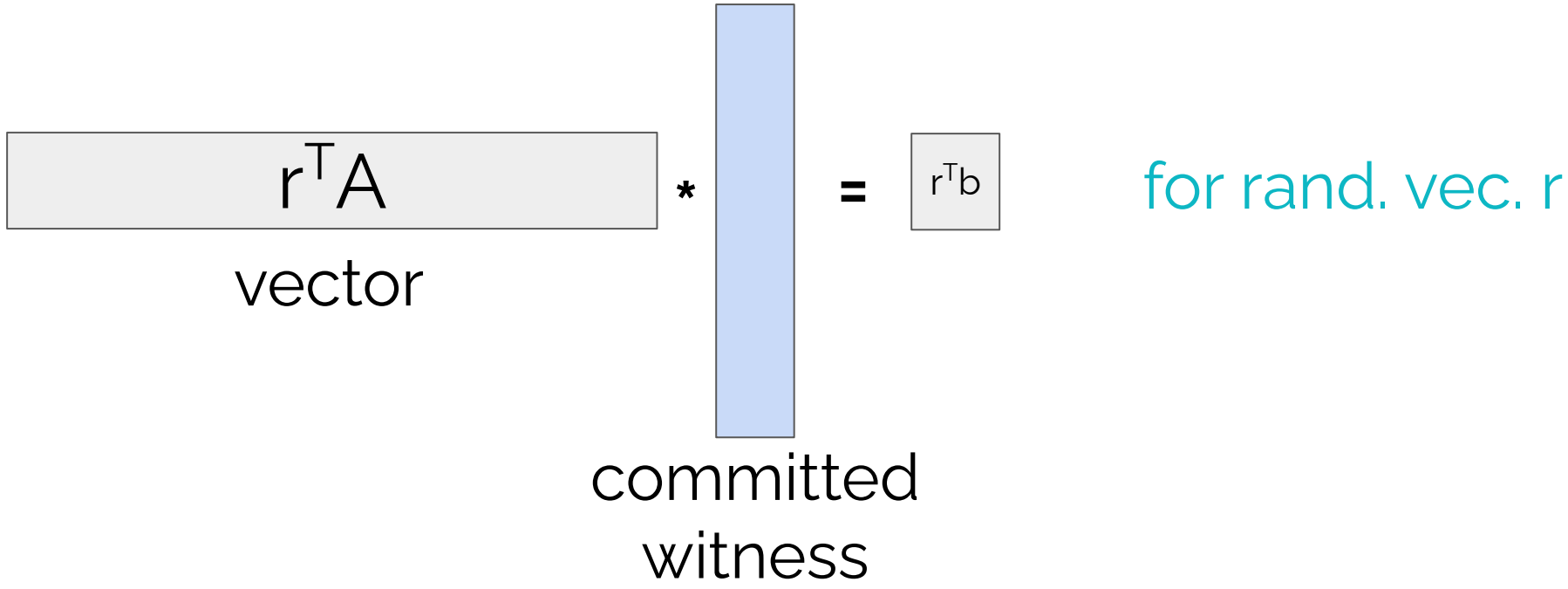
Hash Proving for Weak Signers

Freivald's algorithm: Prove



Hash Proving for Weak Signers

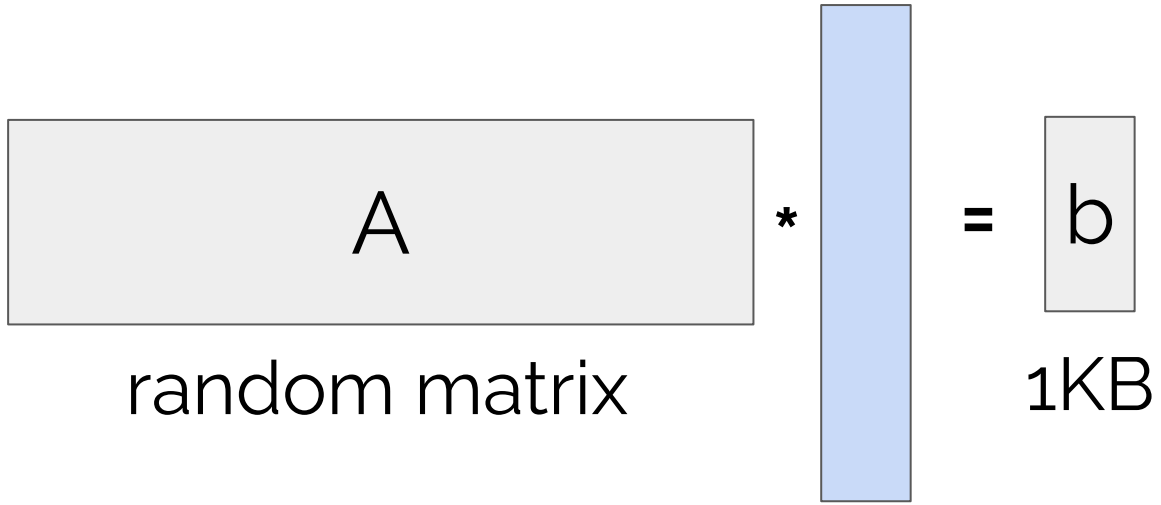
Freivald's algorithm: Sufficient to prove



for rand. vec. r

Hash Proving for Weak Signers

Ajtai binding commitment



Binding for low-norm input

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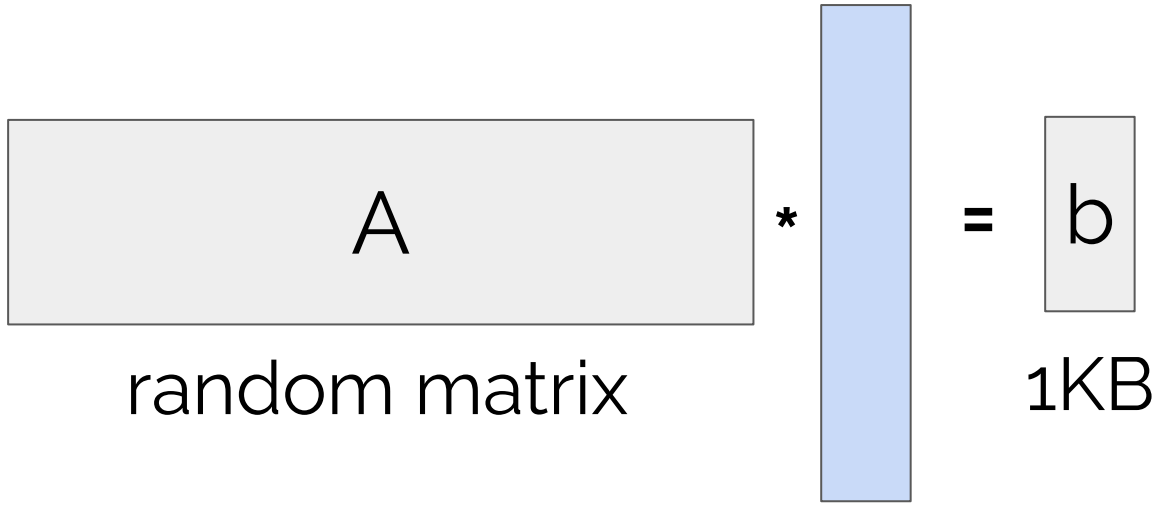
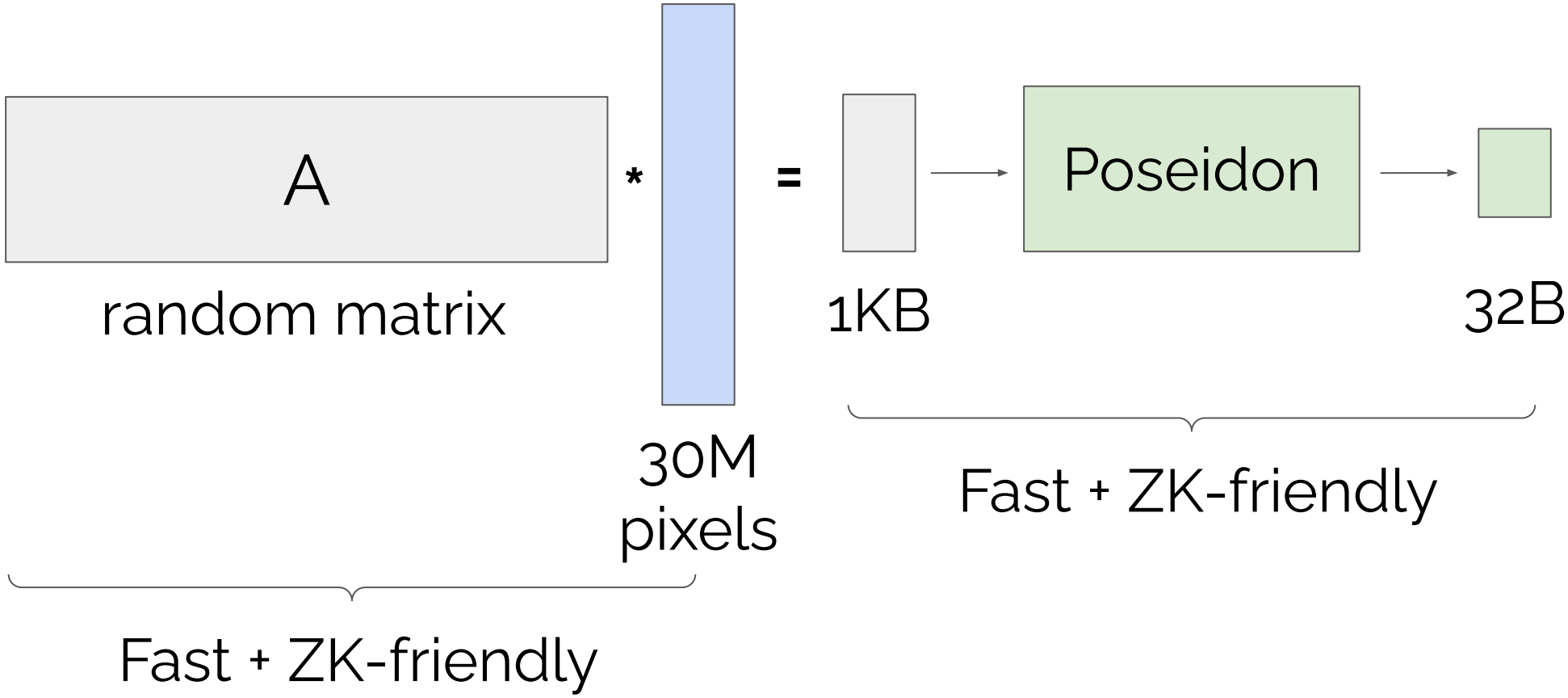


Binding for low-norm input

Challenge: Range-check image pixels

Hash Proving for Weak Signers



Challenge: Range-check image pixels

Range-check Pixels [BCGJM'18, GWC'19, GW'20]

Prove $\vec{x} \in \{0, 1, \ldots, n-1\}^m$

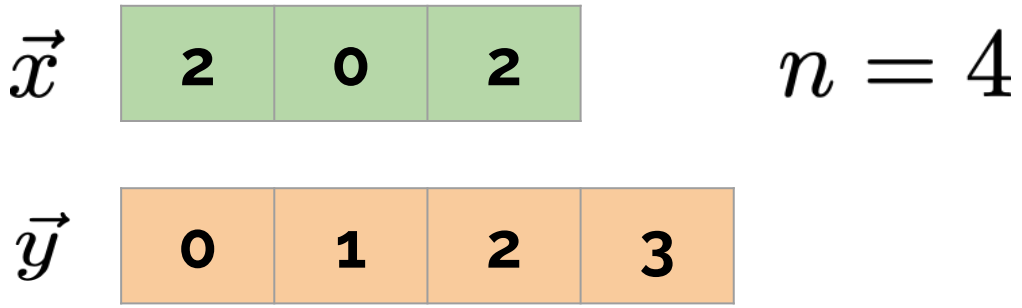
$\vec{x}$ | 2 | 0 | 2 |

$n = 4$

Range-check Pixels [BCGJM'18, GWC'19, GW'20]

Prove $\vec{x} \in \{0, 1, \ldots, n-1\}^m$

- $\vec{y} := [0, 1, \ldots, n-1]$



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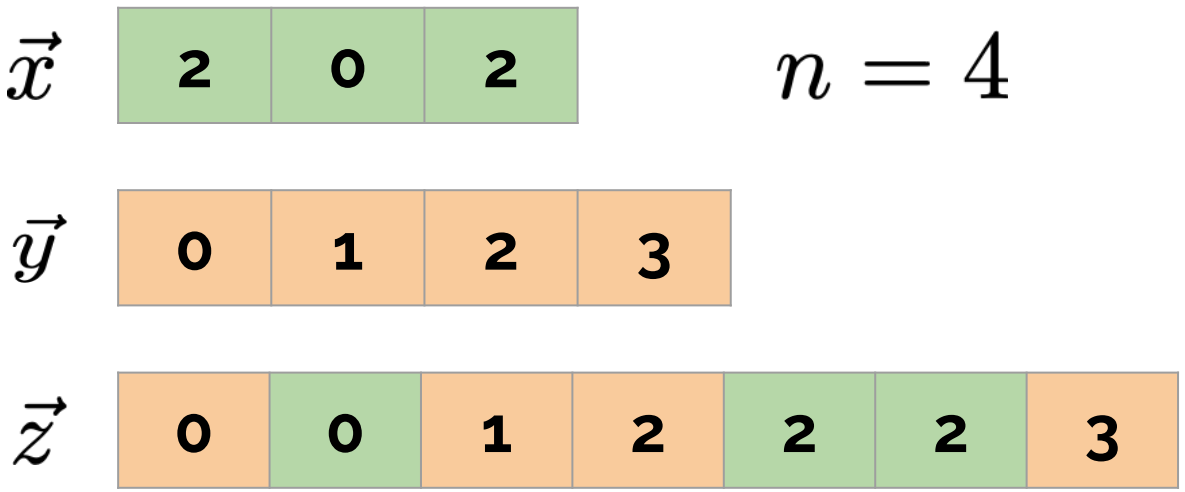
Prove $\vec{x} \in \{0, 1, \ldots, n-1\}^m$

- $\vec{y} := [0, 1, \ldots, n-1]$
- $\vec{z} := \mathrm{sort}(\vec{x} || \vec{y})$



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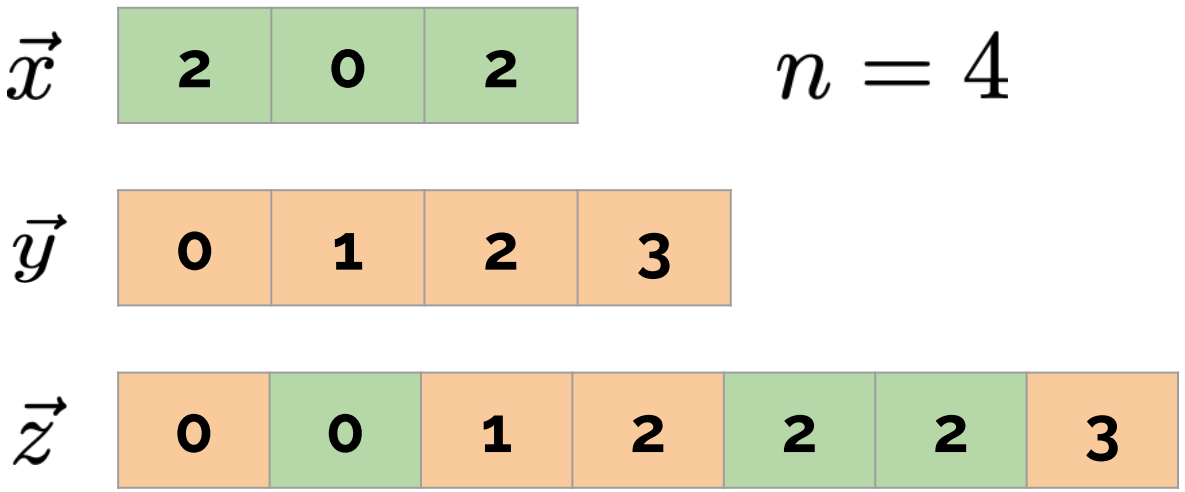


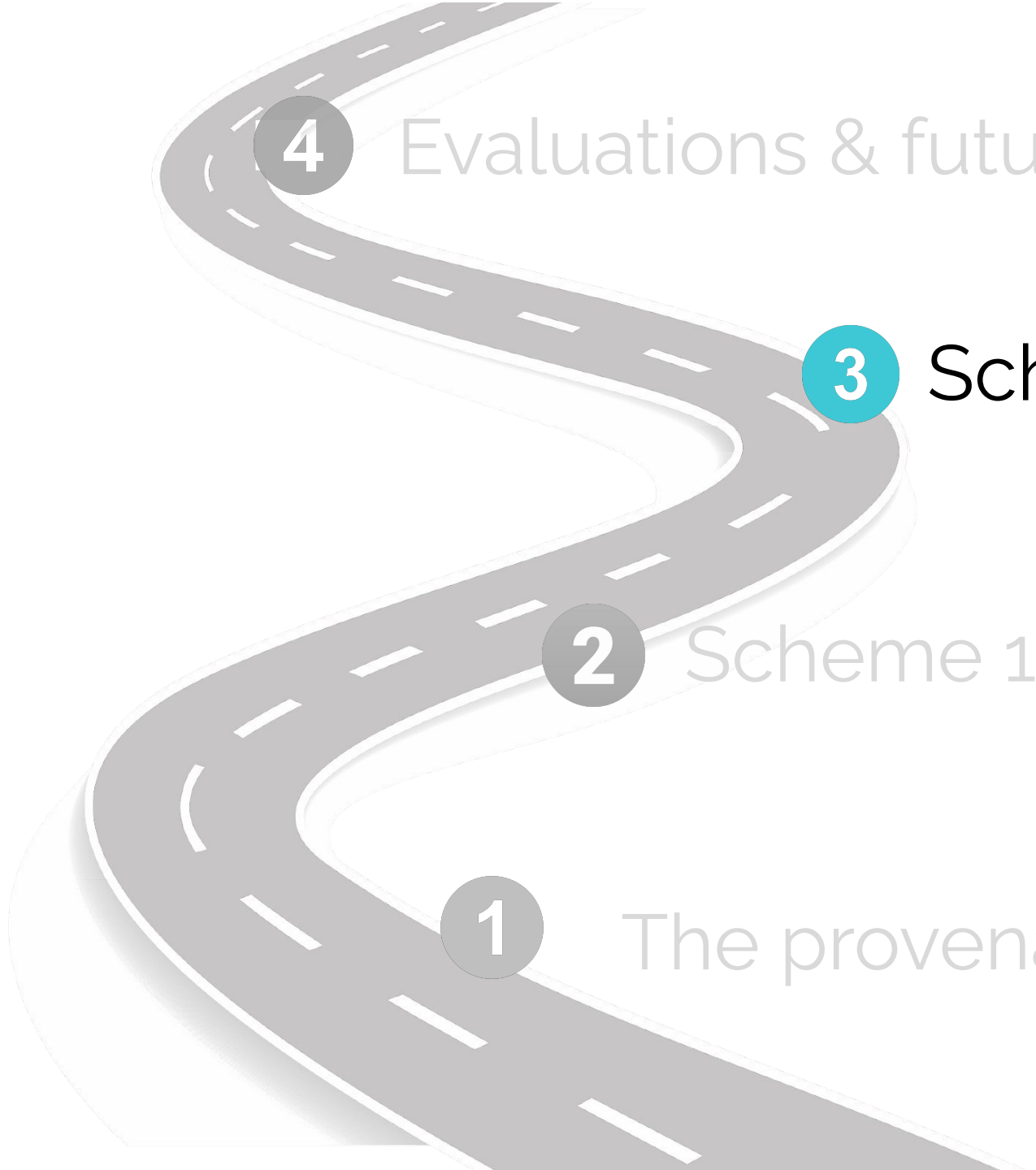
Check

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

Summary

- A lightweight & ZK-friendly signing scheme
- Fit for camera use cases
- Limitation: Hash proving is still the bottleneck

10 mins vs 1 min



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Removing Hash Proving

Scheme 2: Move hashing out from the SNARK circuit

(5~10x proving speedup)

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Building block: Polynomial commitment scheme (PCS)

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- Commit(pp, f(X), r) ⟶ "short" C_f
- EvalOpen(pp, z, y; f, r) ⟶ proof π
  - f(z) = y
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👁 Serve as CRHF

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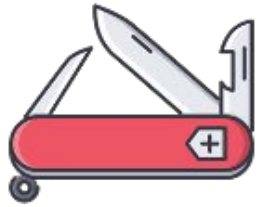


- Commit & open witness

A Commit-and-Prove Scheme

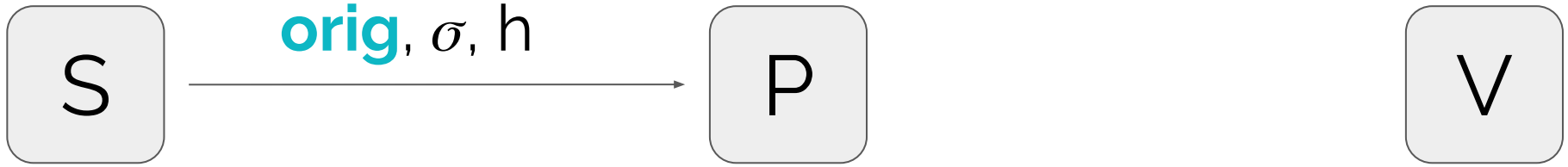
S

P

V

- Create photo **orig**
- h = PCS.Commit(orig)
- σ = Sign(sk, h)

A Commit-and-Prove Scheme



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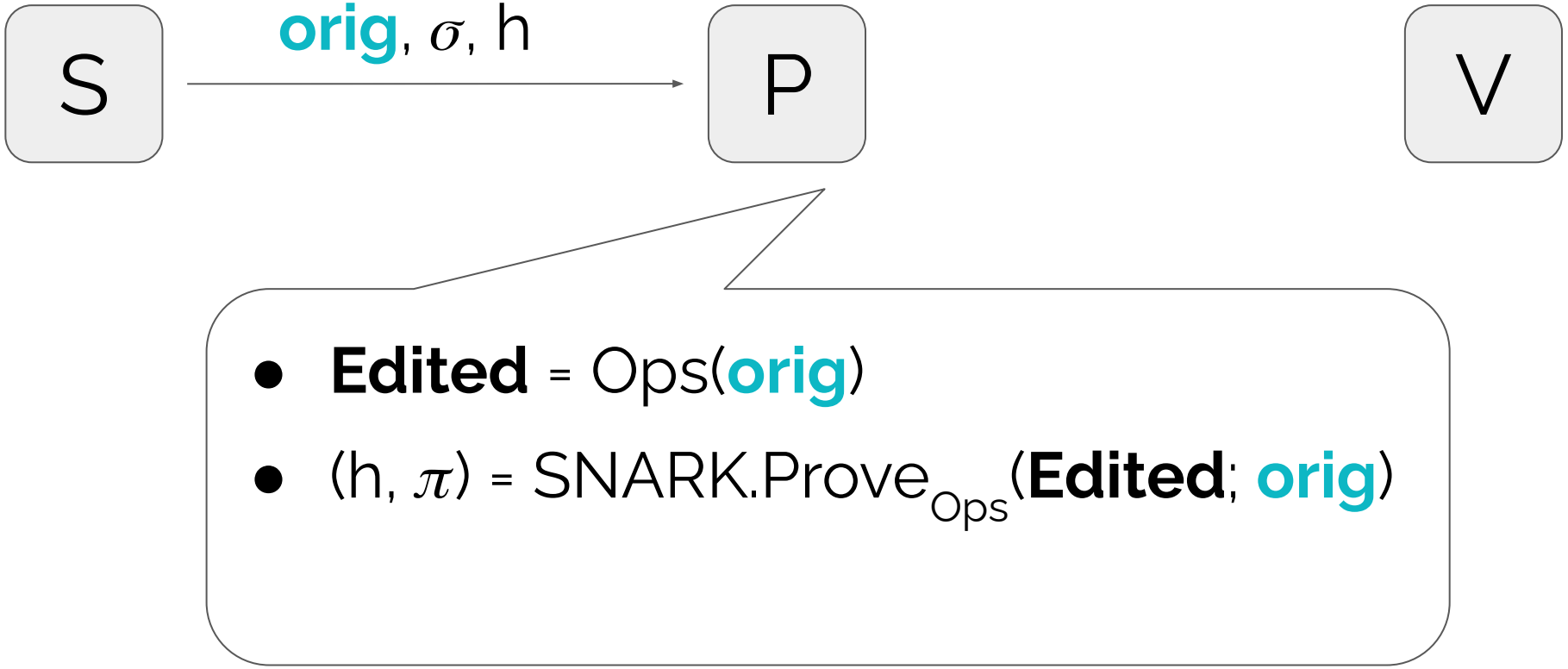

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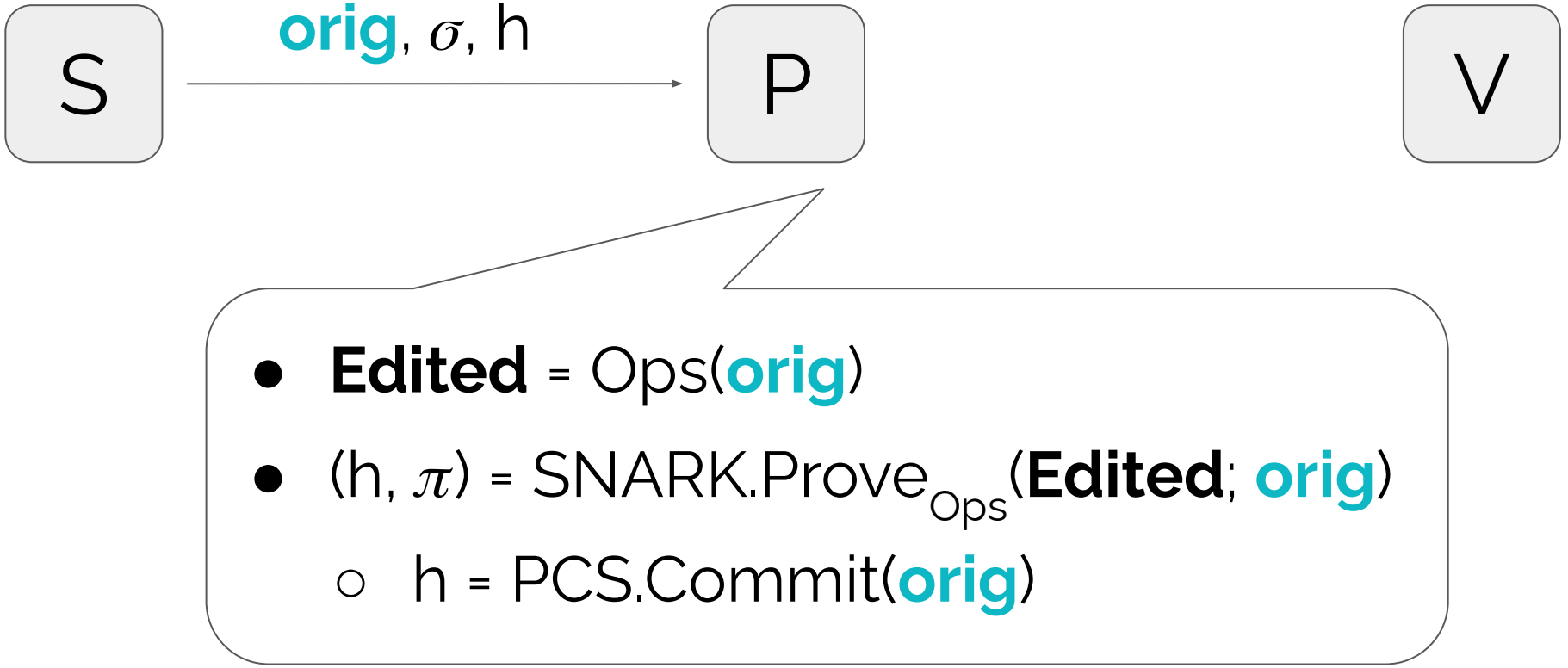

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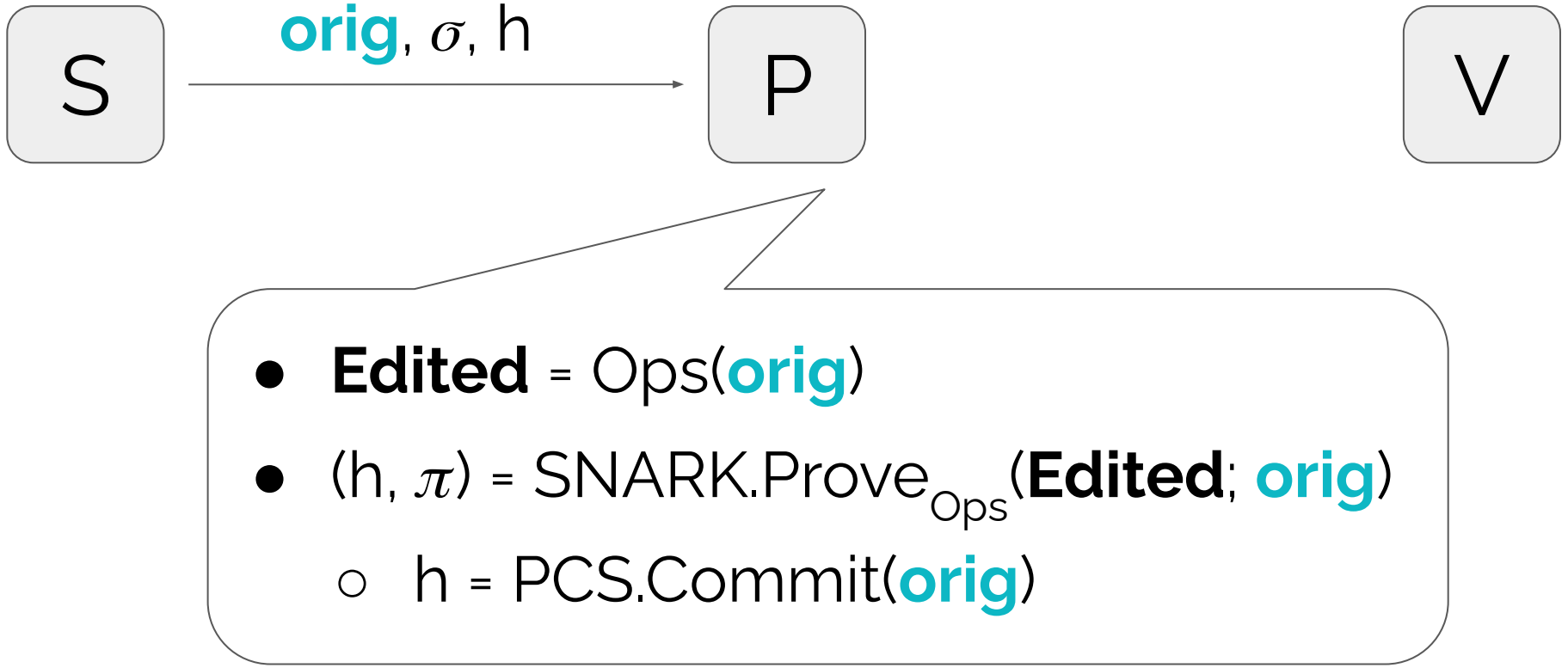
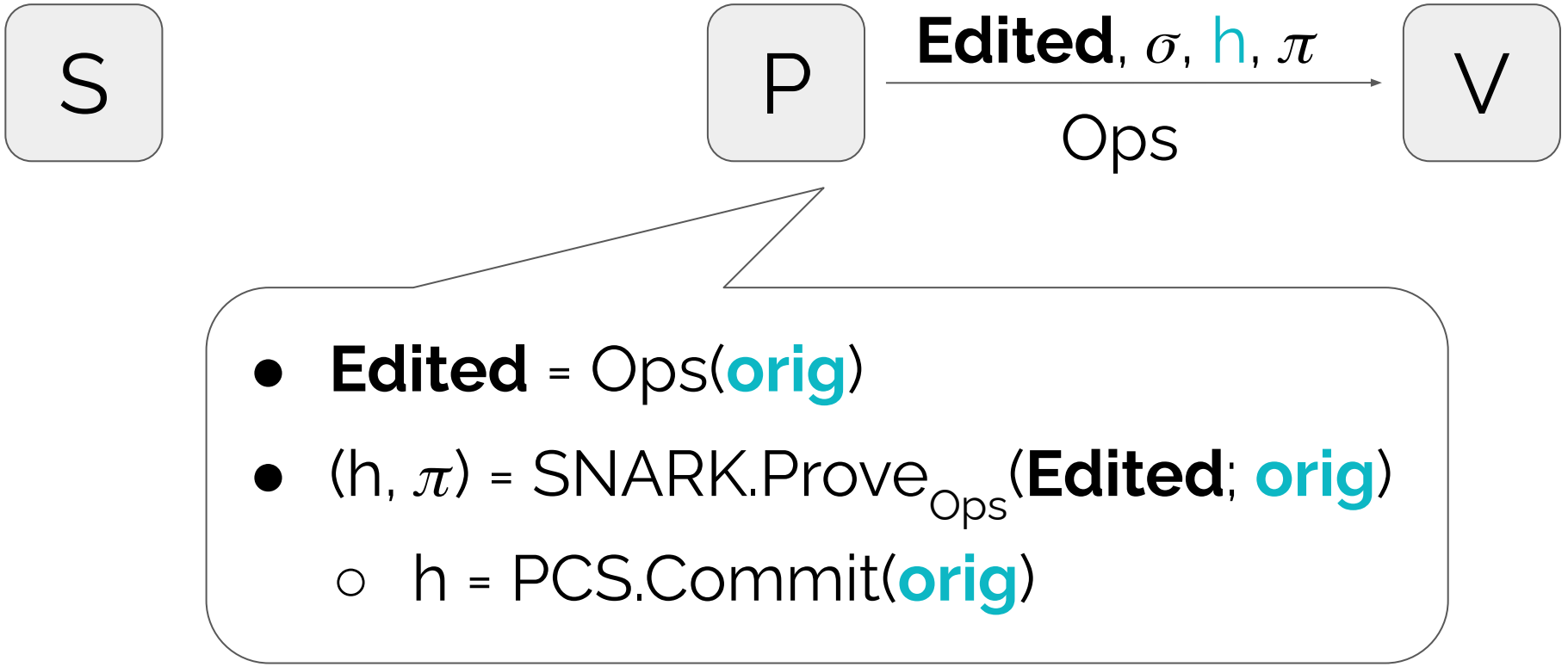


Advantage: Prove the image editing function only

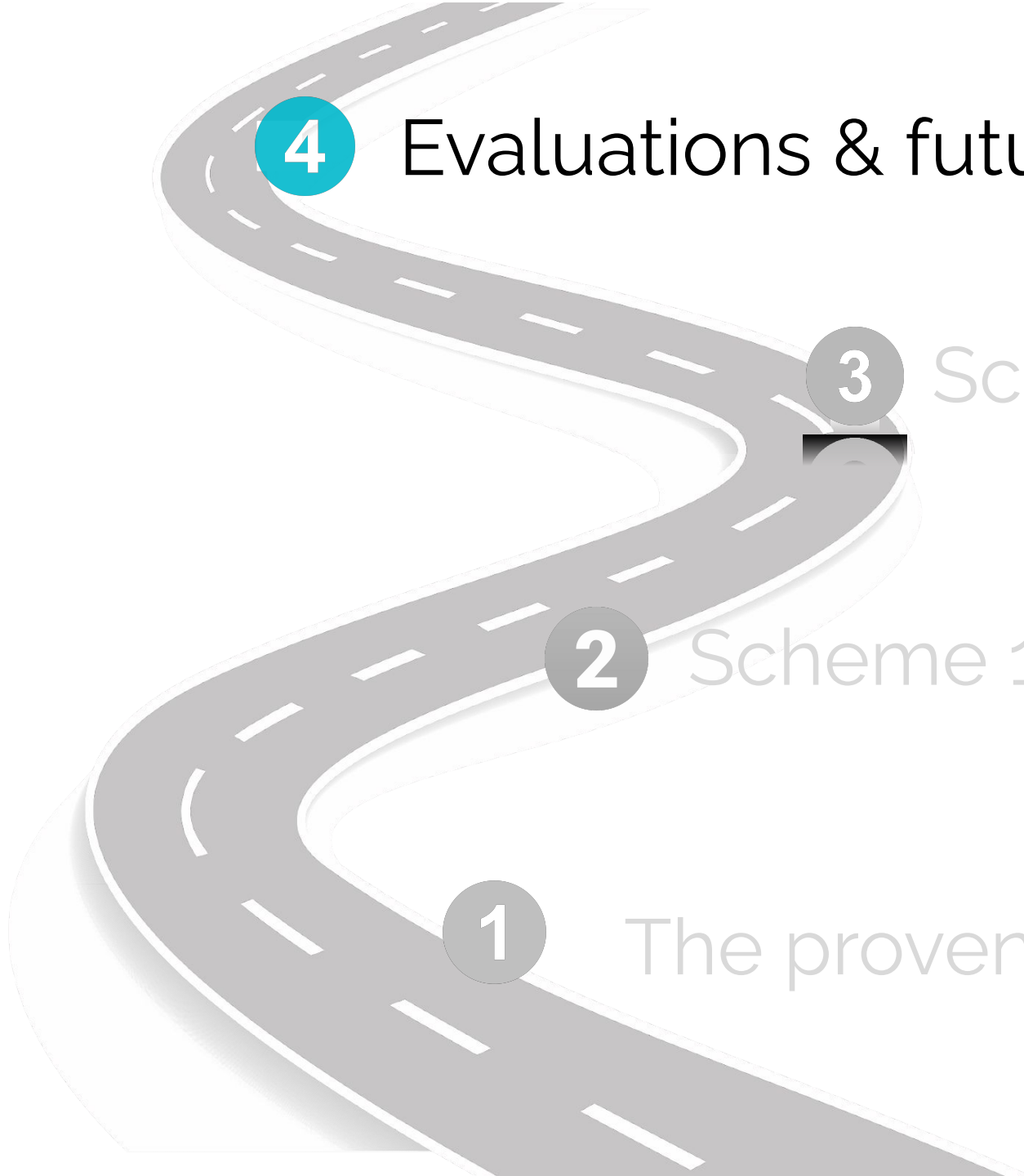
A Commit-and-Prove Scheme



A Commit-and-Prove Scheme

Summary

- A scheme with 5-10x faster proof generation
- Fit for powerful signers (e.g. OpenAI)
- Limitation: Signing is more heavyweight



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Evaluation for 30MP Photos

Photo editing proof:

- 0.93 ~ 4.41 mins / $0.13 on AWS

Lattice hash proof:

- 10.25 mins / $0.41 on AWS (>5x faster than Poseidon)
- ~0.7s (optimized) verification

Plain hashing:

Hashing Scheme	Time (s)	Memory (GB)
SHA256	1.71	0.003
Lattice (64 bit)	4.24	0.003
FRI-PCS	19.84	18.90

Summary & Future Directions

A zkSNARK-based image provenance system

- Supports >90MB images
- **Mode 1:** Lightweight hashing + fast proof generation
- **Mode 2:** Further 5-10x proof generation acceleration

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Future directions

- Lightweight signing without hash proof
- Multi-hop photo editing
- Video transformation


THANKS