Plutus: scalable secure file sharing on untrusted storage

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Why care about storage security?

How secure is your storage?

- Laptop ➡ Network ➡ Disk ➡ Tape
- Trust galore:
  - laptop / hard-disks can be stolen
  - network is shared
  - storage is outsourced
- Securing the network alone is not enough
- How much do you trust your administrator / ssp?

What's out there?

- Network security
  - doesn't have storage semantics
- Encrypt-on-wire
  - layered system
  - typically trusts server
  - NASD, iSCSI w/ IPSec, NFS w/ secure RPC
- Encrypt-on-disk
  - encrypt before it leaves clients
  - stored encrypted, typically used only for local storage
  - "sharing" problem not yet addressed
  - CFS, CryptFS, Truffles, Cepheus, Win EFS

Where are we going?

- Introduction
- Plutus
- Handling Revocations
- Implementation
- Summary

Our mantra

The fundamental design principles

- Decentralize key management and distribution
  - clients all the key related work
  - better scalability
  - better security
  - flexibility in policy
- Minimize server trust requirement
  - server can be broken into
  - anyway assuming untrusted network

Translation…

Encrypt-on-disk system

- Data on disk encrypted
  - files and (optionally) directory entries
- Data on network integrity protected
  - no need to re-encrypt bulk data

Client-centric system

- Client does most of the work
  - crypto, key management and distribution
- Server: store and retrieve bits from disk
  - validate writes

Plutus techniques summary

- Store all data encrypted
  - asymmetric read/write keys
- Owners distribute keys to share data
- Protect network integrity
- Server verified writes
- File-groups
- Lazy revocation
  - key rotation

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Plutus

- Store all data encrypted
  - say we use something like DES
- Owners distribute keys to share data
- Protect network integrity
- Server verified writes

Attack:

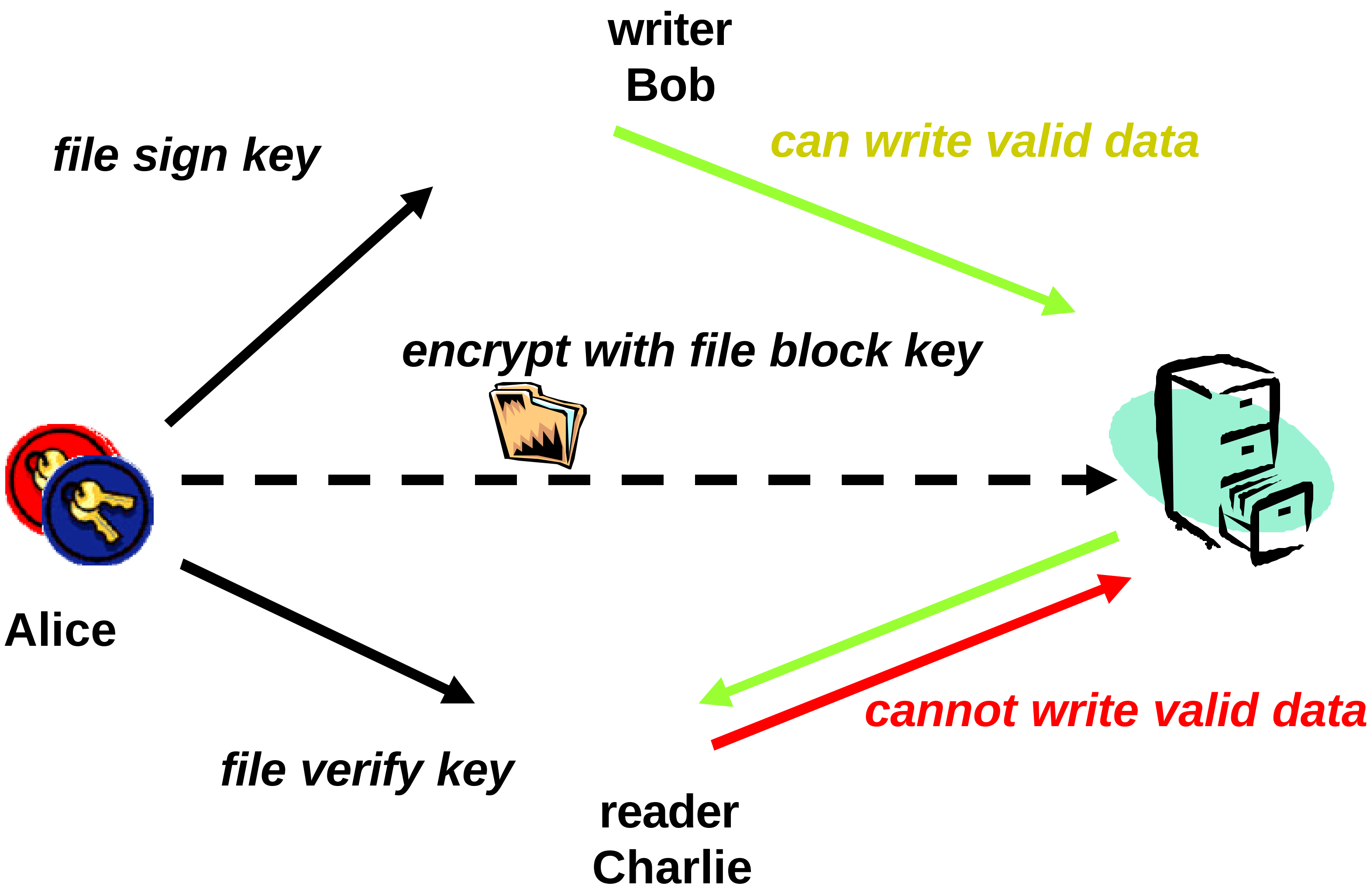
- Reader and server collude to update data
  - a data modify attack

Preventing readers from writing: asymmetric encryption

- Observations
  - Readers and writers need to be given different keys
  - Readers need to see what writers have written
  - Try converting into data destroy attack
    - should only be able to detect it

- Solution: asymmetric keys
  - Encrypt file with “file block key”
  - Protect integrity with “file-sign / file-verify” keys

Differentiating read/write access



Overhead: Too many keys!

- Problem
  - Key distribution overhead
  - Clients not always online
  - Key generation overhead

- Observation: use same key on multiple files

- Solution: file-groups
  - Use same key for files with similar sharing
  - Translating to unix
    - file-group = files with same owner, group, mode bits
    - study: appx 30 keys per user

You're outa here!
revocation

- How to revoke a user's access to a file

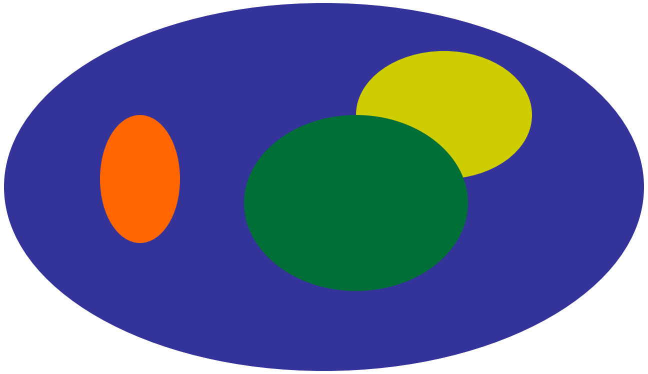
- Change keys and hand them out again
  - re-encryption effort
  - key re-distribution effort

You’re … yawn … outa … zzz …here lazy revocation

- Observations
  - might be ok to leave unchanged data open
- Solution: lazy re-encryption
  - On revocation
    - change keys
    - mark files for re-encryption
  - Only re-encrypt when written next

Complication:
lazy revocation + file-groups

- File-groups
  - same key multiple files
- On write following revocation
  - key for re-encrypted file different!
- Don’t want explosion in keys due to revocations

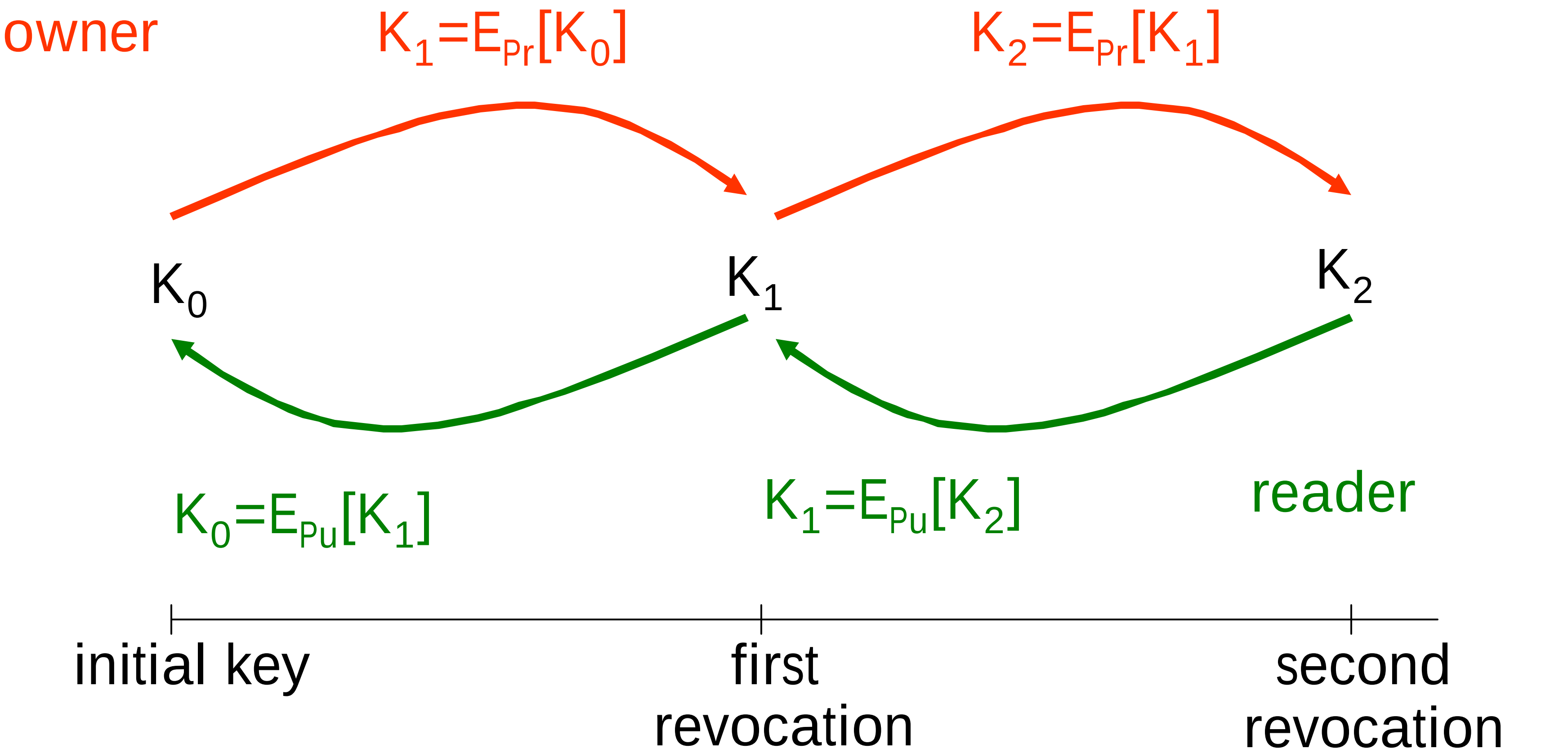


Recursive keys

- Keys for a file-group
  - rotate file lockbox key
  - only owner can generate next in sequence
  - given current key, readers generate previous keys

- On revocation owner generates new keys
- Writers get latest file-sign key
- Readers are given latest file lockbox key
  - rotate back to get older keys on seeing older files
  - derive file-verify keys from corresponding lockbox key

Key-rotation



Key-rotation: the math

Owner (and reader)

- generate random prime e greater than sqrt(N)
  - use file lockbox key as seed

Owner

- generate corresponding “d” (file-sign key)

Writer

- given “d”

Note

- Reader cannot get file-sign key
- Writer cannot get file-verify key

Design summary

- Store all data encrypted
  - asymmetric read/write keys
- Owners distribute keys to share data
- Protect network integrity
- Server verified writes
- File-groups
- Lazy revocation
  - key rotation

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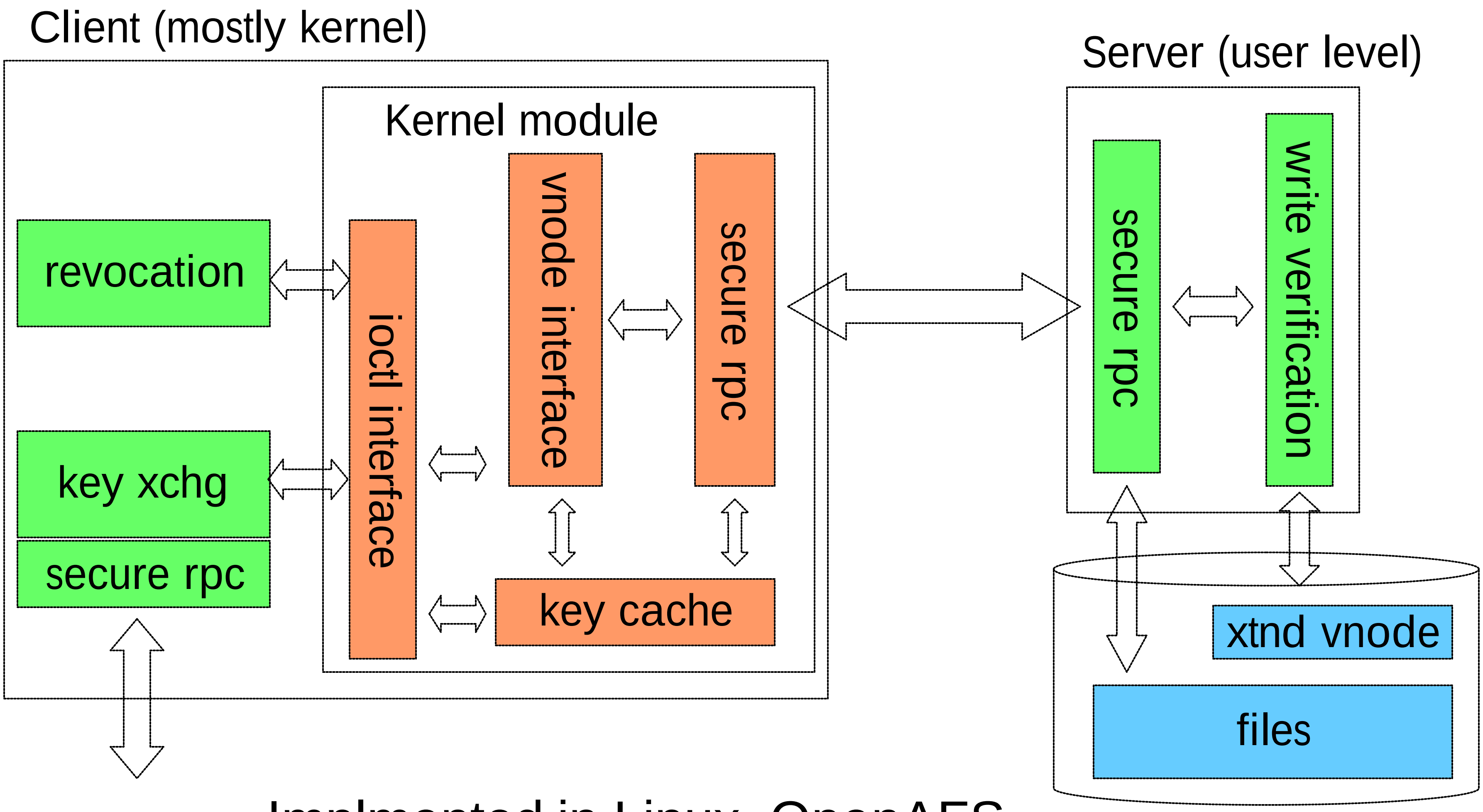
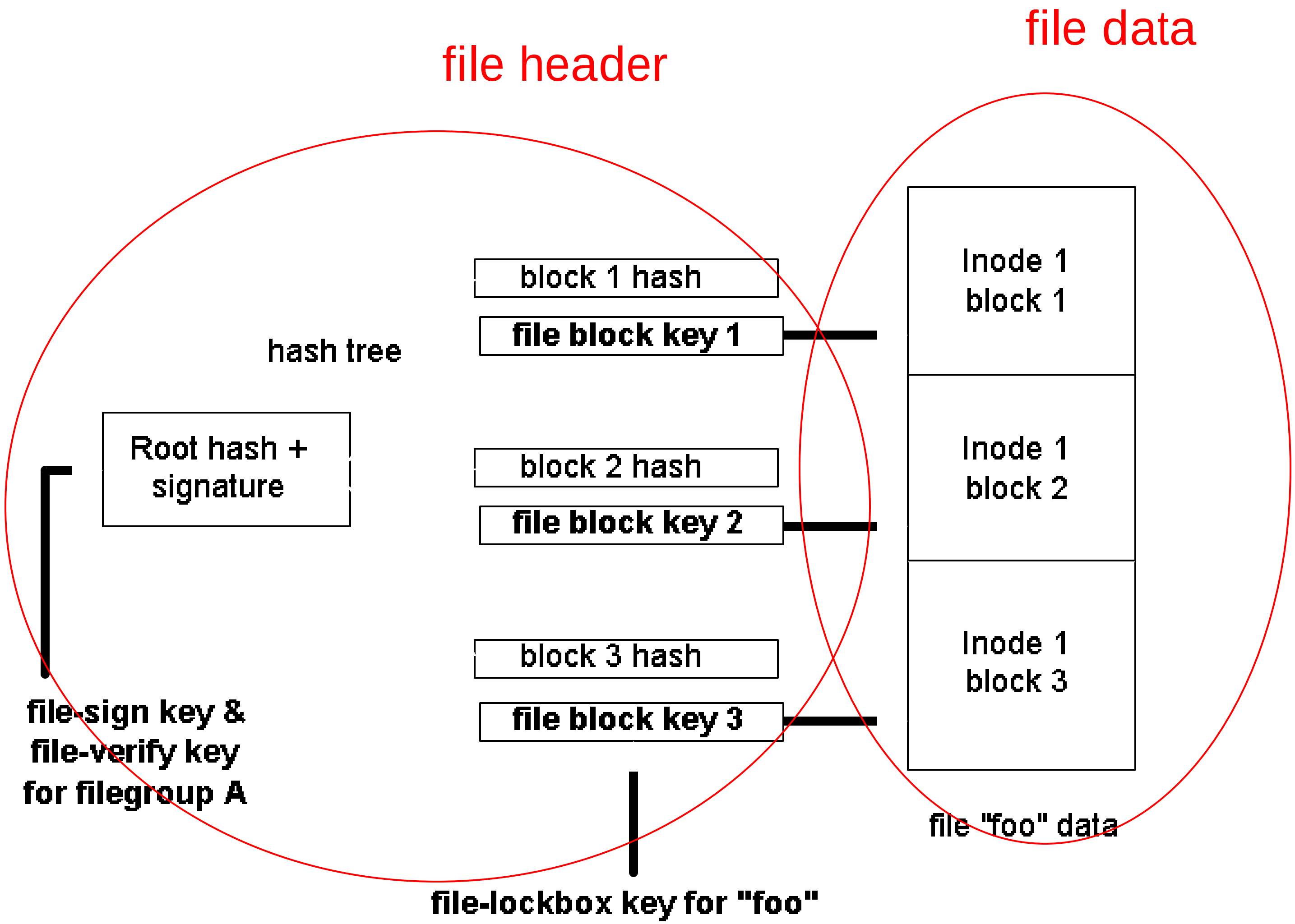
AFS incarnation



- Implmented in Linux, OpenAFS
- Crypto: SHA1, RSA1024, 3DES

Key summary – the file side



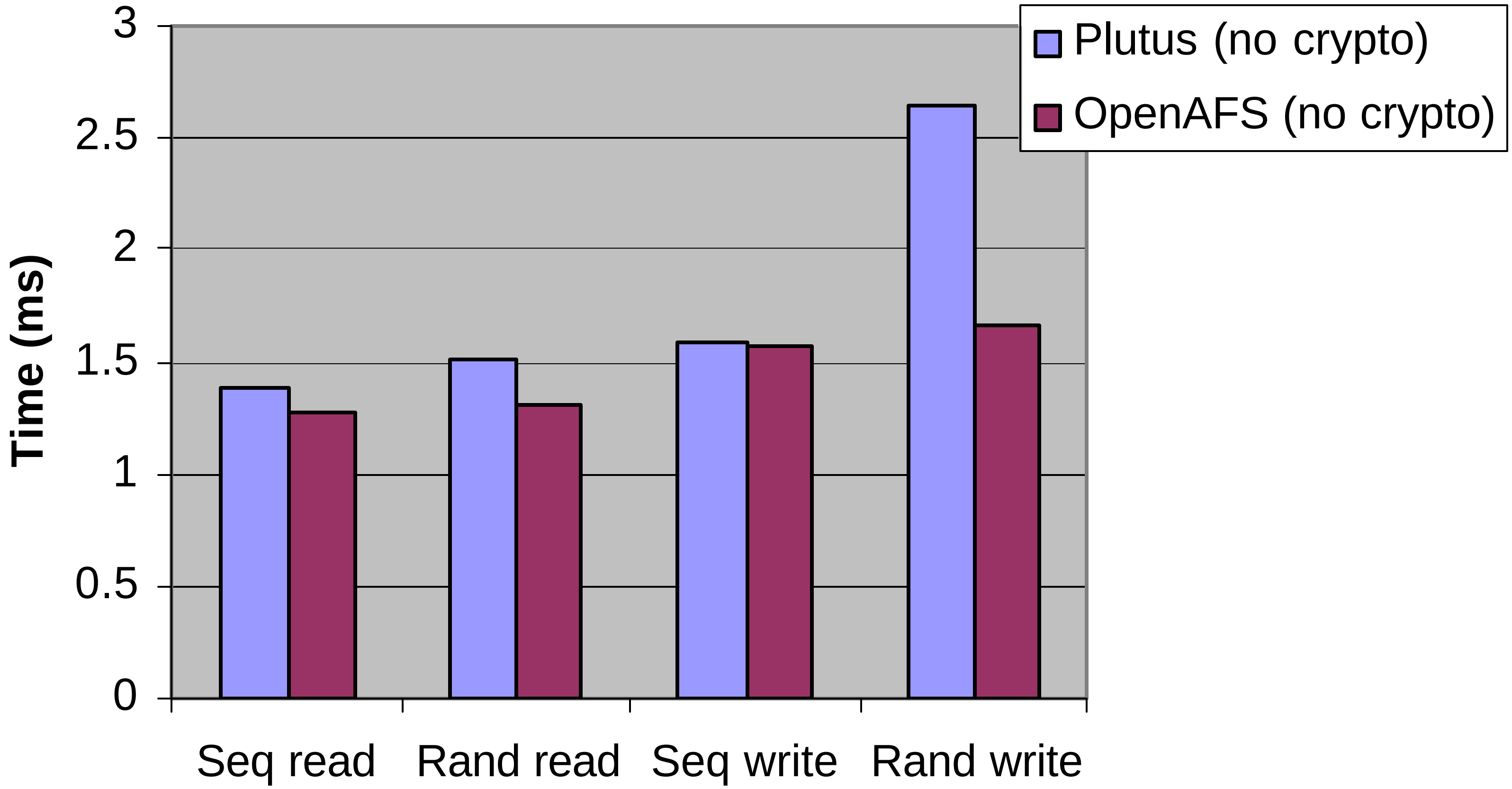
How long does it take

- RSA key generation
  - 2500 ms paid by owner on every filegroup creation
- File read/write
  - per 4KB block: 0.7 ms of crypto
  - per file: 28.5 ms by writer, 8.5 ms by reader

  - write verification: 0.01ms per file

1.26GHz P3 with 512MB ram: SHA1, RSA1024, 3DES

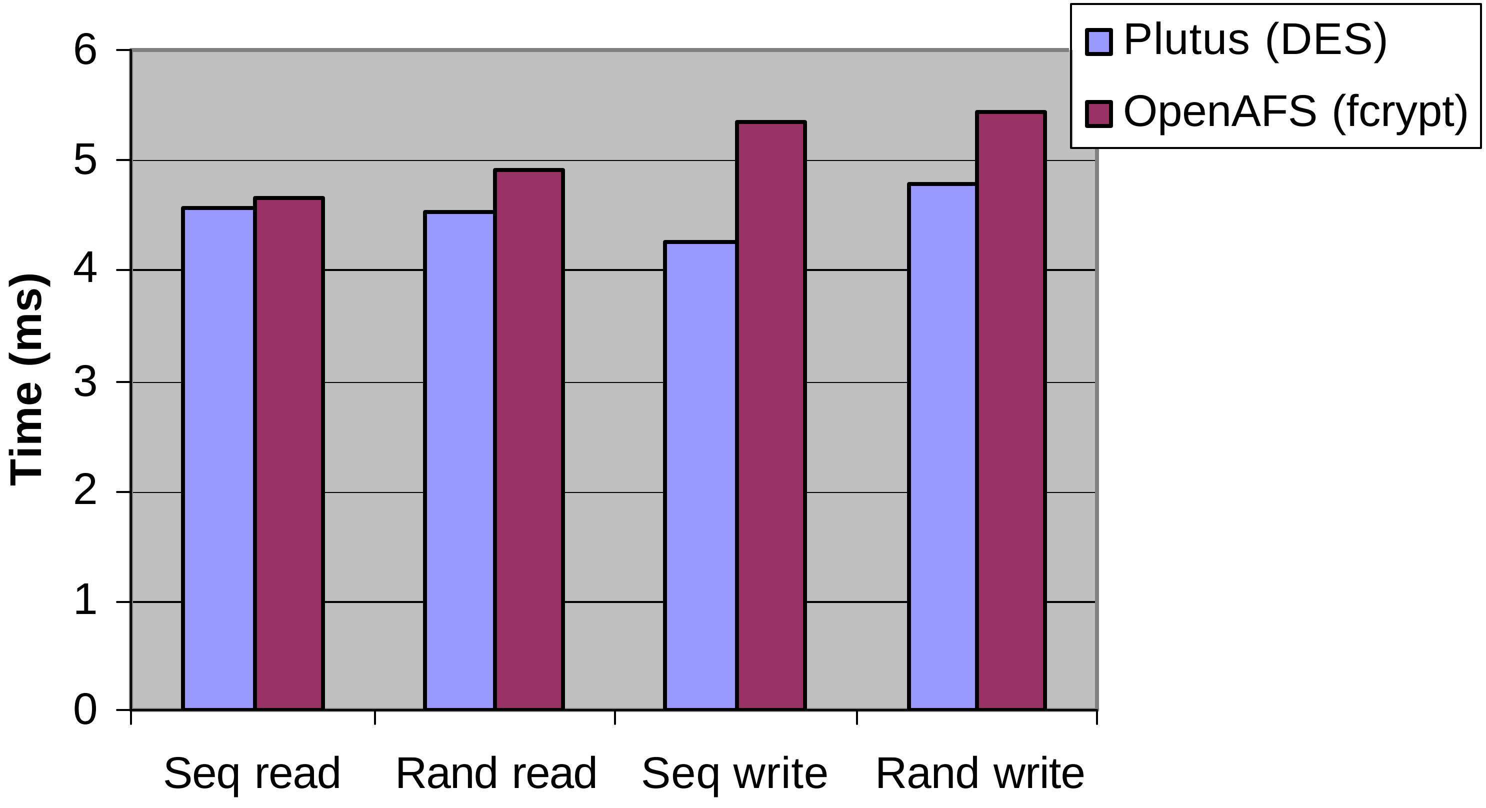
Data structures overhead



Accessing a remote 40 MB file

- Hash tree structure doesn’t take much time

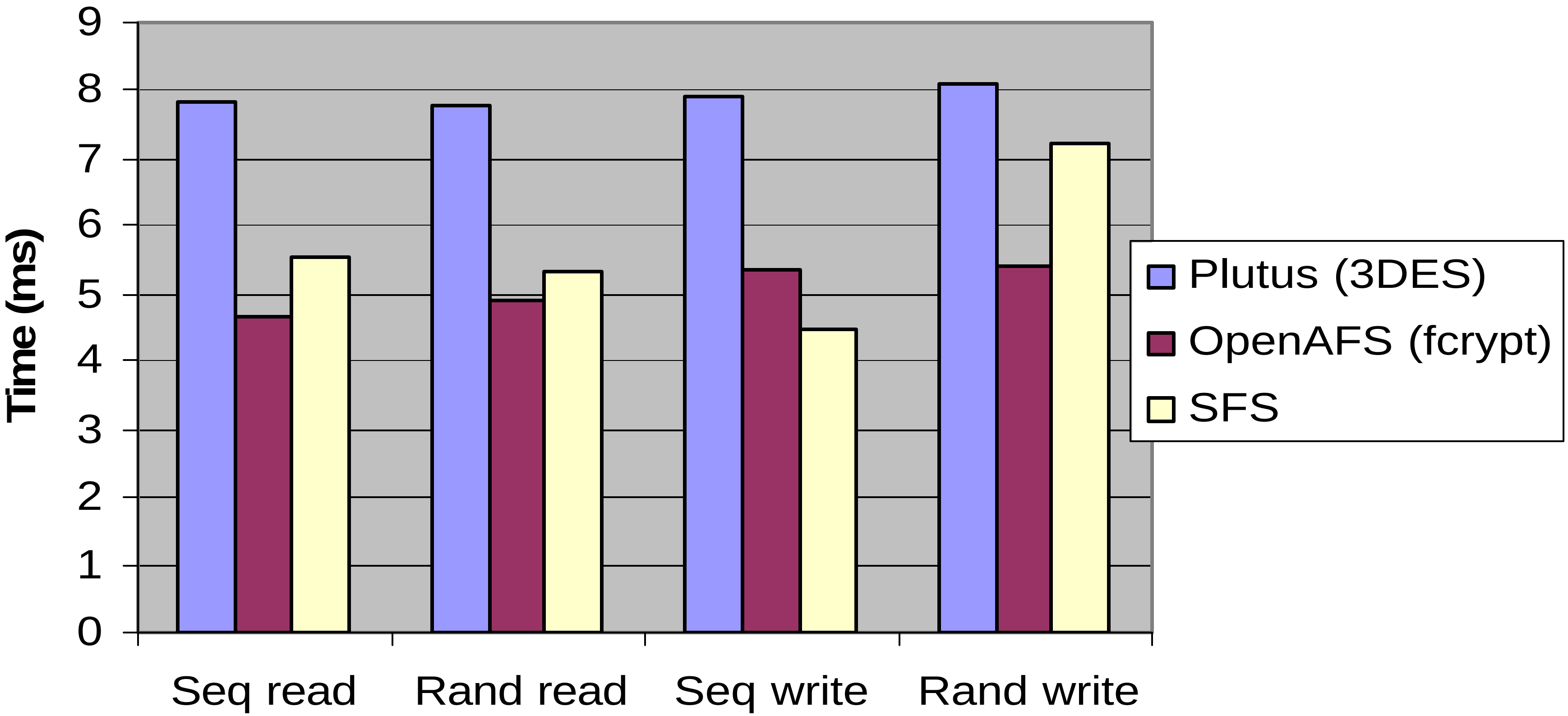
Encrypt-on-disk vs. wire-encryption



Accessing a remote 40 MB file

- Comparable performance

Plutus performance (overall)



Accessing a remote 40 MB file

OpenAFS's fcrypt comparable to DES
SFS's ARC4 14X faster than 3DES

- Plutus compares favorably with SFS

The key takeaways

1. Use keys to pass “access rights”
   + don’t need to maintain lists
   – complicates revocation
2. File groups: use same keys for similarly shared objects
   + simpler key management
3. Key rotation: keys can be related but secure
   + useful for evolving keys
4. Lazy re-encryption
   - don’t do the crypto till absolutely necessary