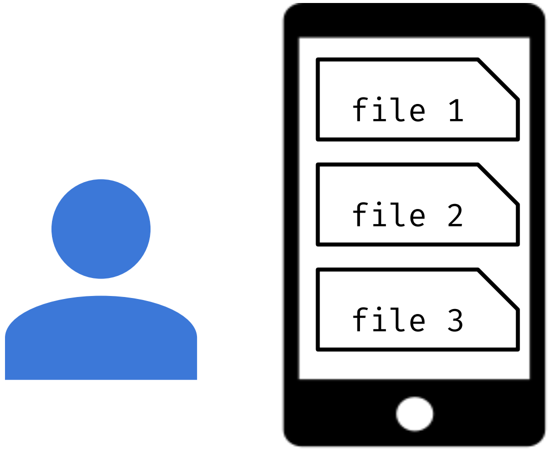
BurnBox

Self-Revocable Encryption in a World of Compelled Access

Nirvan Tyagi Muhammad Haris Mughees Thomas Ristenpart Ian Miers

Usenix Security 2018

Compelled Access Setting



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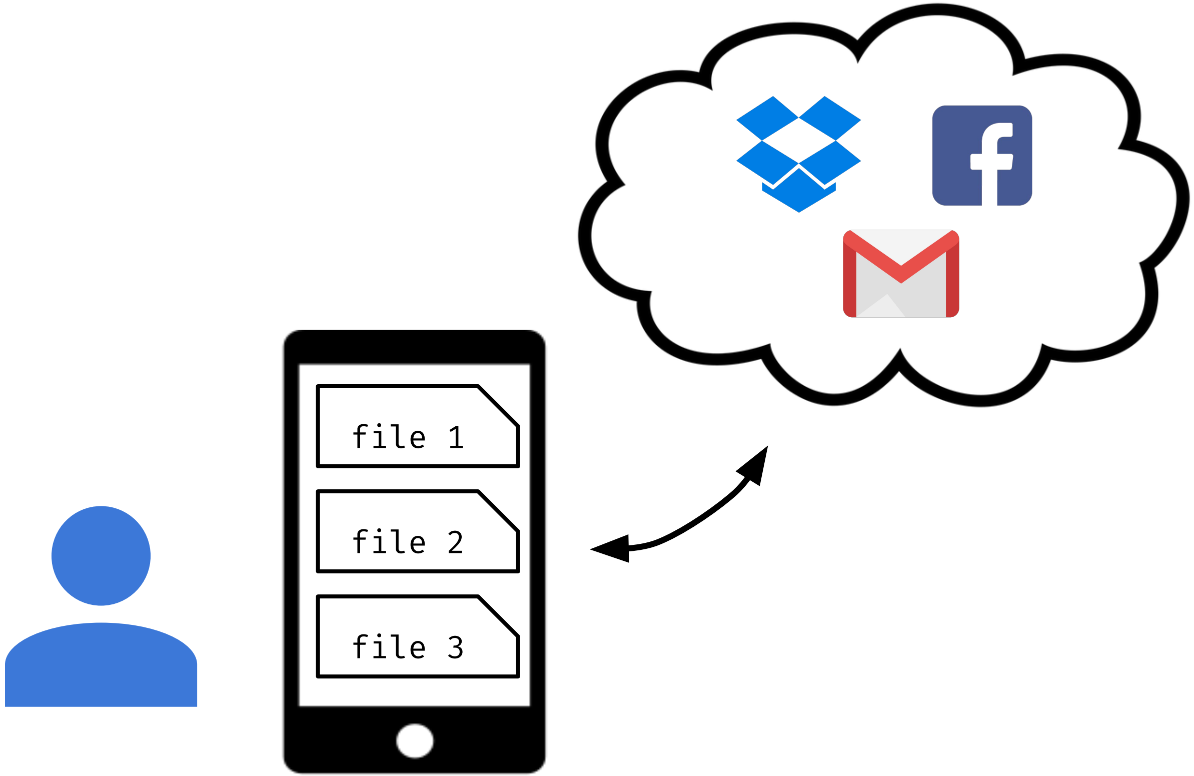

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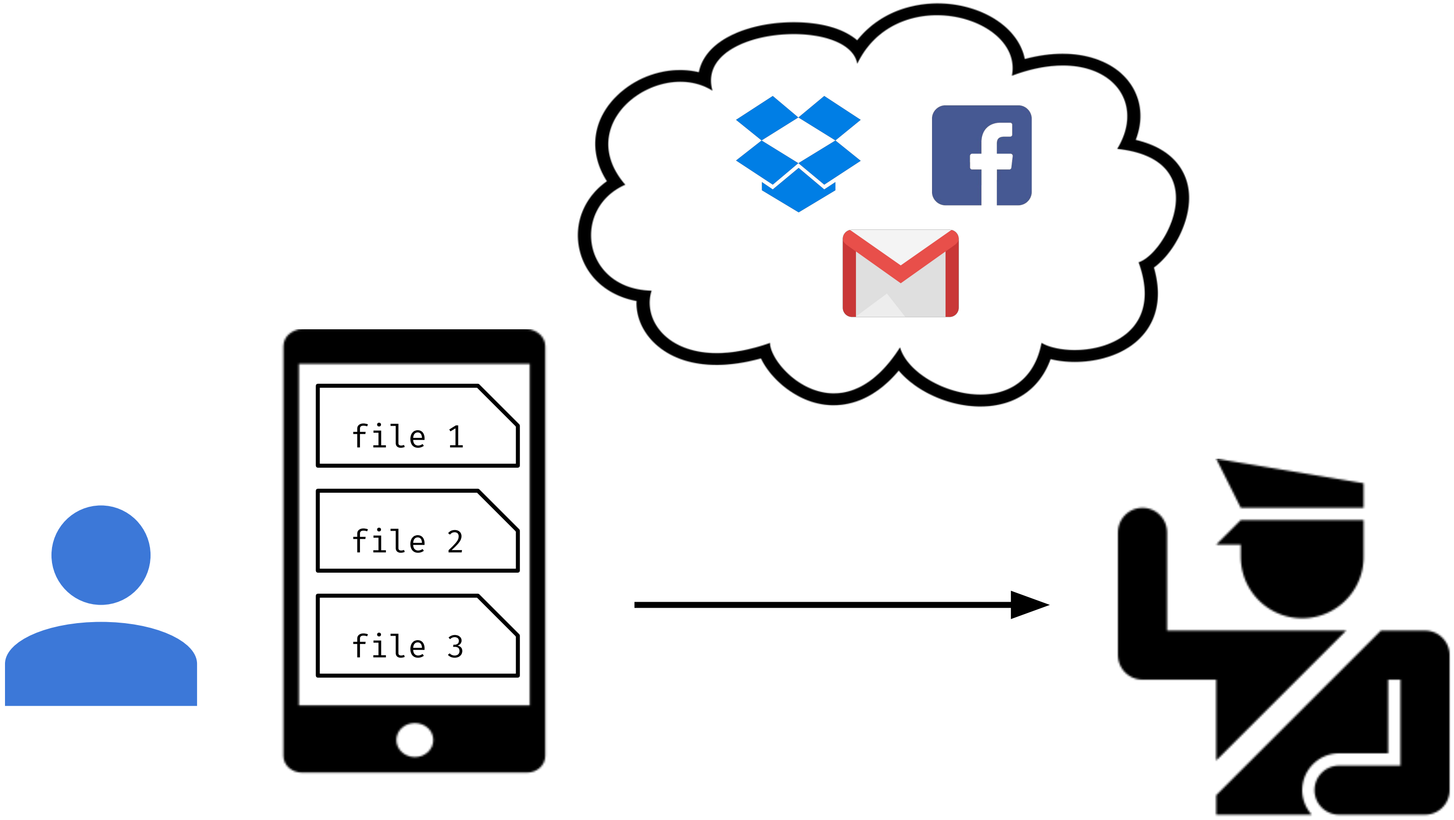

e.g.,
border crossing,
airport security,
police checkpoints

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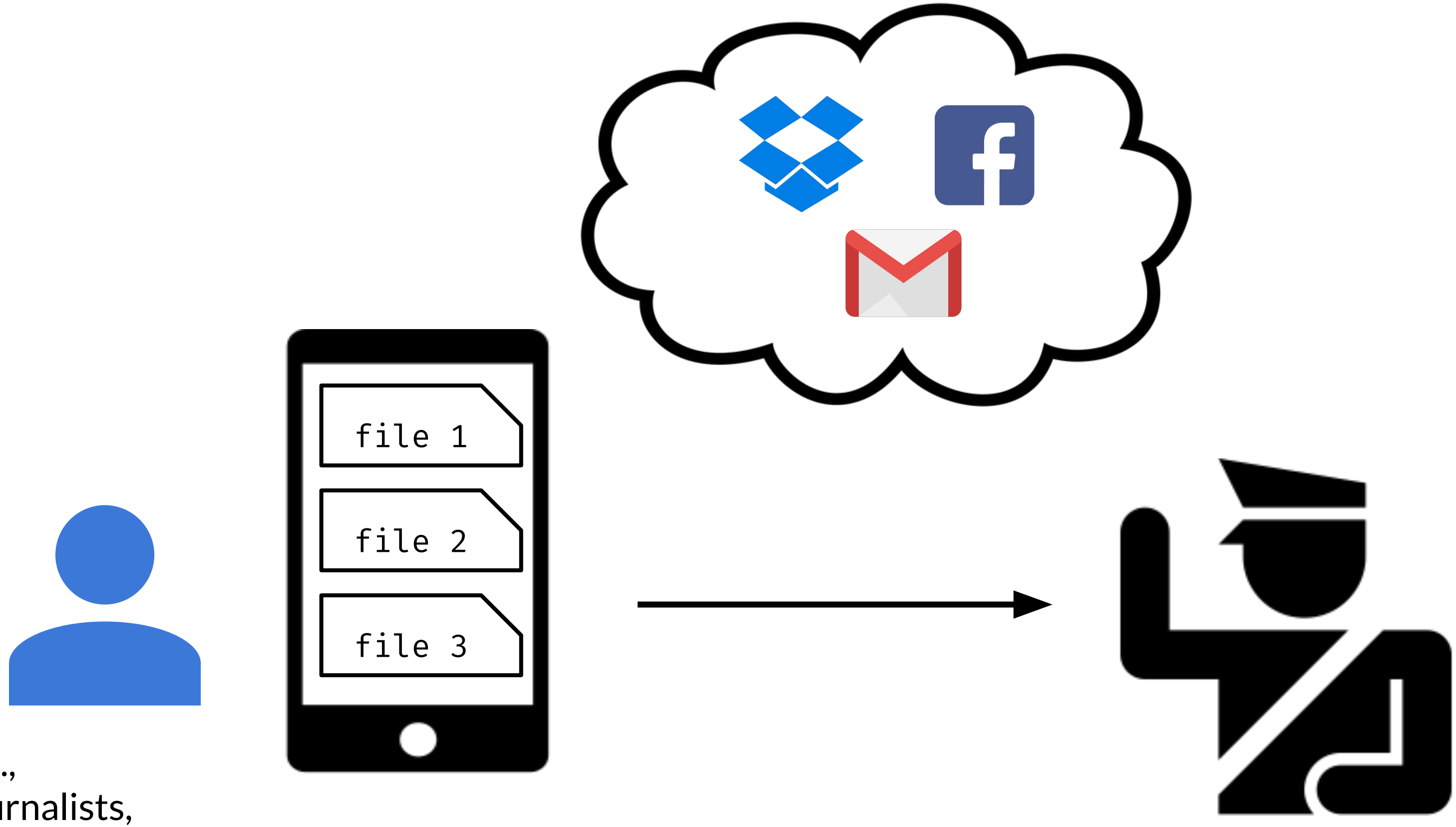

e.g.,
journalists,
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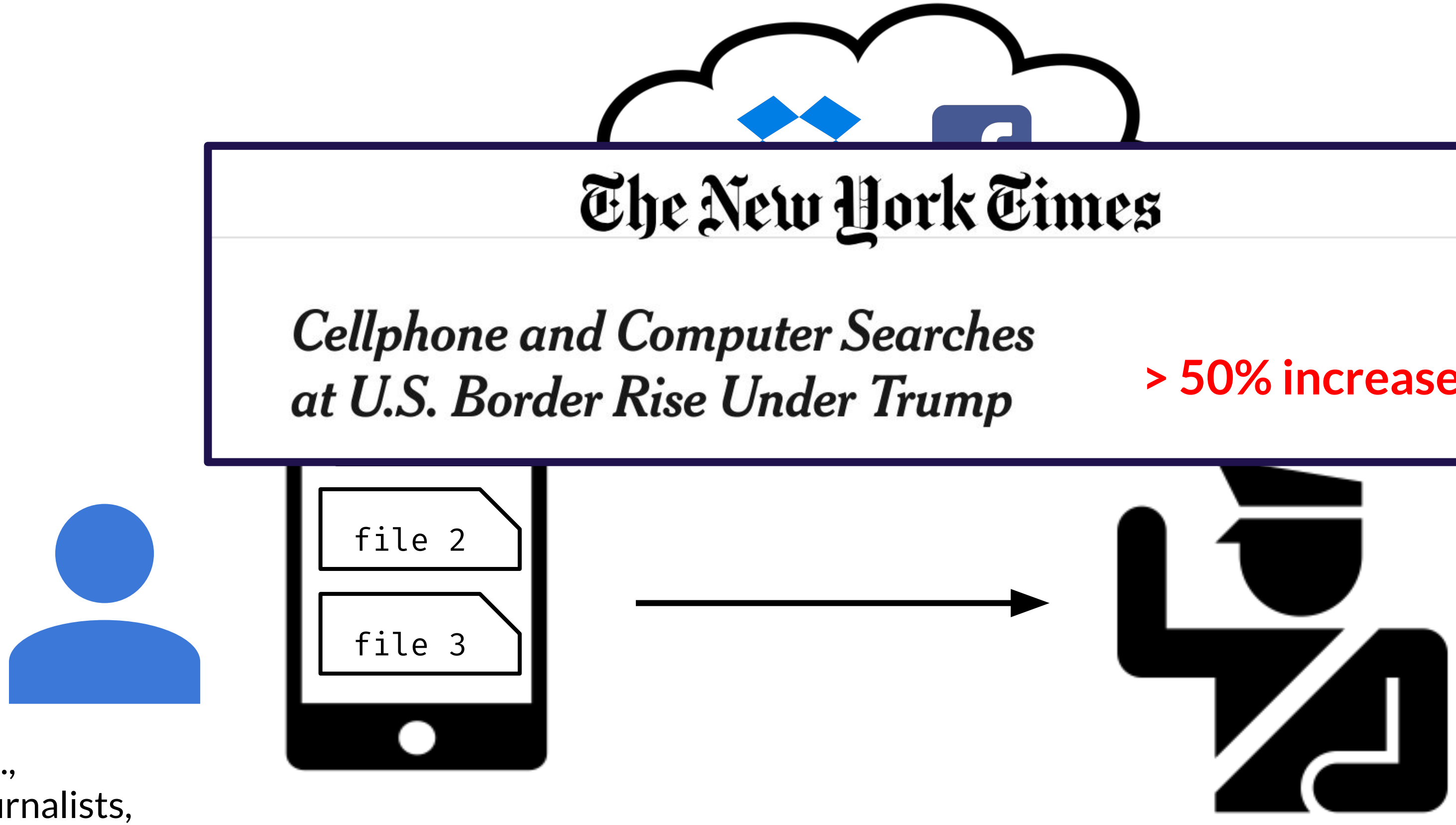

The New York Times

Cellphone and Computer Searches at U.S. Border Rise Under Trump

> 50% increase

e.g.,
journalists,
dissidents, activists

e.g.,
border crossing,
airport security,
police checkpoints

Contributions

- BurnBox: Cloud storage secure in compelled access setting
  - Allow users to honestly comply with authorities while preserving confidentiality
  - Secure deletion: permanently delete files
  - Temporary revocation: self-revoke access to files temporarily
- Formal compelled access security notions and analysis
- Proof-of-concept prototype

Deniable/Steganographic file systems hide files by deceiving authority

[CDNO96, ANS98, ADW97, Truecrypt]

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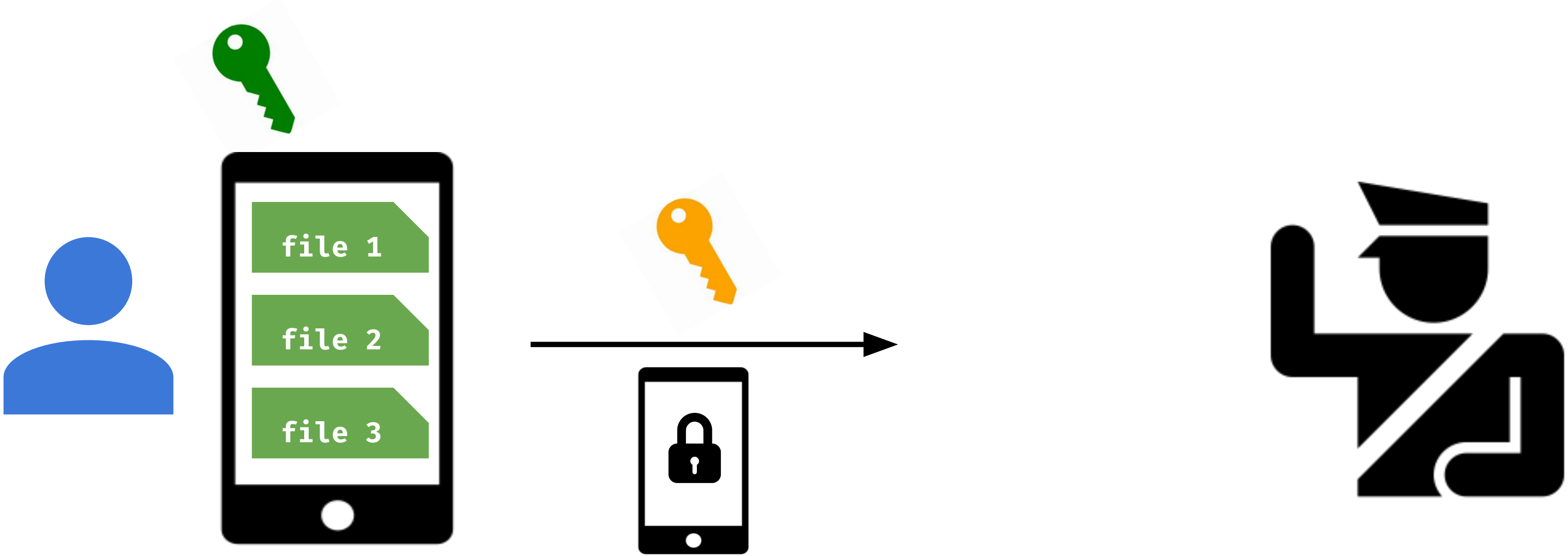

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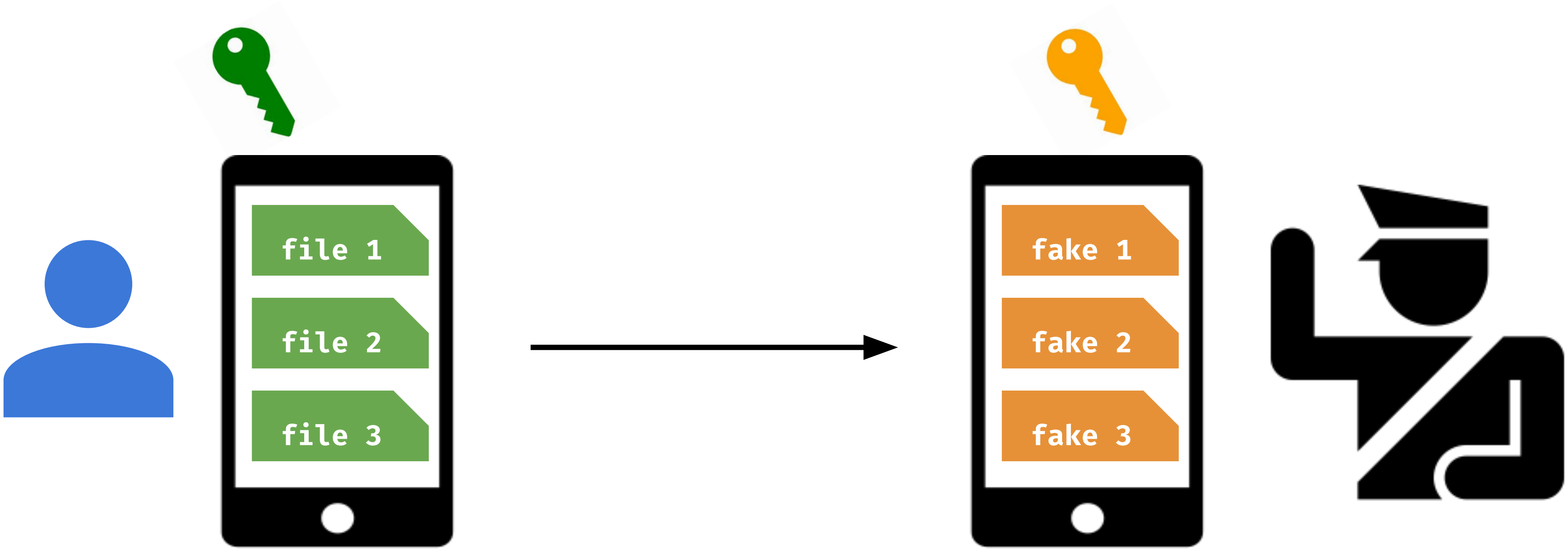

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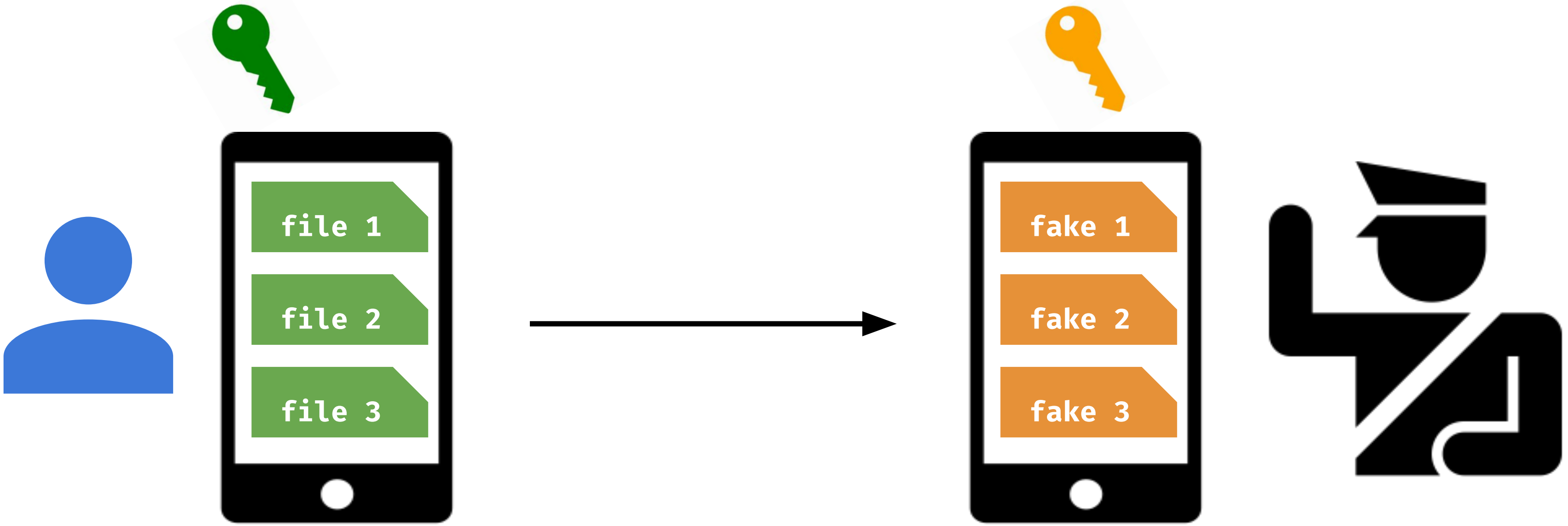
Limitation: High usability burden where deception is inherent to security

- Maintenance of “realistic-looking” fake content
- Ability to convincingly lie about duress key



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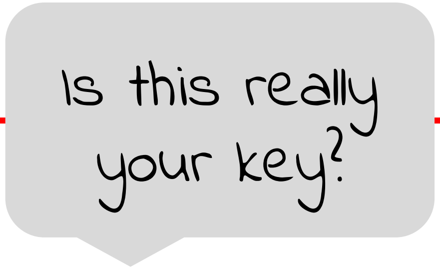

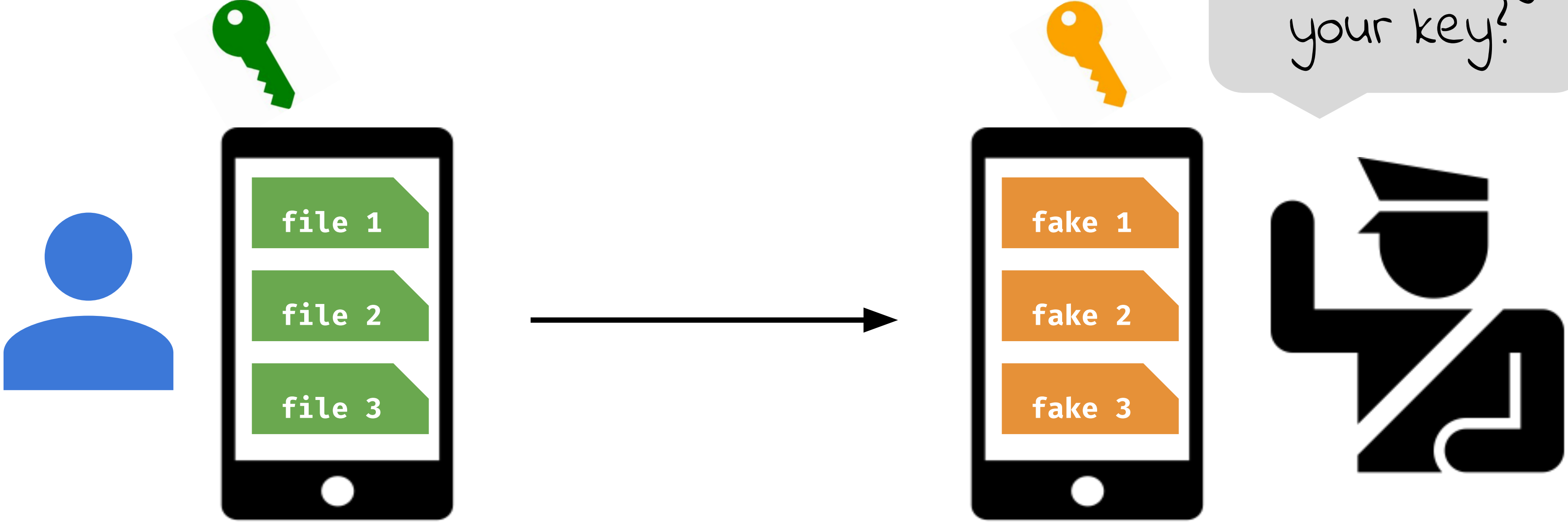

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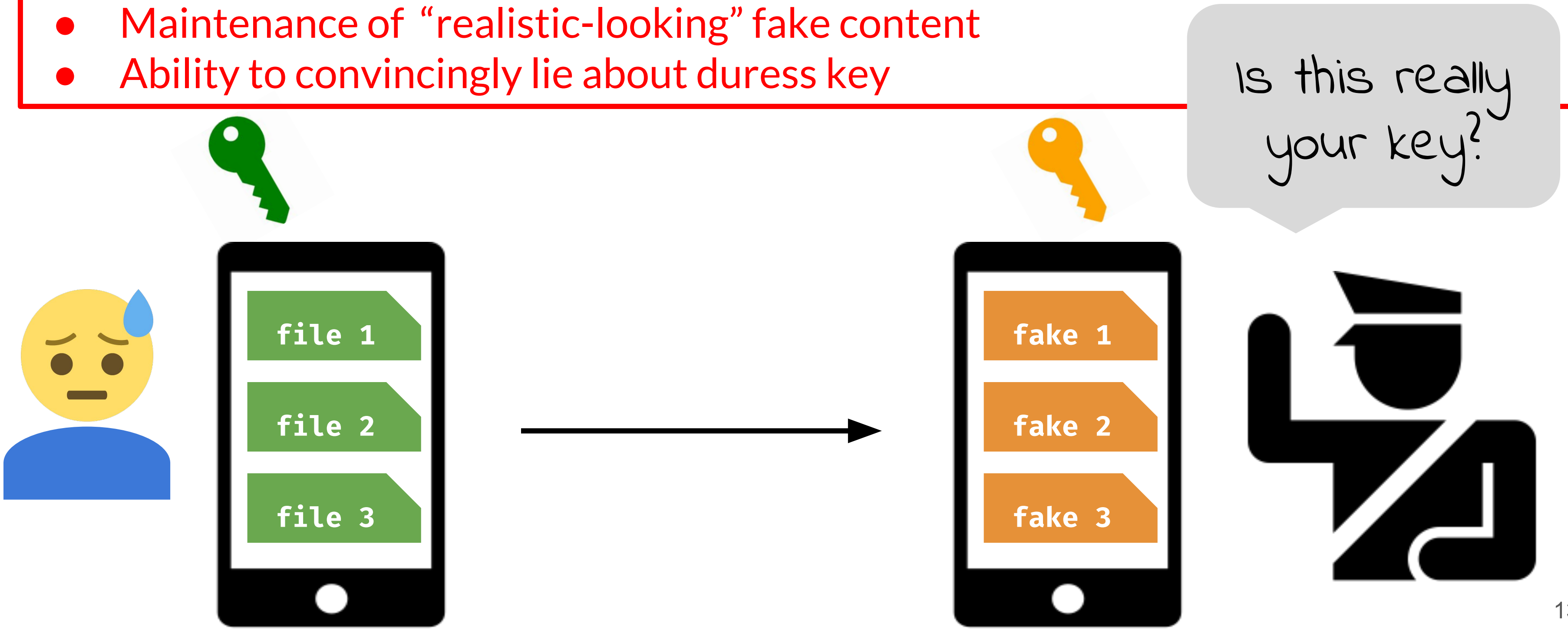

A Different Approach

1. Allow users to honestly comply at compelled access checkpoints

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    Strawman: burner device or full wipe of device

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    BurnBox: selective temporary self-revocation of sensitive files

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    Strawman: burner device or full wipe of device

    BurnBox: selective temporary self-revocation of sensitive files

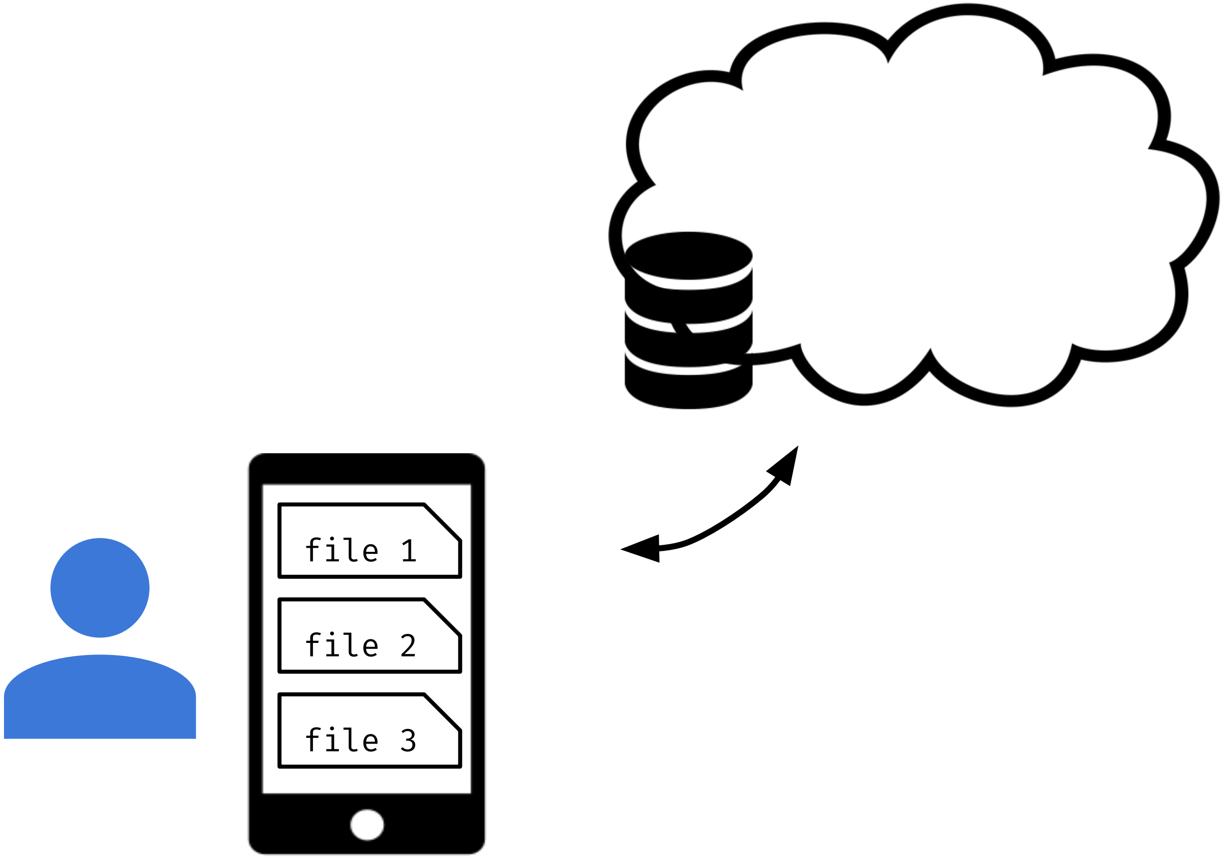
2. Designed specifically for use with the cloud

    BurnBox: secure against passive cloud adversaries

Threat Model

Untrusted Cloud Storage

- Write-only store
- Passive attacker



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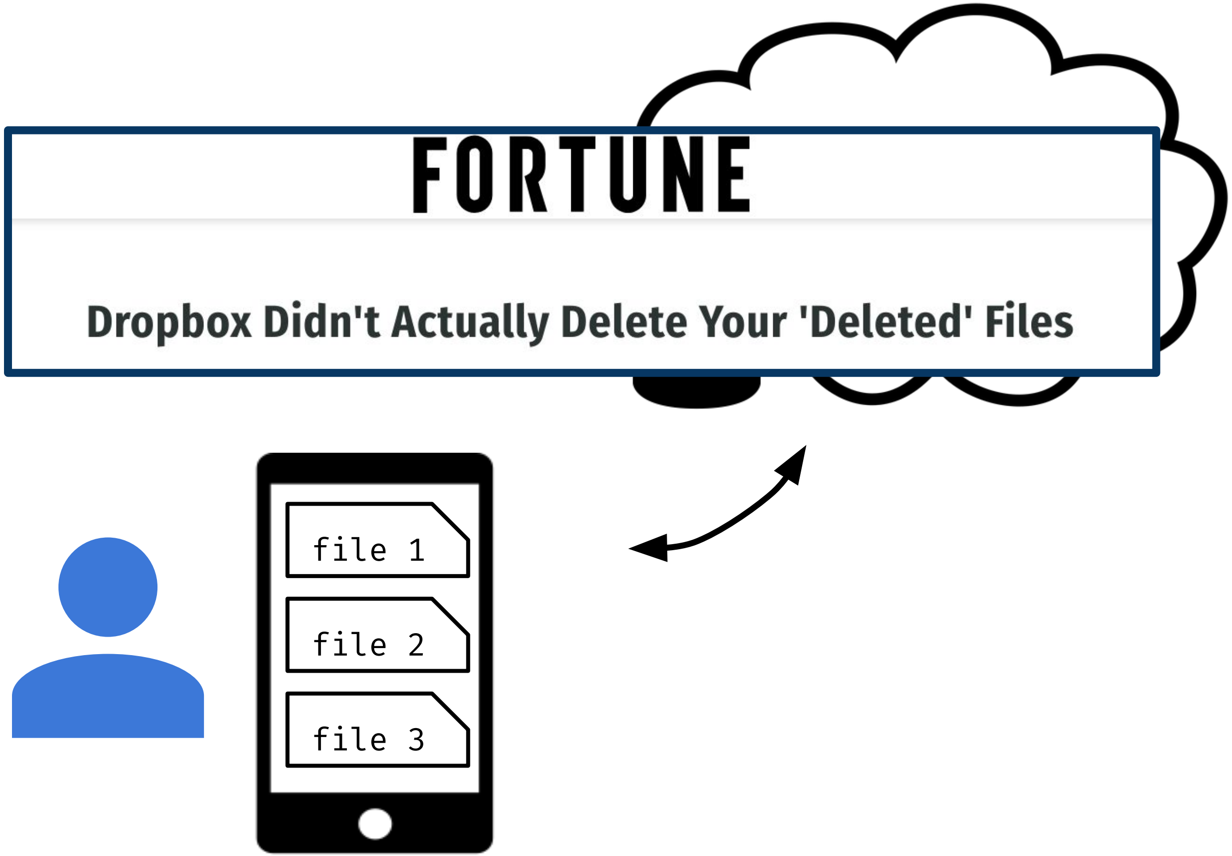

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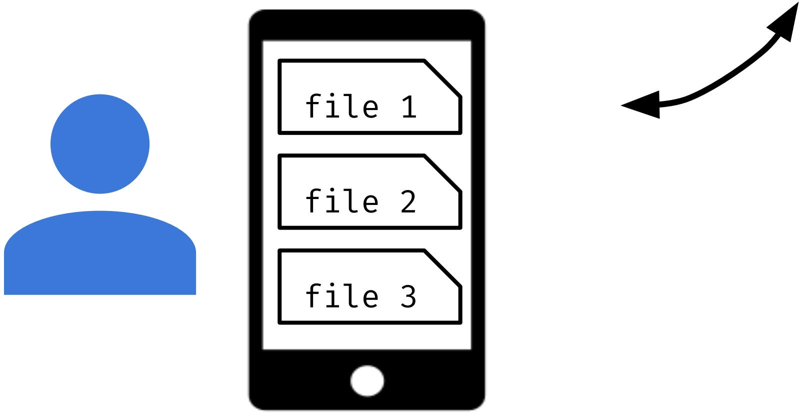
FORTUNE

Dropbox Didn't Actually Delete Your 'Deleted' Files



The Washington Post

Investigations

U.S., British intelligence mining data from nine U.S. Internet companies in broad secret program

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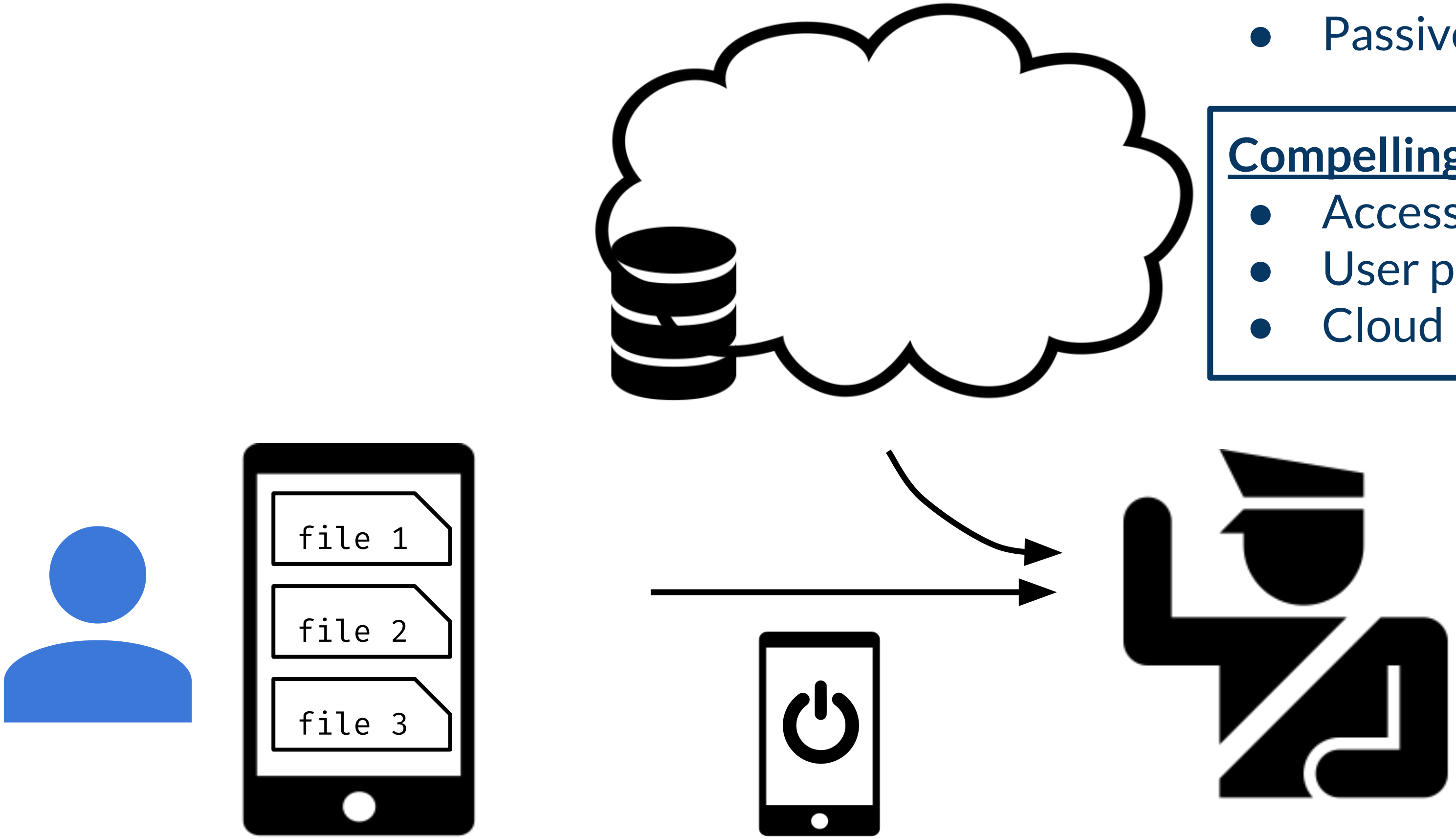
Compelling Agent

- Access to local device
- User passwords
- Cloud history



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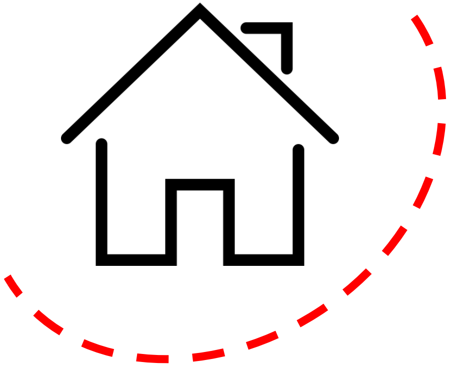

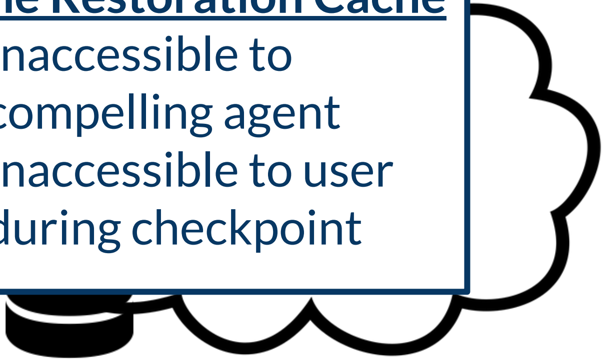

Offline Restoration Cache

- Inaccessible to compelling agent
- Inaccessible to user during checkpoint

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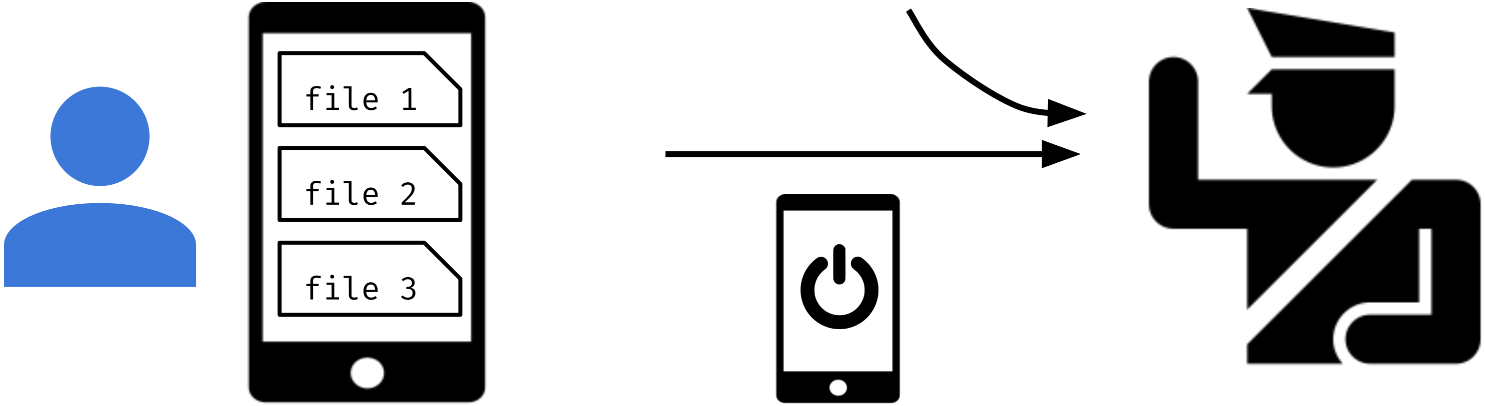
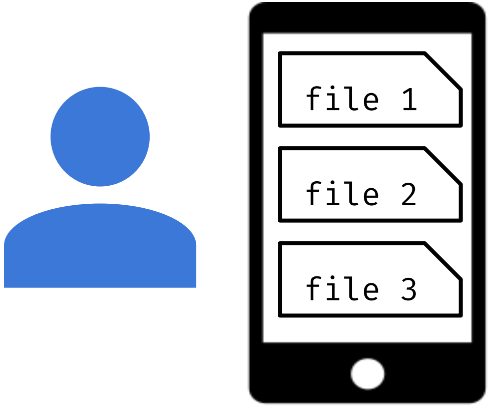


BurnBox Overview



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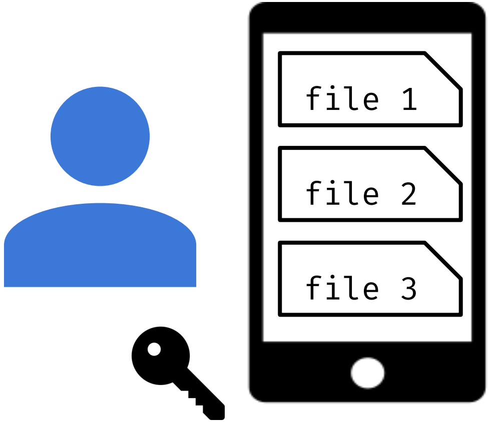
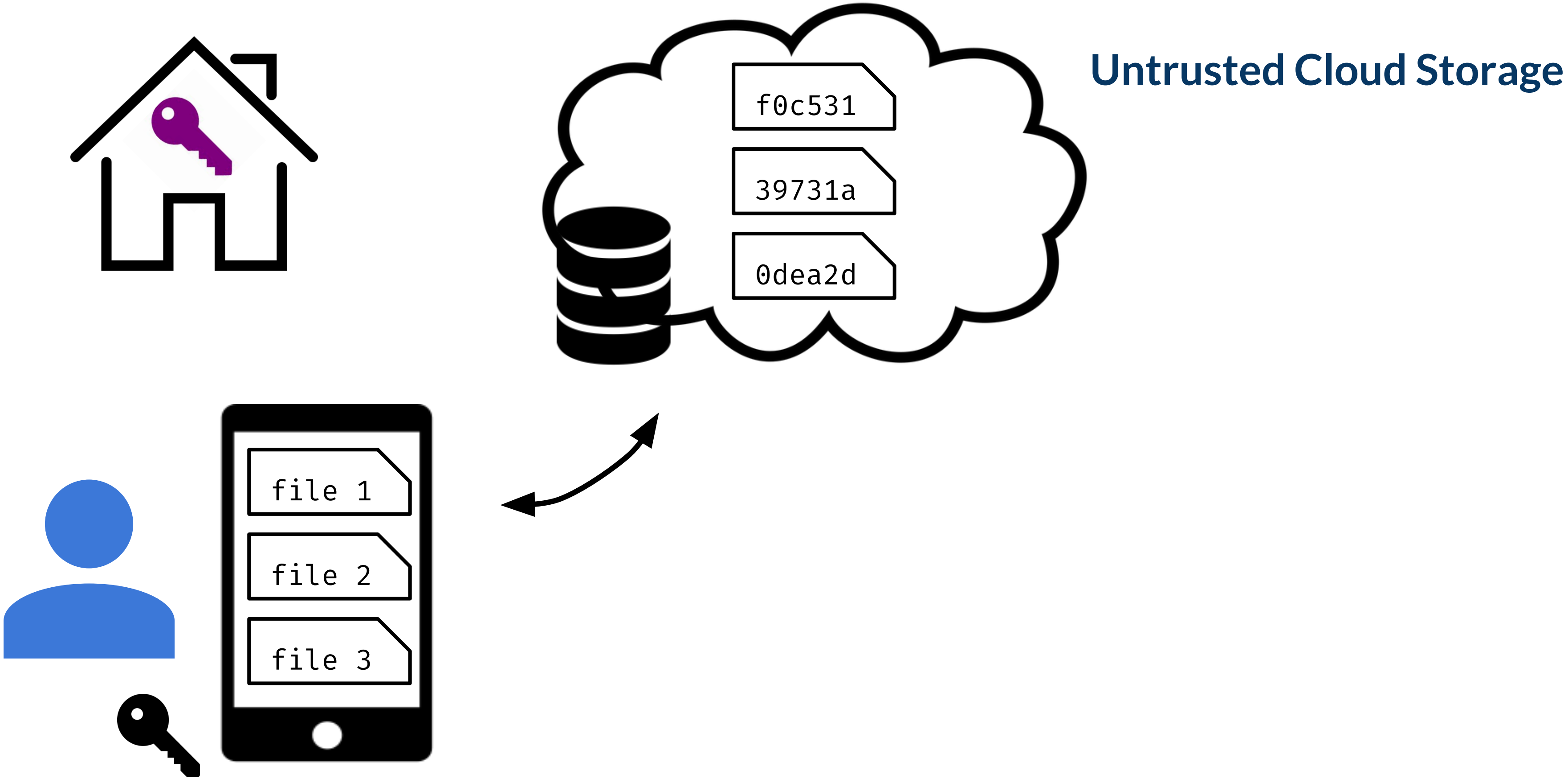


Local Device

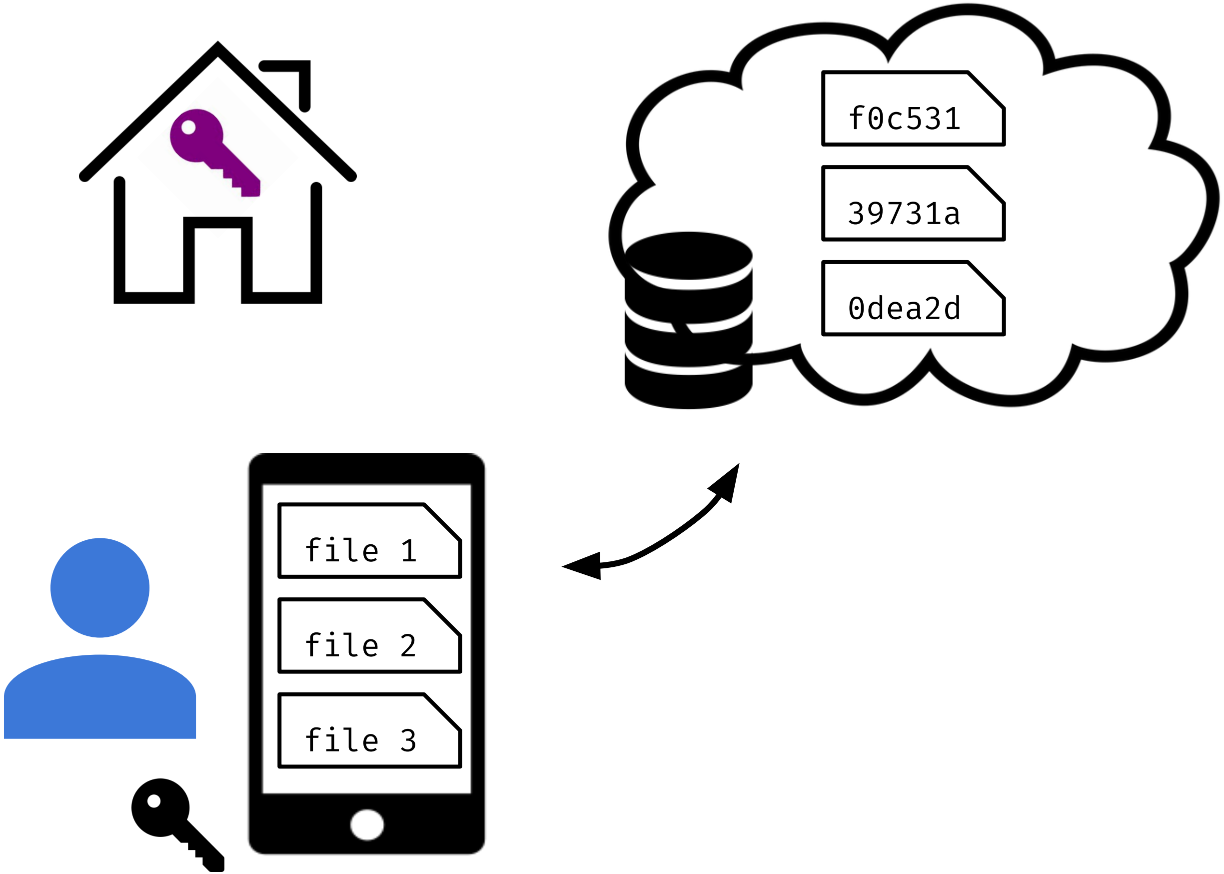
BurnBox Overview



BurnBox Overview

Before Compelled Access

User selectively deletes and revokes sensitive files



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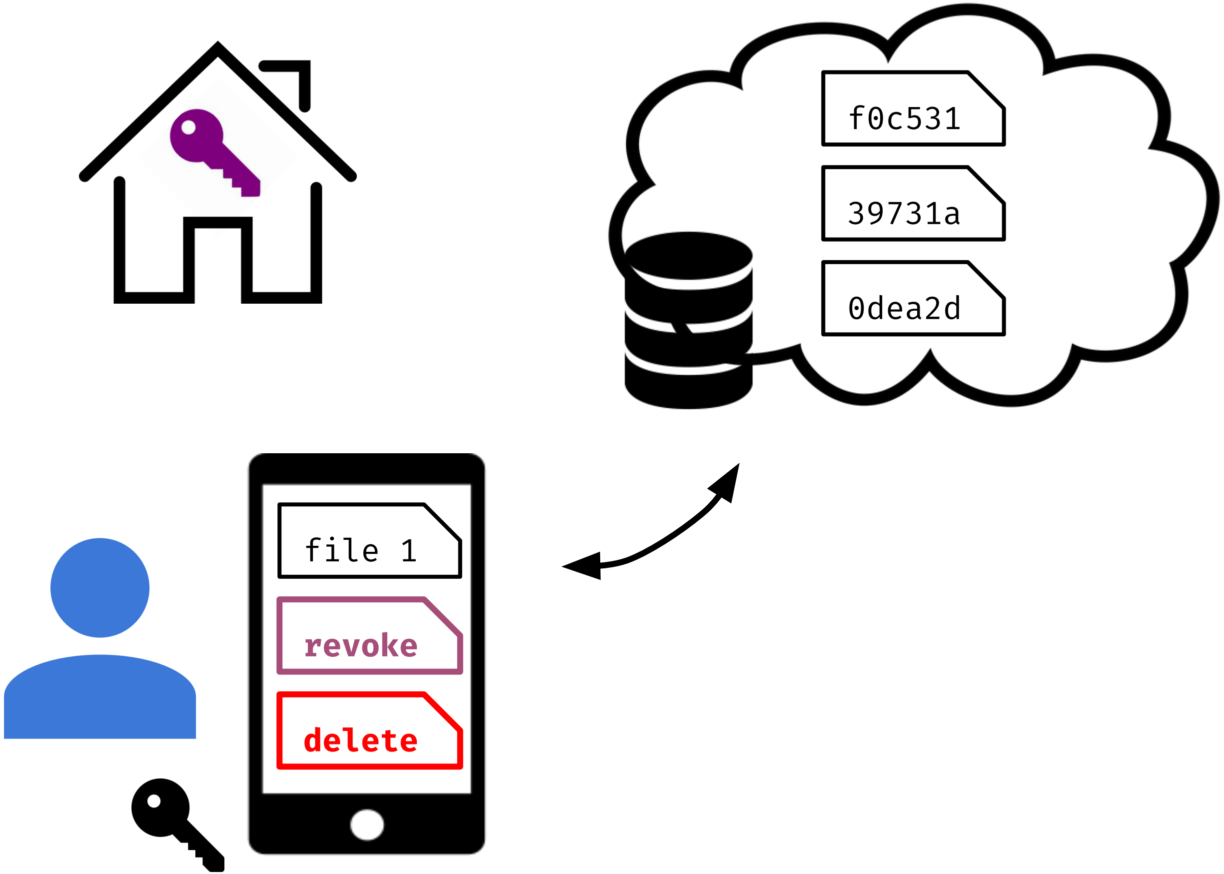

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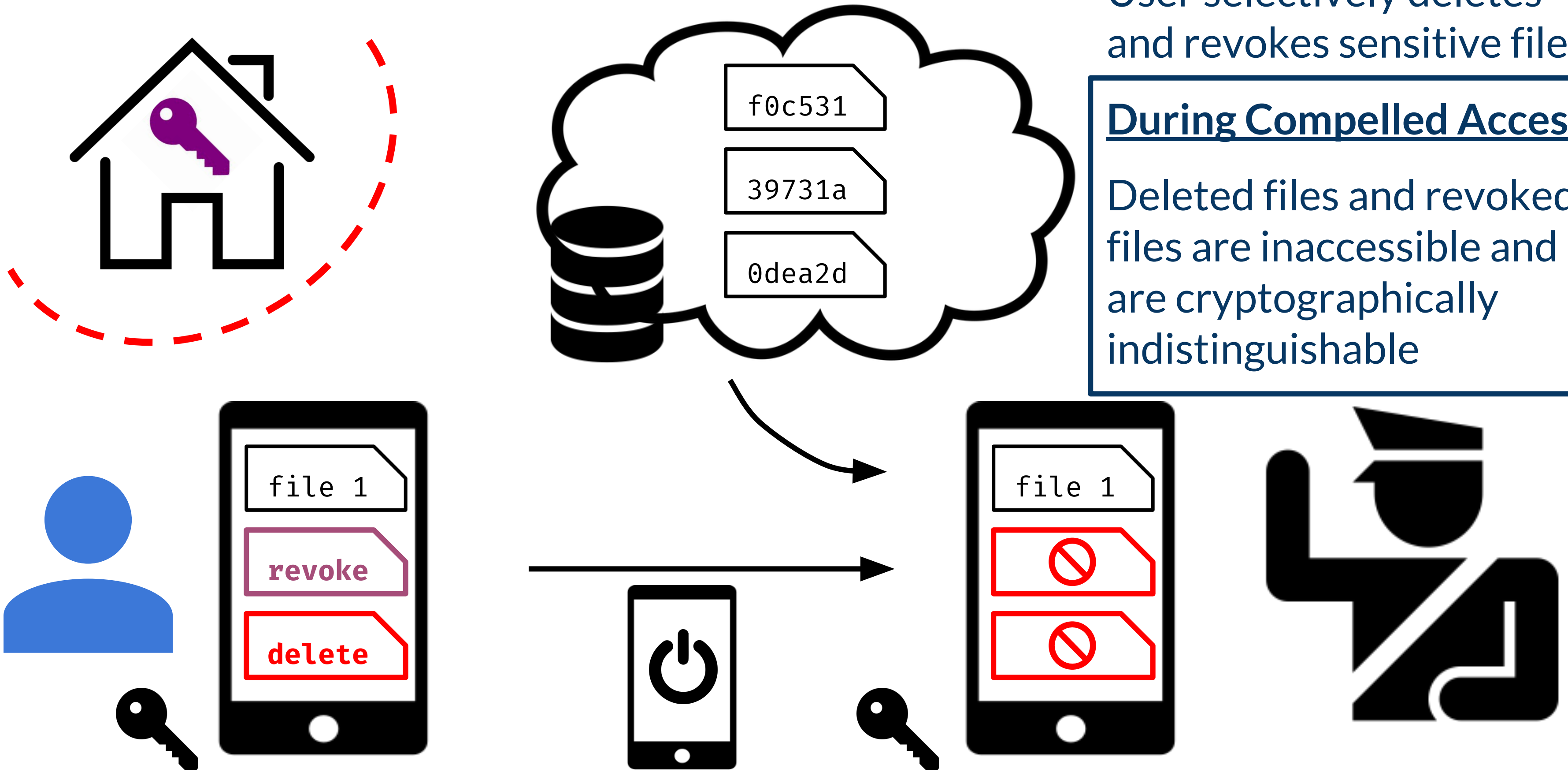

Before Compelled Access

User selectively deletes and revokes sensitive files

During Compelled Access

Deleted files and revoked files are inaccessible and are cryptographically indistinguishable

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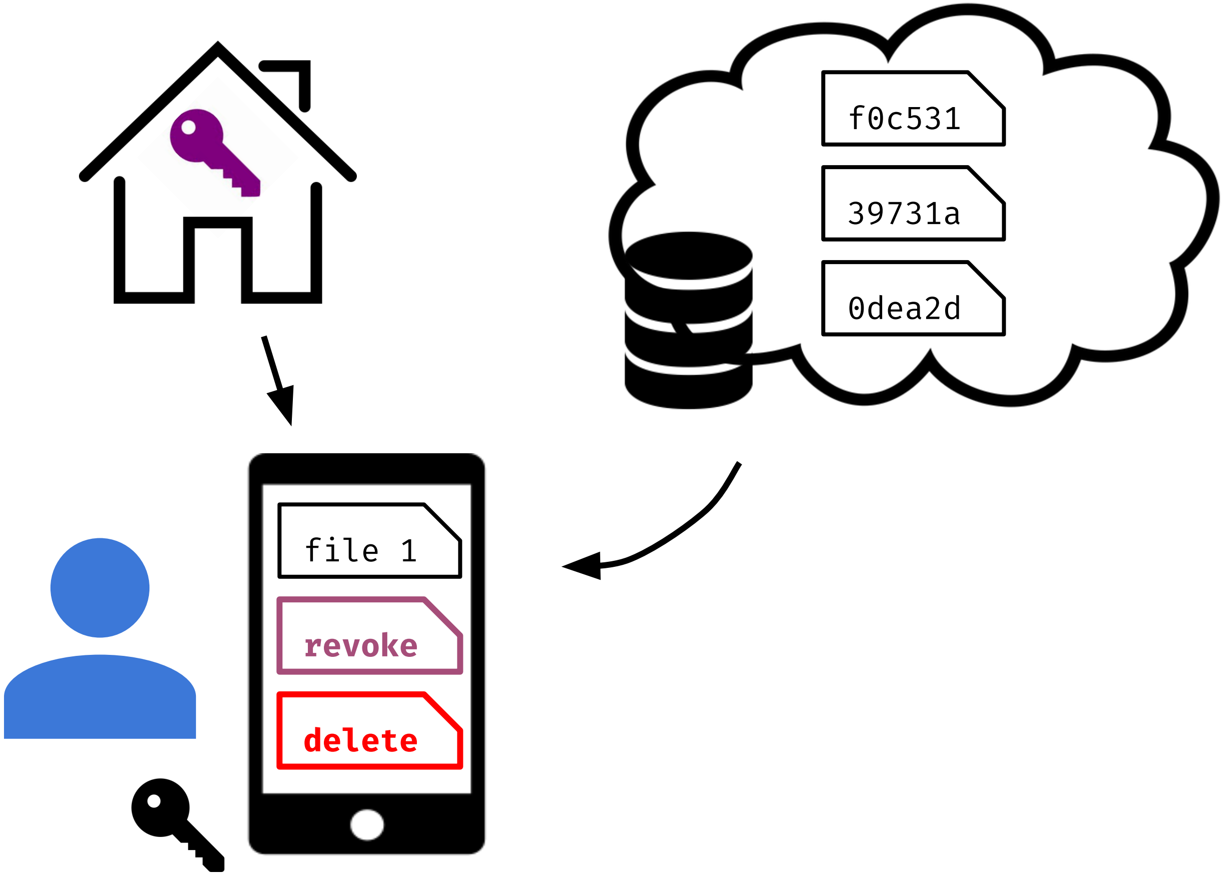

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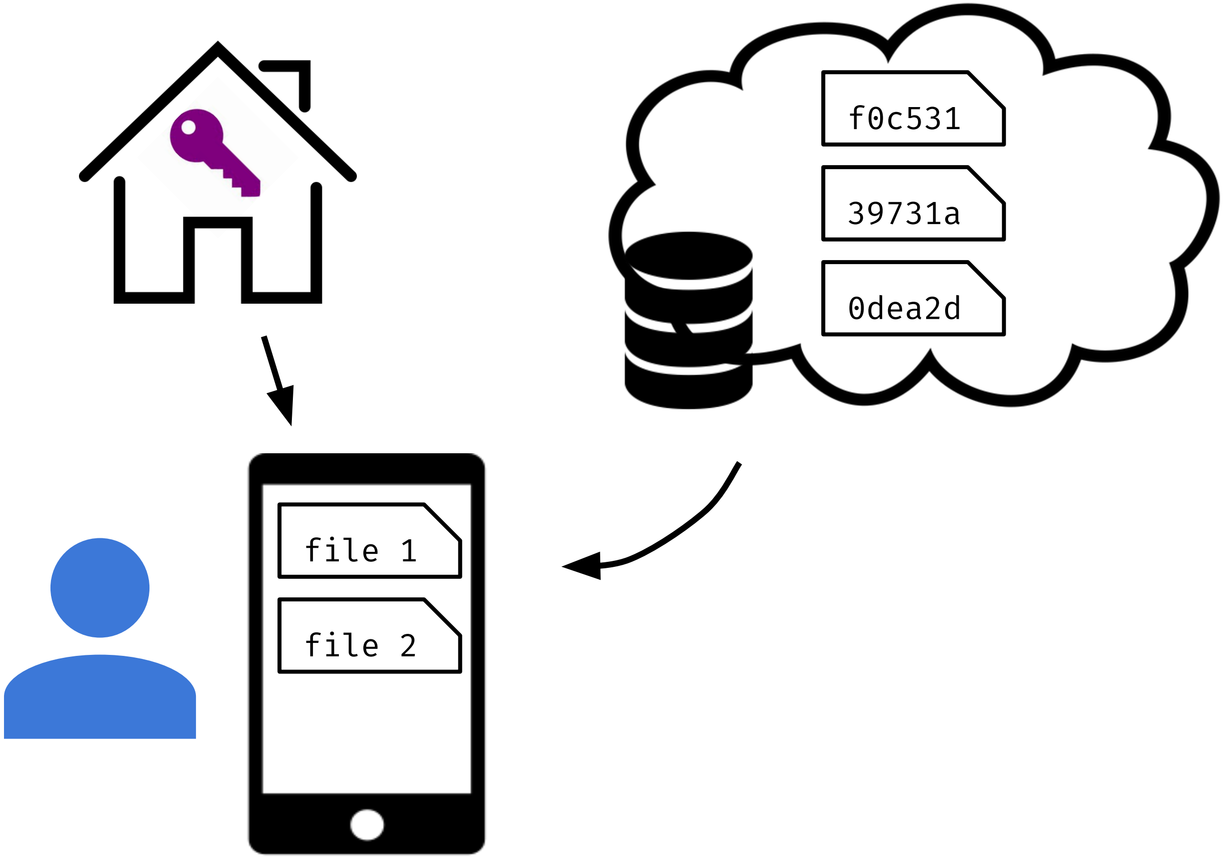

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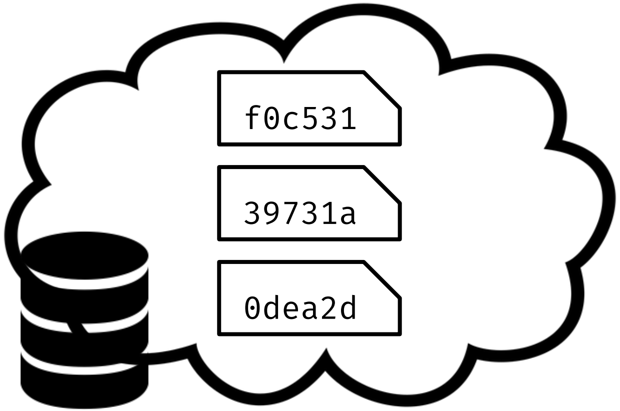
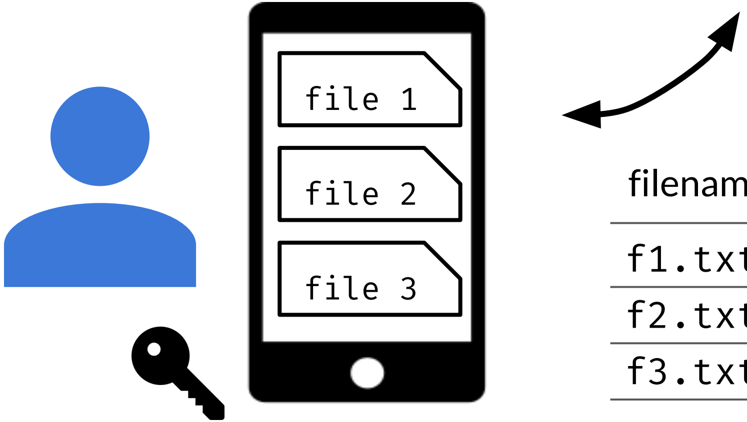
Conventional client-side encryption

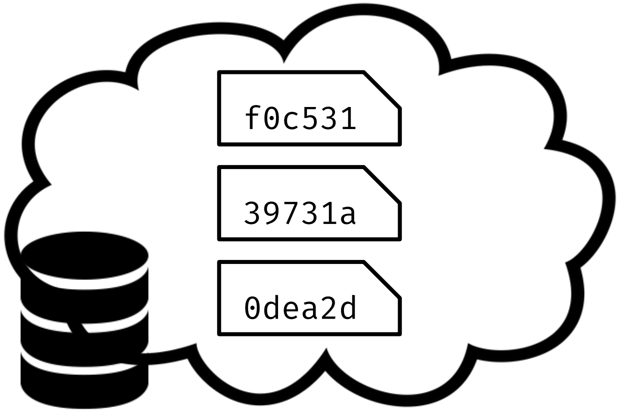


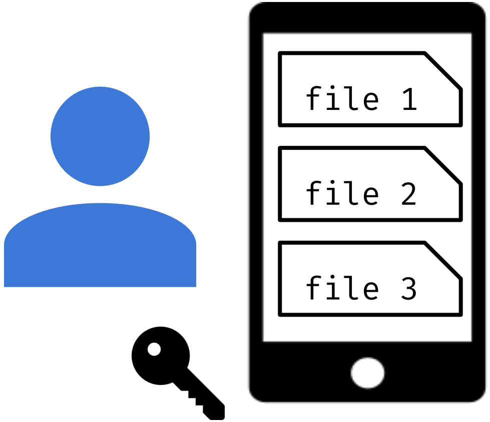


Device State

filename	encryption key	encrypted file
f1.txt	cc64c3	f0c531
f2.txt	5707dd	39731a
f3.txt	1be052	0dea2d

Compelled access reveals local keys





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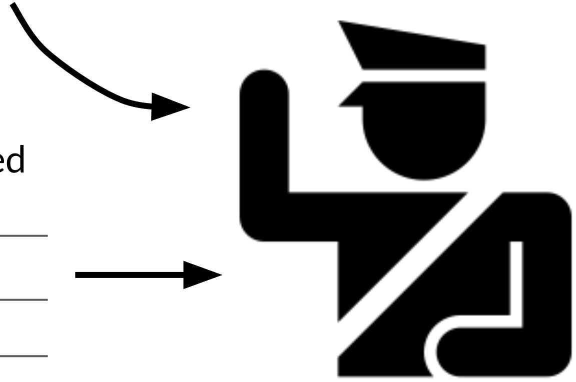
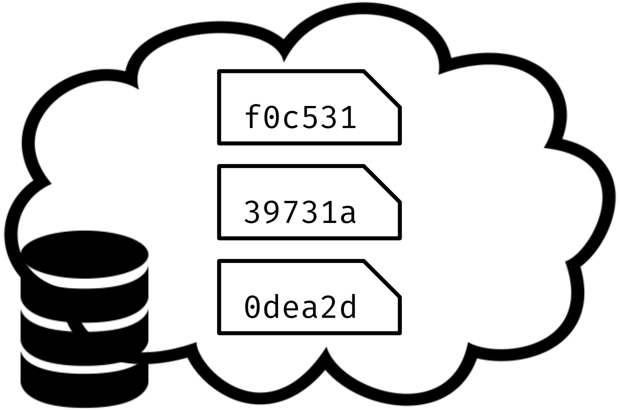
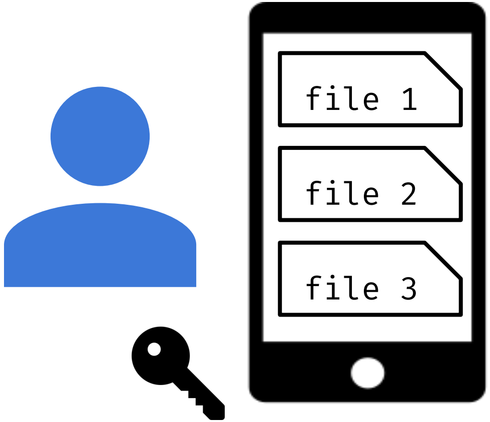


Delete rows of sensitive files





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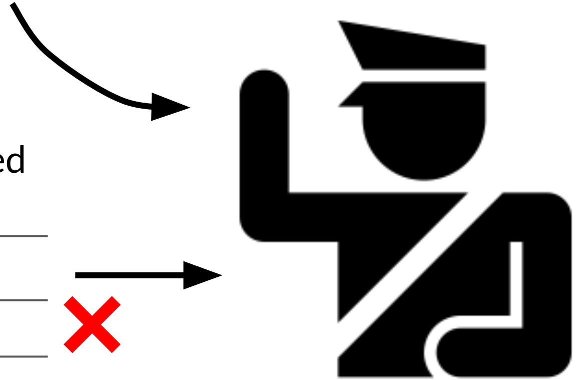
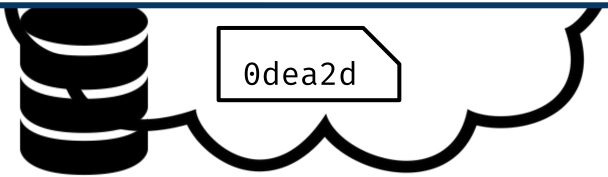
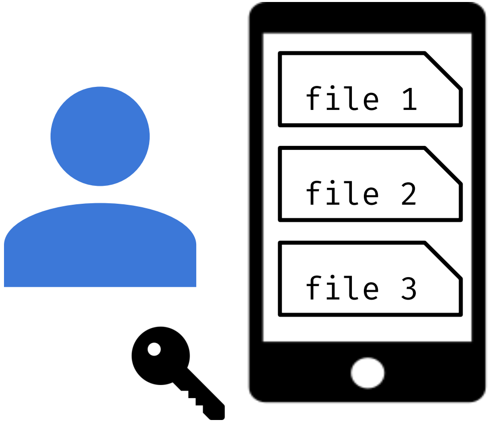


Delete rows of sensitive files

Problem 1: How to support revocation?
Problem 2: Secure deletion of persistent state is ***hard***.





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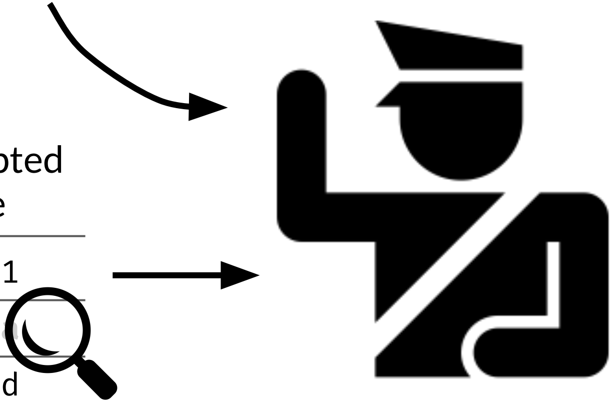
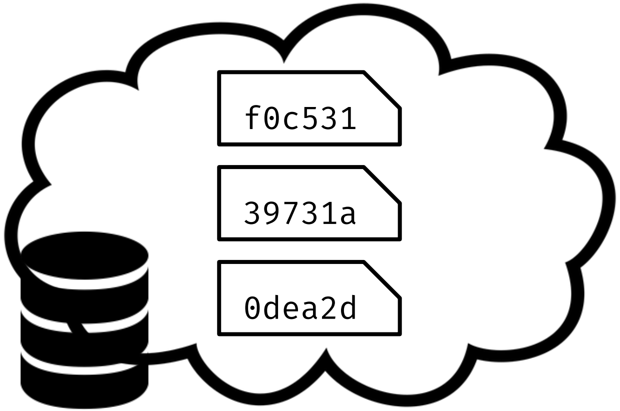
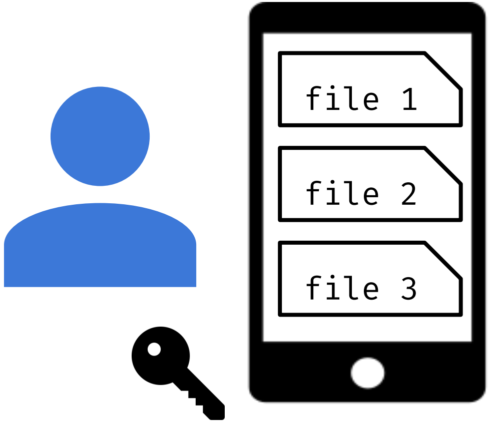


Forensic analysis

Revocation: use public-key encryption





Device State

filename	encryption key	encrypted file	restoration ciphertext
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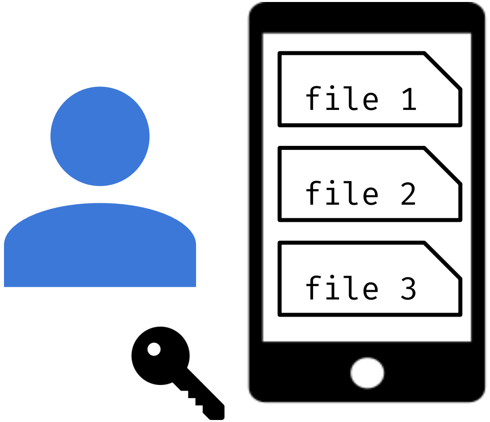

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Revoke

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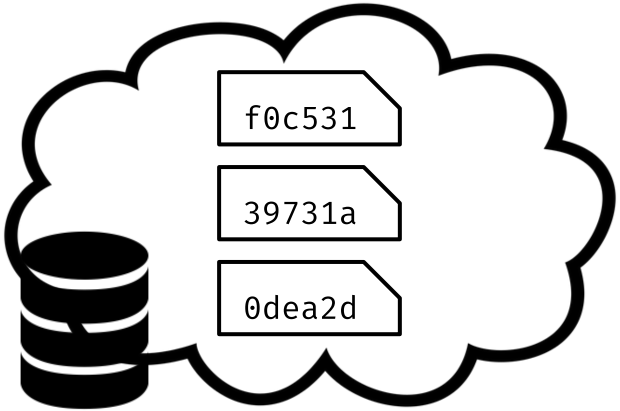

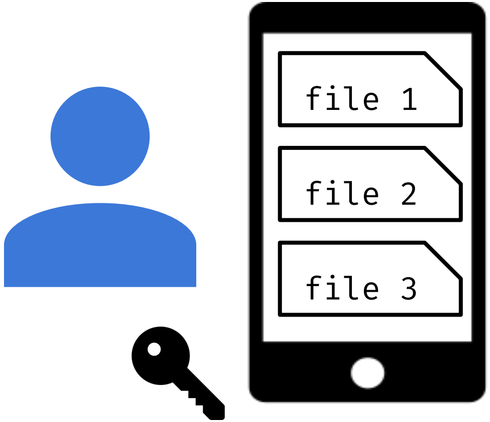

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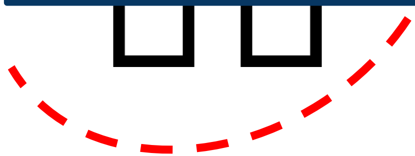

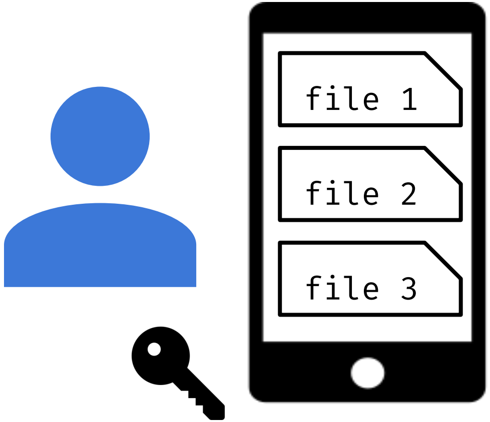

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Revoke

Delete

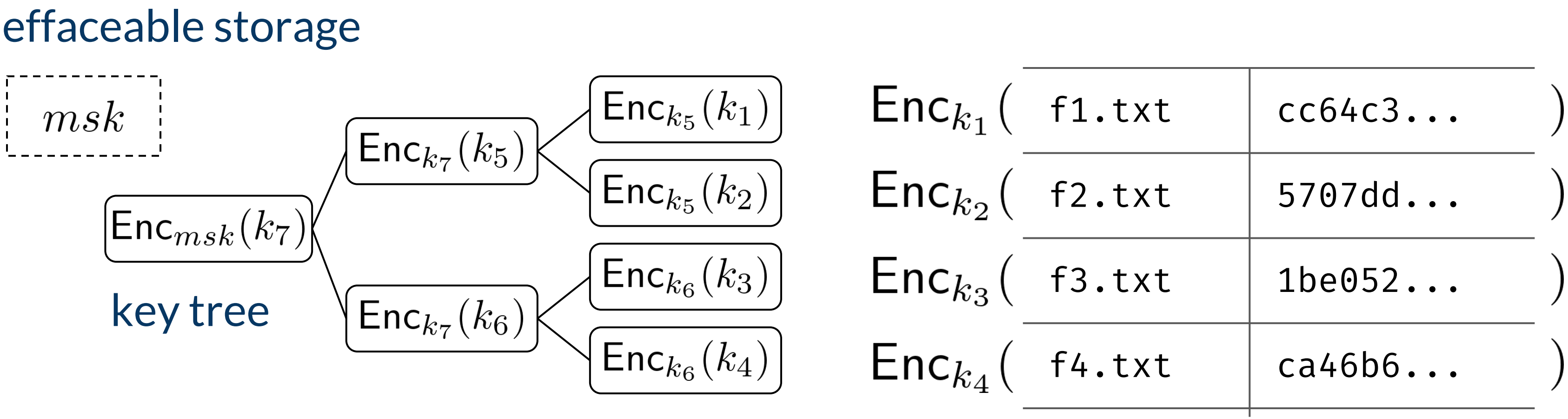
Erasable Index

- File keys stored in append-only table

$\mathsf{Enc}_{k_1}($	f1.txt	cc64c3...	$)$
$\mathsf{Enc}_{k_2}($	f2.txt	5707dd...	$)$
$\mathsf{Enc}_{k_3}($	f3.txt	1be052...	$)$
$\mathsf{Enc}_{k_4}($	f4.txt	ca46b6...	$)$

Erasable Index

- File keys stored in append-only table
- Secure deletion of row keys with trusted hardware [RRBC13]
  - Trusted hardware assumed to manage small "effaceable" storage
  - E.g., TPM, iOS/Android keystore APIs



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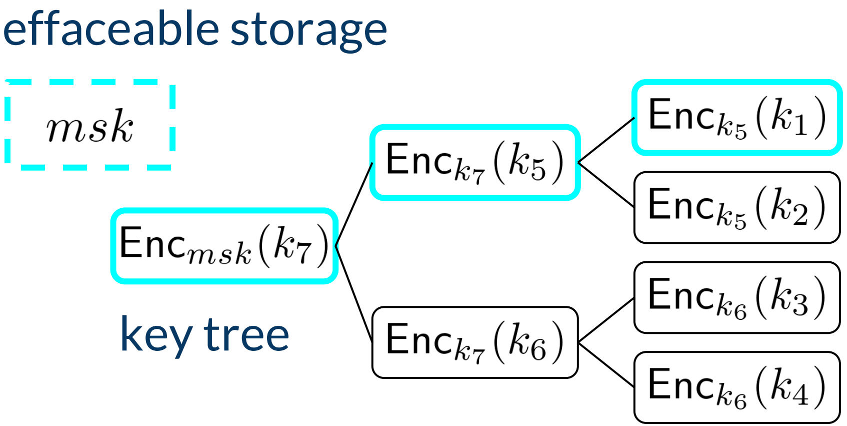

$\mathsf{Enc}_{k_1}($	`f1.txt`	`cc64c3...`	$)$
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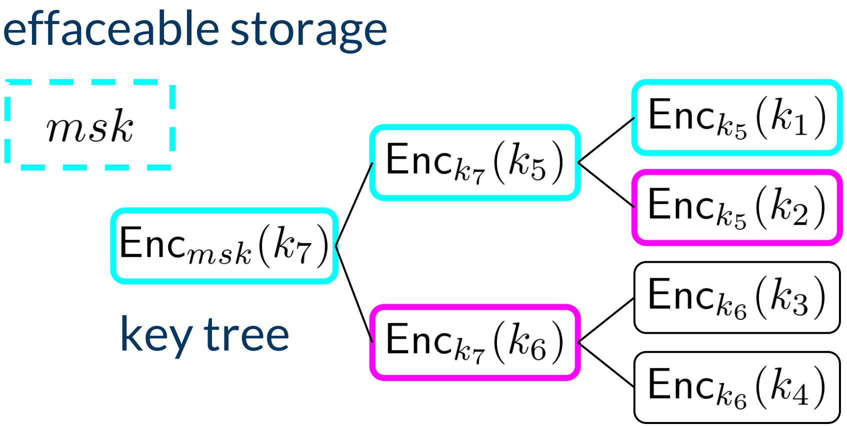

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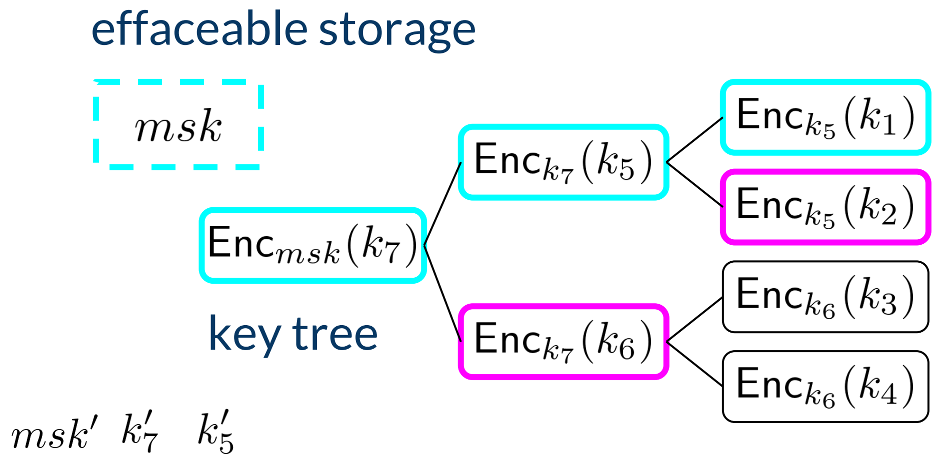

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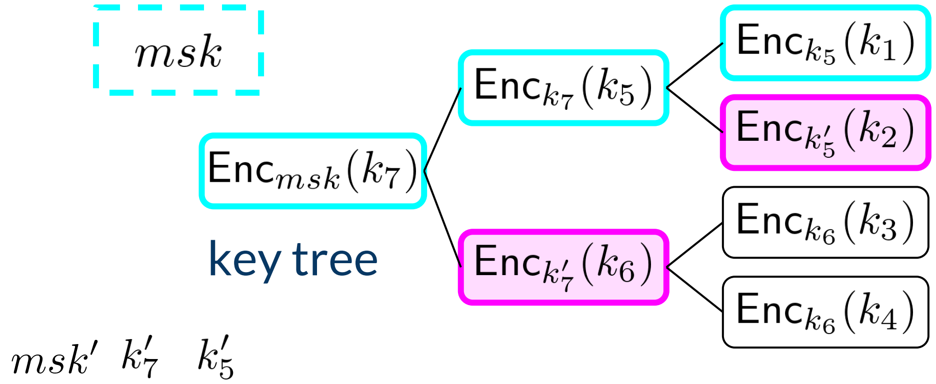
effaceable storage



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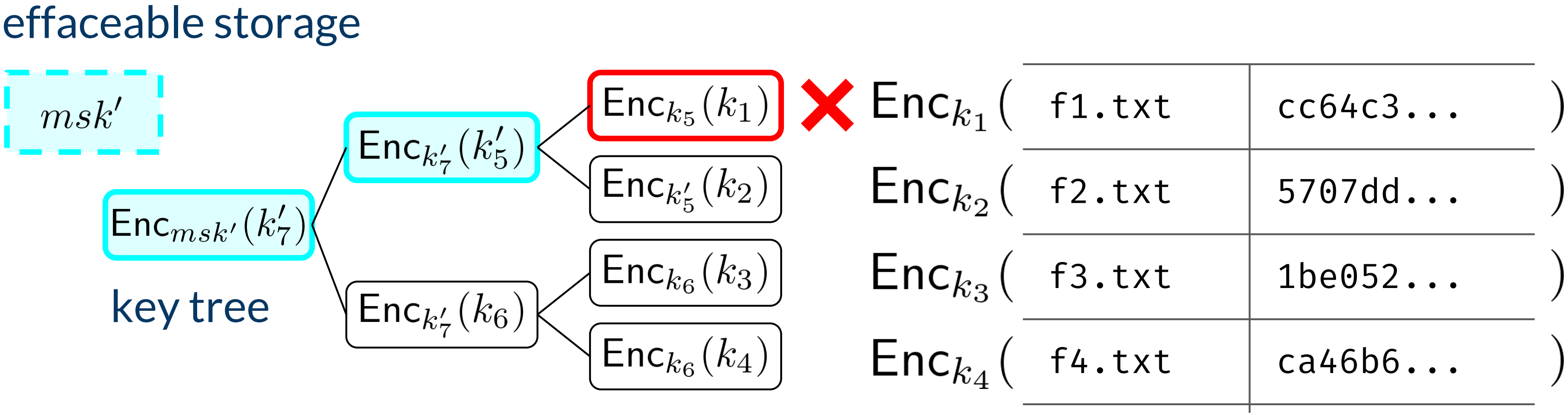
  - E.g., TPM, iOS/Android keystore APIs



Efficiency and other approaches?

Erasable index uses:

- Storage on the order of number of files
- Linear time search by filename

In practice, this is actually fine

Related asymptotically better approaches not secure against threat model

- Puncturable pseudorandom functions [GMM86]
- History-independent data structures [NT01]

Security Analysis

- Provide formal security models
- Limit leakage to well-specified access pattern history
    - Pseudonymous operation history

Adversary observing:

Cloud communication history
Encrypted cloud contents
Erasable index on local device

=

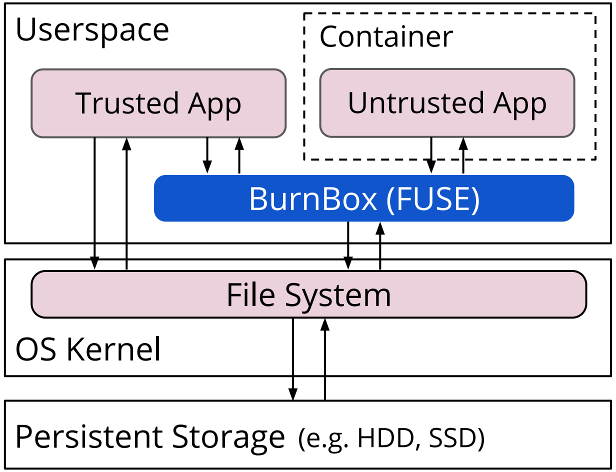
Pseudonymous operation history
E.g.,
Add file A at 1:00
Access file A at 4:30

Open question: Inference attacks on file accesses?

[CGPR15,NKW15]

Prototype

- Implemented as file system in userspace (FUSE)
  - Available at github.com/mhmughees/burnbox
  - About as efficient as standard client-side encryption



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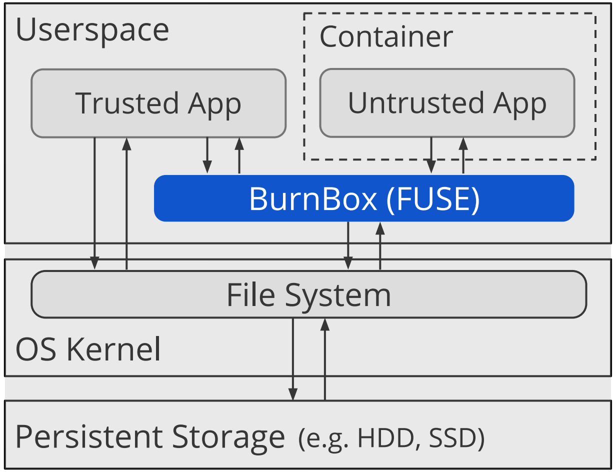

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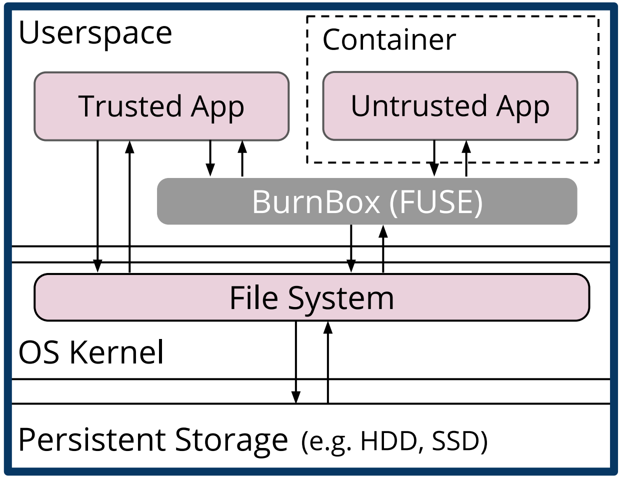

Prototype

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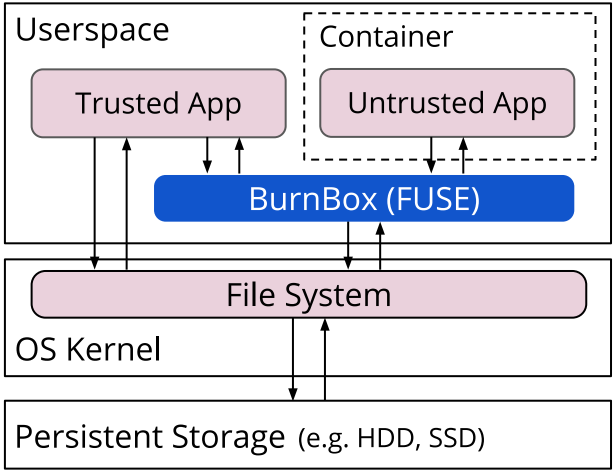
  - About as efficient as standard client-side encryption
- Best effort to address application and OS leakage [CHKGKS08,DLJKSXSW12]
  - Memory-locked pages
  - Containers for untrusted applications
  - Guidelines for off-the-shelf OS configurations



Contributions

- BurnBox: Cloud storage secure in compelled access setting
  - Allow users to honestly comply with authorities while preserving confidentiality
  - Secure deletion: permanently delete files
  - Temporary revocation: self-revoke access to files temporarily
- Formal compelled access security notions and analysis
- Proof-of-concept prototype
  - github.com/mhmughees/burnbox