Enabling Security in Cloud Storage SLAs with CloudProof

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Motivation

- Cloud storage provides extensive resources, scalability, and reliability

A main concern is security

- Data leakage/corruption due to bugs, hackers, employees
- Many customers perceive security as main concern

Security properties

- Confidentiality (C): only authorized users can read data
- Integrity (I):
  - Each get returns the content put by an authorized user
- Write-serializability (W):
  - Each user committing an update is aware of the latest update to the same block
- Freshness (F):
  - Each get returns the data from the latest committed put

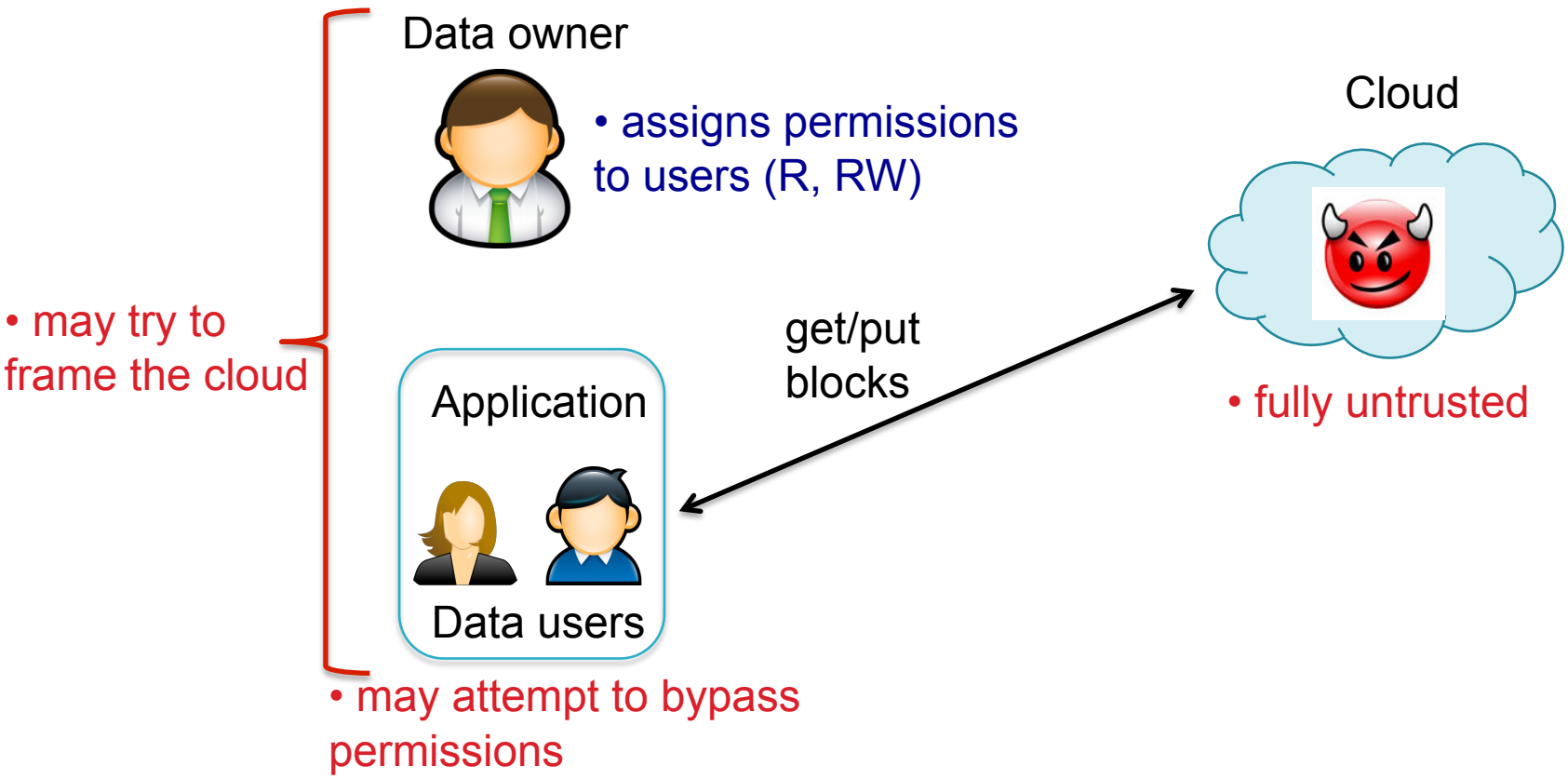
→ Problem: cloud services do not guarantee security in SLAs

→ Need proofs of misbehavior

CloudProof

- A secure storage system for the cloud:
  1. Security mechanisms needed for SLAs with security:
     - Detection of violations for integrity, write-serial., and freshness (IWF)
     - Publicly-verifiable proofs of violation for IWF
       - Any external party can be convinced of cloud misbehavior
       - Users cannot falsely accuse cloud
  2. Scalable design of security mechanisms
     - Scalable access control using modern cryptographic tools

Model


Data owner
• assigns permissions to users (R, RW)
Cloud
• may try to frame the cloud
get/put blocks
Application
Data users
• fully untrusted
• may attempt to bypass permissions

Strawman

Block

Enc_{sk}[content] Version no.
Sig_{SK}[encr. content]

For each block:

- Confidentiality: owner gives a secret key for encryption, sk, to allowed readers
- Integrity: owner gives public key pair for signing, SK, PK to allowed writers

Problems:

- No detection for write-serial., freshness
- No proofs of violation

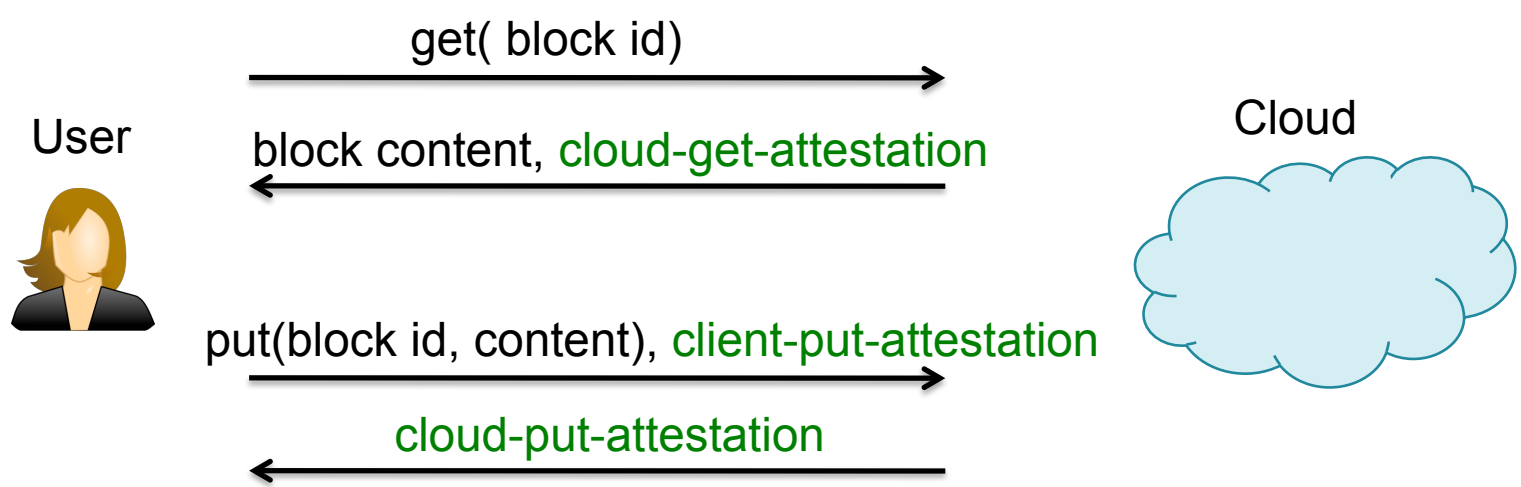
} in this talk

- Access control/key distrib. not scalable

} see paper

Detection and proofs of violation for IWF

- Attestations

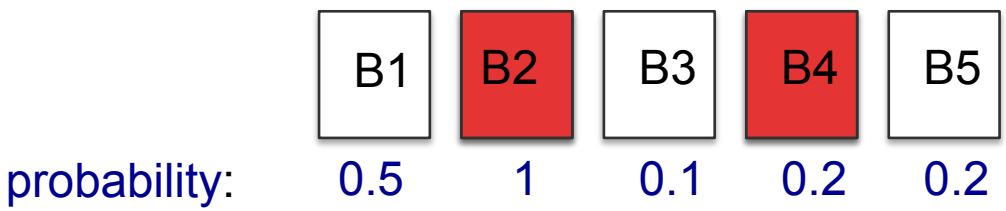


- Proofs verifiable by any outside party
- Non-repudiable signature scheme [Micali et. al.,'99]
- Each party verifies attestation signatures

Auditing

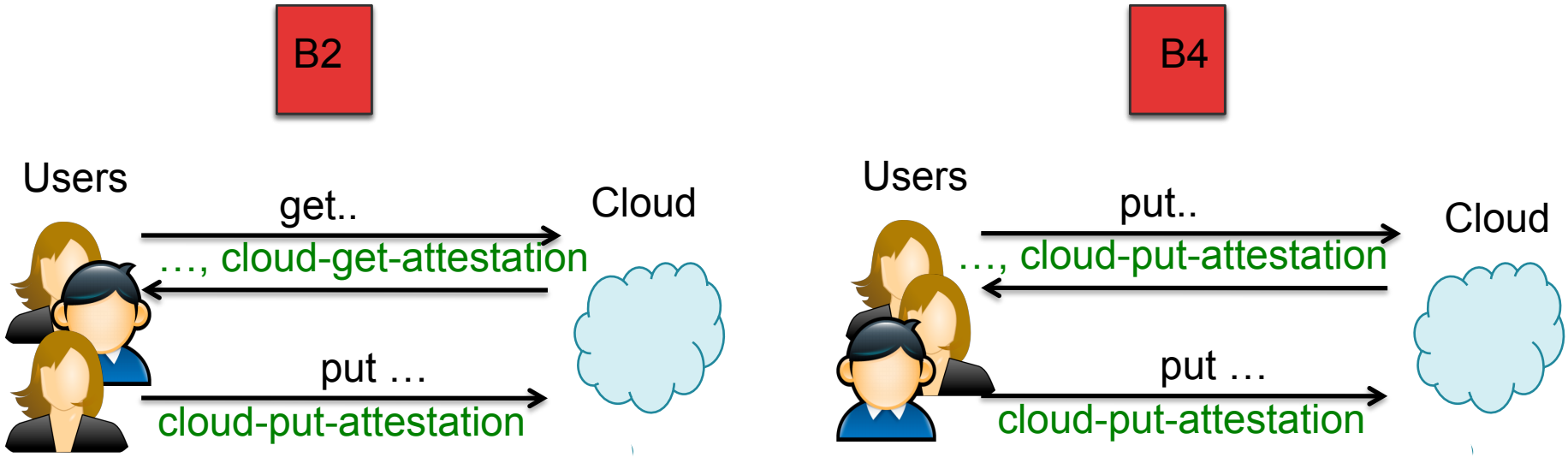
- Integrity: users check attestations from cloud

- W and F: Owner does probabilistic auditing
  - Time divided in epochs (e.g., day)



  - Only owner and authorized users know in which epochs a block is audited

During the epoch



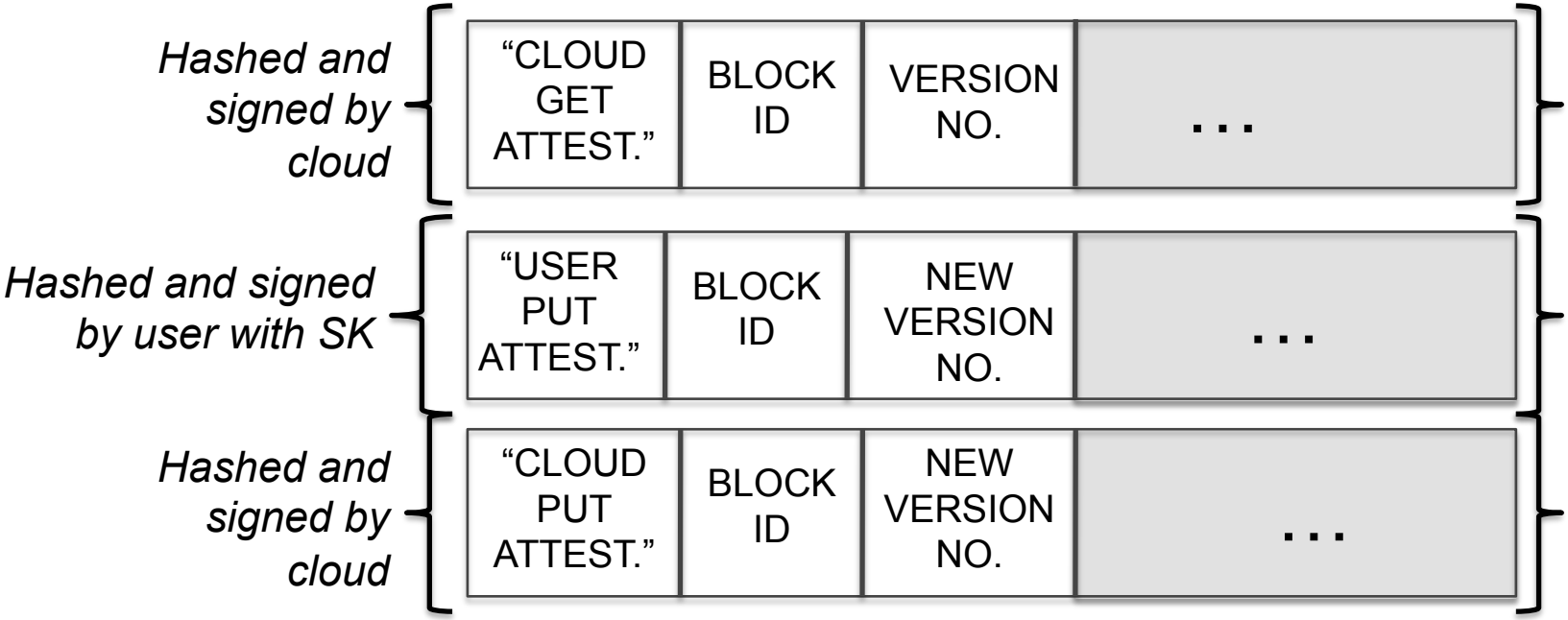
Data owner

cloud-get-attestation
cloud-put-attestation
cloud-put-attestation
cloud-put-attestation

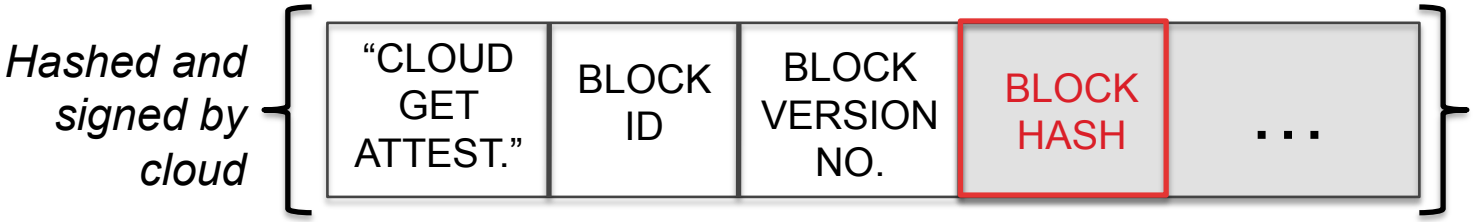
At the end of epoch

- For the blocks to audit:
  - Owner requests all cloud-attestations from the cloud
  - Audits attestations from clients and from cloud
  - Audit guarantees write-serial. and freshness for entire epoch

Attestation Structure



Integrity

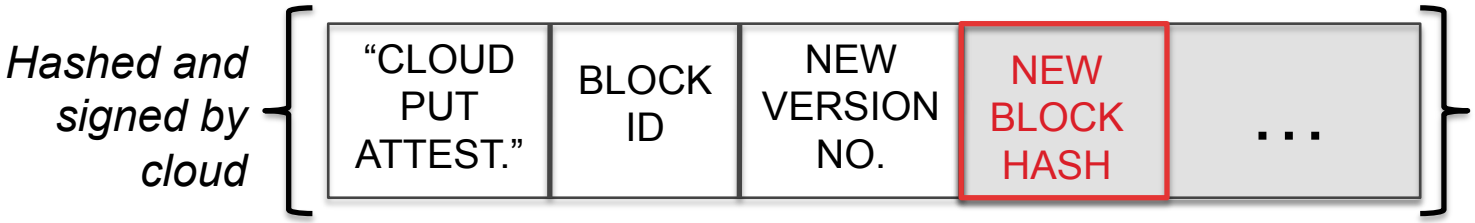


Block

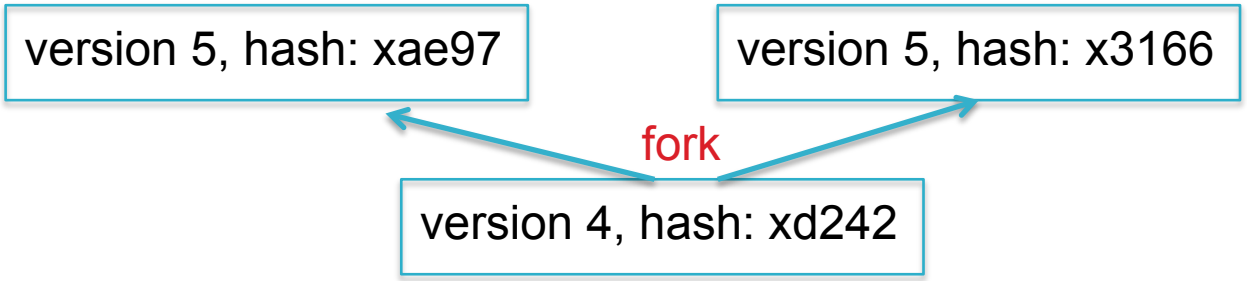
Enc_{sk}[content] version no.
Sig_{SK}[encr. content]

- Detection: signature does not verify
- Proof of violation: attestation

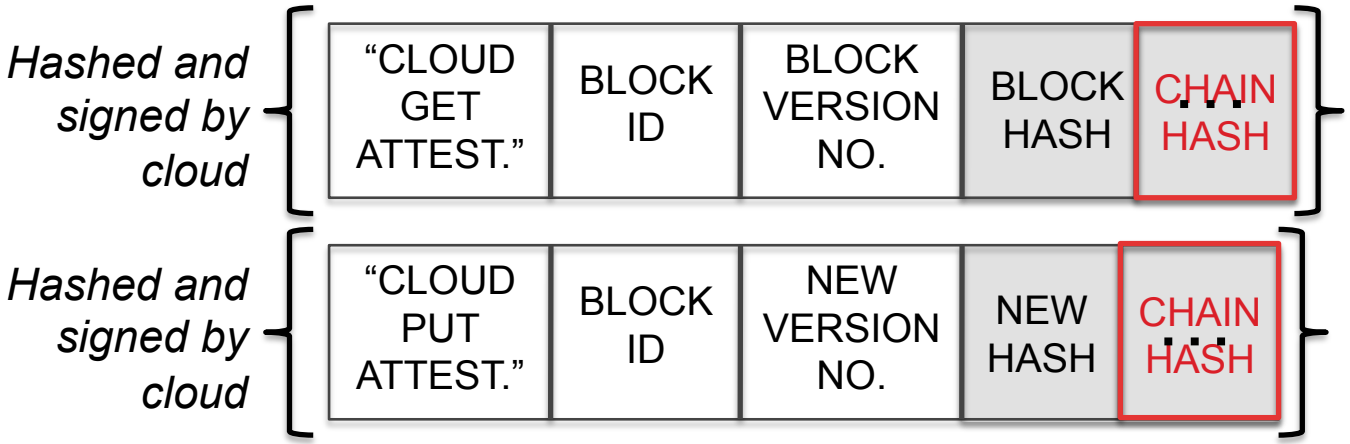
Write-serializability



- Detection: Fork in sequence of put attestations
- Proof of violation: the forked sequence of attestations



Freshness



- chain hash = hash (data in current attestation, previous attestation)
- Detection: attestations do not chain correctly

Freshness (cont'd)

- Detection: attestations do not chain correctly

Users

put: blockid 5, hash x18, …

A1 = (cloud-put-attestation, blockid 5, version 1, hash x18, …)

put: blockid 5, hash x22, …

A2 = (cloud-put-attestation, blockid 5, version 2, hash x22, h(A1, data in A2), …)

Cloud

get: blockid 5

A3 = (cloud-get-attestation, blockid 5, version 1, hash x18, h(A2, data in A3)? Detected!

- Proof of violation: broken chain of attestations

Implementation

- C#, Windows Azure:
  - Storage component: blobs and queues
  - Compute component: web and worker roles

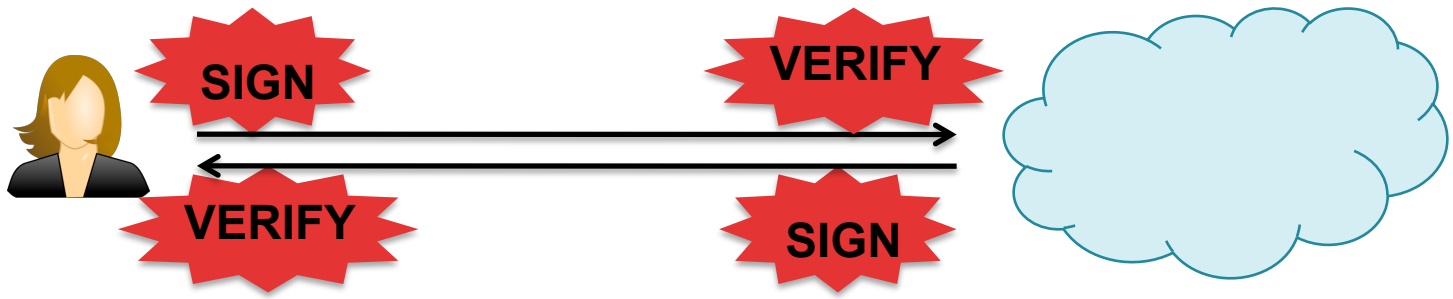
- Four modules: owner, user, cloud, auditor
- .NET crypto tools: AES, SHA-1, RSA

Evaluation

- What is the overhead at users/cloud?
  - Latency/throughput
- What is the workload of the owner?
  - Access control/auditing

User/server overhead

- Mostly from sign-verify of attestations

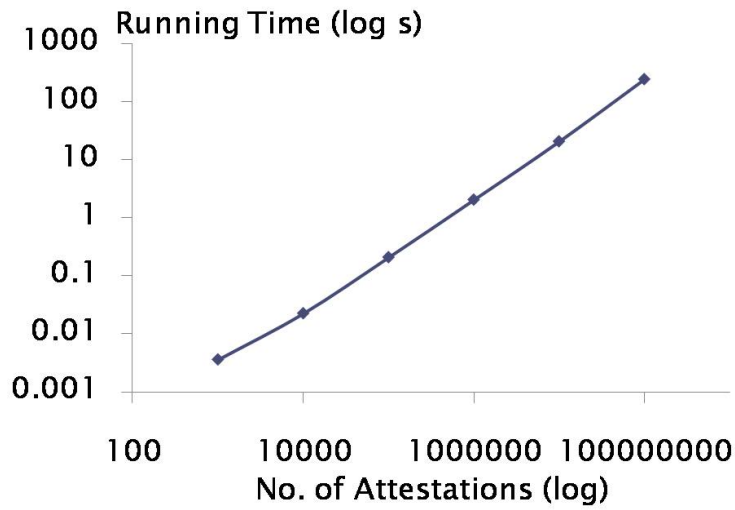


- Delay added per request: 30 ms at server, 40 ms at user
- Can optimize: e.g., batch many attestations in one signature using a Merkle hash

- Throughput scales roughly linearly at server

Owner work

- Two offline tasks:
  - Key distrib.: for a widely-used software with > 5000 developers, membership changes take <1.6 sec/month
  - Auditing cost is modest and parallelizable



• 4 min for 10^8 attestations

- Detection probability increases exponentially in no. of epochs of violation

Related work

- Secure file/storage systems (e.g., SiRiUS, SUNDR, Plutus):
  - No proofs of violation
  - No W and F detection due to different model
  - Access control not as scalable
- Proofs of retrievability/possession (e.g., POR, HAIL)
- Byzantine fault tolerance (e.g., BFT)

Conclusions

- CloudProof is a secure storage system for the cloud:
  - Detection of WF via auditing
  - Proofs of violation for IWF via attestations
  - Scalable access control using broadcast encryption

Thanks!