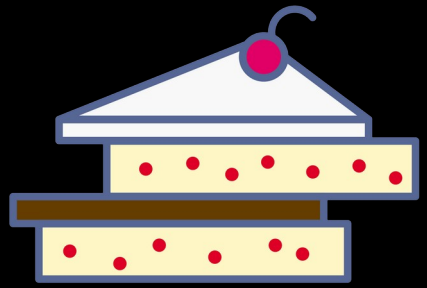
Shufflecake

Plausible Deniability in 2025



Tommaso Gagliardoni, Horizen Labs

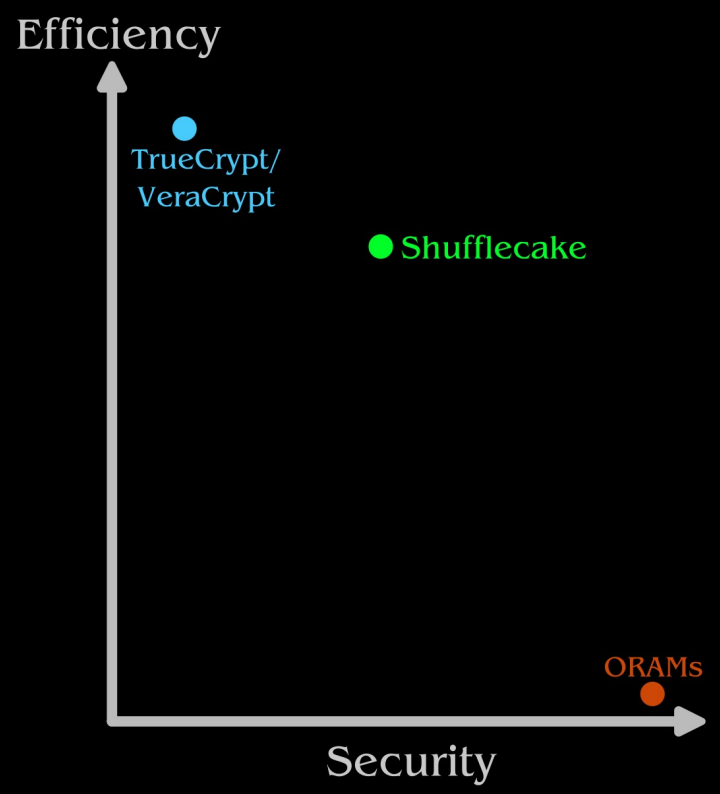
From a joint work with Elia Anzuoni

Open Source Cryptography Workshop 2025

2025-03-25, Sofia, Bulgaria

Shufflecake: TL;DR

- Encrypts, hides existence of disk partitions
- Plausible deniability like TrueCrypt/VeraCrypt
- Security and usability improvements
- Cryptographic proof of security
- Faster than ORAM-based solutions
- Potential to improve security even further
- FLOSS (“free” as in “freedom”)



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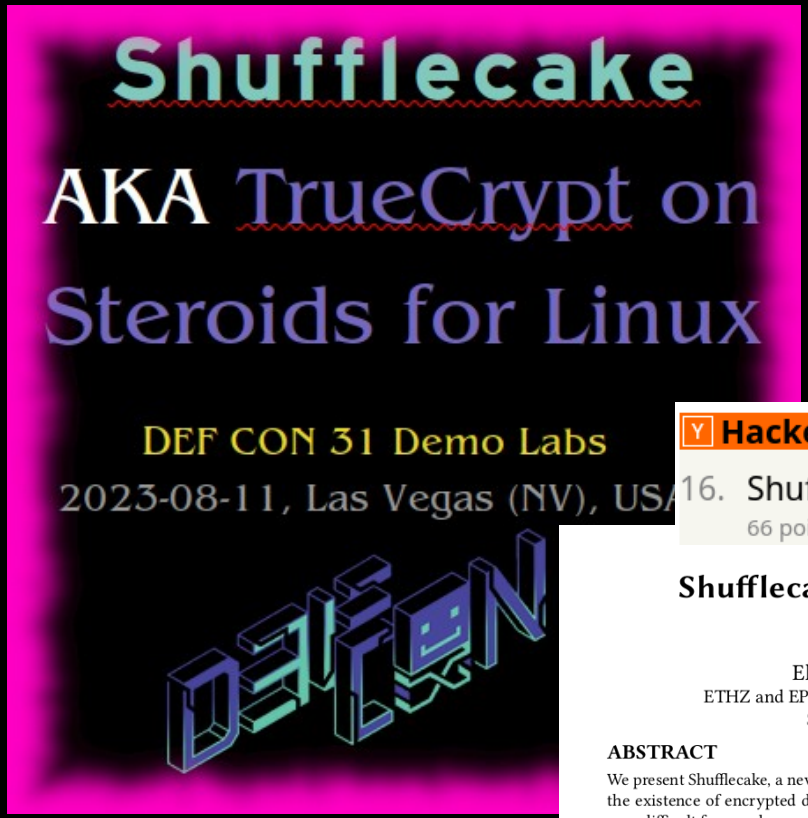

Introducing Shufflecake: Plausible Deniability For Multiple Hidden Filesystems on Linux (kudelskisecurity.com) 90

Posted by EditorDavid on Saturday November 12, 2022 @02:34PM from the magic-mounting dept.

Thursday the Kudelski Group's cybersecurity division released "a tool for Linux that allows creation of multiple hidden volumes on a storage device in such a way that it is very difficult, even under forensic inspection, to prove the existence of such volumes."

"Each volume is encrypted with a different secret key, scrambled across the empty space of an underlying existing storage medium, and indistinguishable from random noise when not decrypted."

Hacker News new | past | comments | ask | show | jobs | submit

16. Shufflecake: Plausible deniability for hidden filesystems on Linux (2023) (iacr.org)
66 points by simonpure 9 hours ago | hide | 22 comments

Shufflecake: Plausible Deniability For Multiple Hidden Filesystems On Linux

Elia Anzuoni
ETHZ and EPFL and Kudelski Security
Switzerland

Tommaso Gagliardoni
Kudelski Security
Switzerland

ABSTRACT

We present Shufflecake, a new plausible deniability design to hide the existence of encrypted data on a storage medium making it very difficult for an adversary to prove the existence of such data.

by means of (physical, legal, psychological) coercion, they can obtain the encryption keys to any encrypted content identifiable on the user's device. The security goal in this scenario, then, becomes to still retain secrecy of some selected, "crucial" data on the disk, by making the presence of such data not even identifiable, thus allow-

30th Anniversary 2023 acm SIGSAC

ACM CCS 2023
26-30 NOV., 2023

Who am I

Tommaso “tomgag” Gagliardoni

- PhD in cryptography at TU Darmstadt, Germany
- Past: IBM Research, Kudelski Security
- Now: Horizen Labs, based in Zurich
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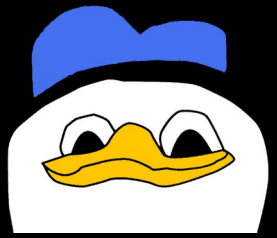

More business ⟷ Less business

Overview

- TL;DR
- Bio
- Introduction
- TrueCrypt (and VeraCrypt)
- Shufflecake
- Implementation
- Future directions
- How to contribute

You are here

Introduction

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- BitLocker (Windows)
- FileVault 2 (MacOS)
- LUKS (Linux)
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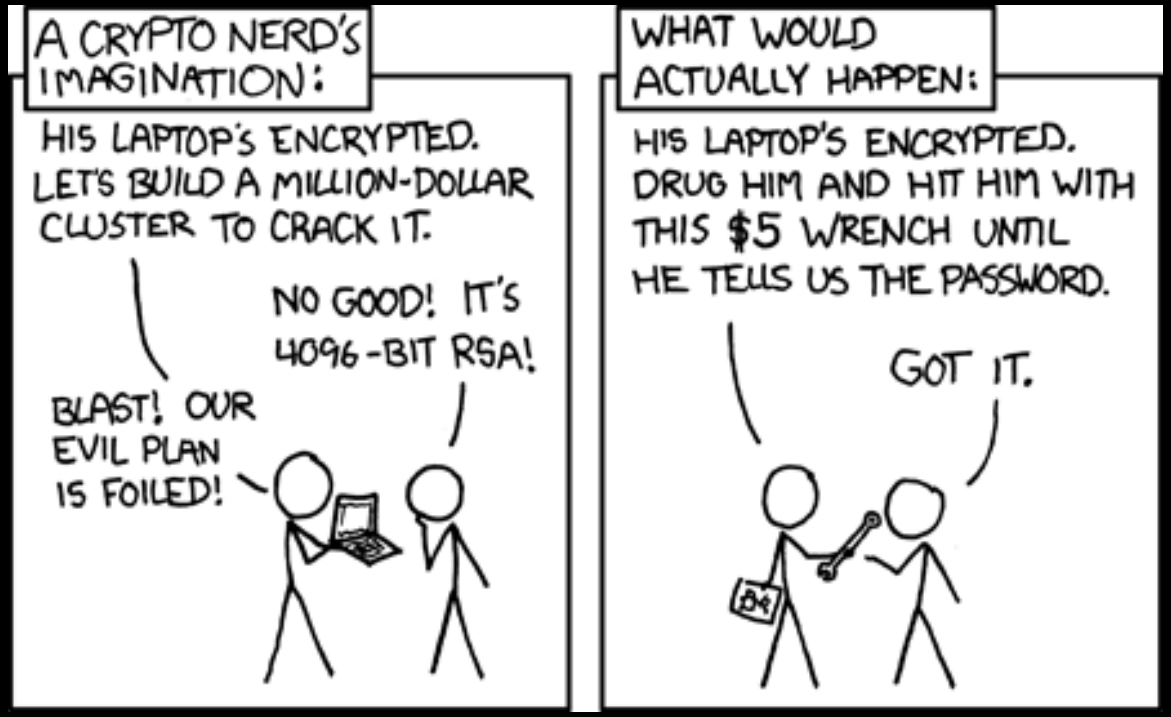

Source: https://xkcd.com/538/

How bad is it?

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Legislation by nation
- Antigua and Barbuda
- Australia
- Belgium
- Cambodia
- Canada
- Czech Republic
- Finland
- France
- Germany
- Iceland
- India
- Ireland
- New Zealand
- Poland
- South Africa
- Spain
- Sweden
- Switzerland

Key disclosure law

Article Talk

From Wikipedia, the free encyclop[redacted]

Key disclosure laws, also known a[redacted] law enforcement. The purpose is t[redacted]

Man jailed over computer password refusal

5 October 2010

Oliver D[redacted]

A teenag[redacted] passwor[redacted]

ELECTRONIC FRONTIER FOUNDATION

US v. Fricosu

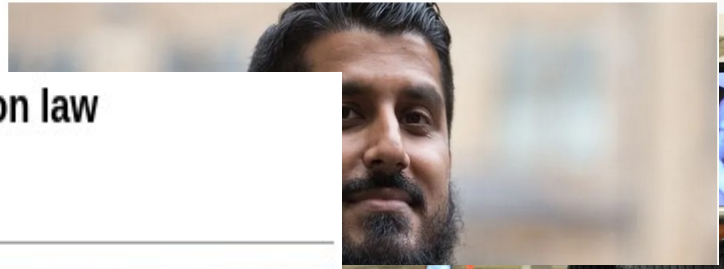
EFF urged a federal district court in Colorado to block the government's attempt to force a woman to enter a password into an encrypted laptop, arguing that it would violate her Fifth Amendment[redacted]

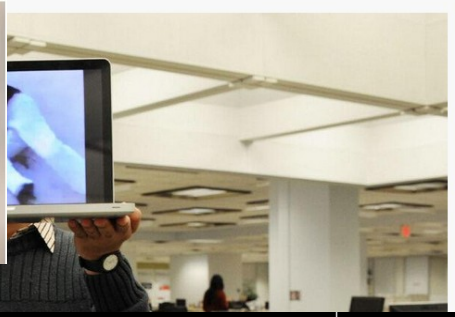
How a Syrian refugee risked his life to bear witness to atrocities

A few hours before leaving his home in Syria to begin a new life in Canada, Mostafa picked up a kitchen knife and began cutting into his left arm

Why Cage director was guilty of withholding password

25 September 2017





Campaigners hit by decryption law

By Mark Ward
Technology correspondent, BBC News website

Animal rights activists are

Plausible Deniability (idea)

Must hide sensitive information in undetectable way

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- You have PD software installed – can't deny existence of encryption
- "I forgot the password" – nope
- Must "give in" some decoy data and hide the rest

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Note: different from Steganography

Who is this for?

- Repressed minorities in low-democracy countries
- Investigative journalists
- Whistleblowers
- Human right activists in repressive regimes

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* : with certain restrictions, depending on the "flavor" of PD

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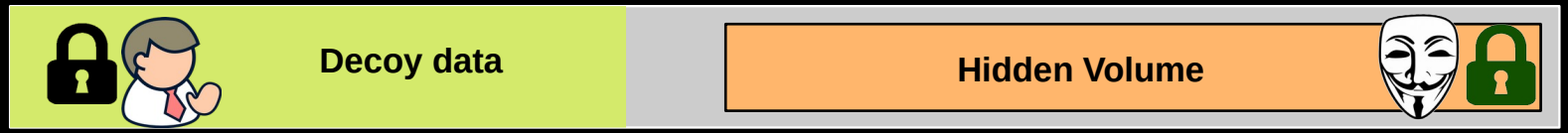

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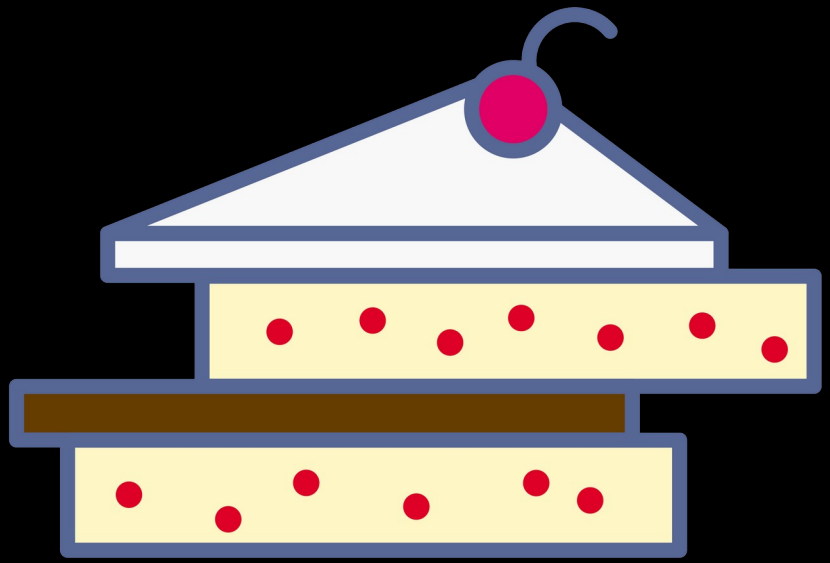
- File-System agnostic
- Many nested layers
- Concurrent volume use
- One password to open
- GPLv2



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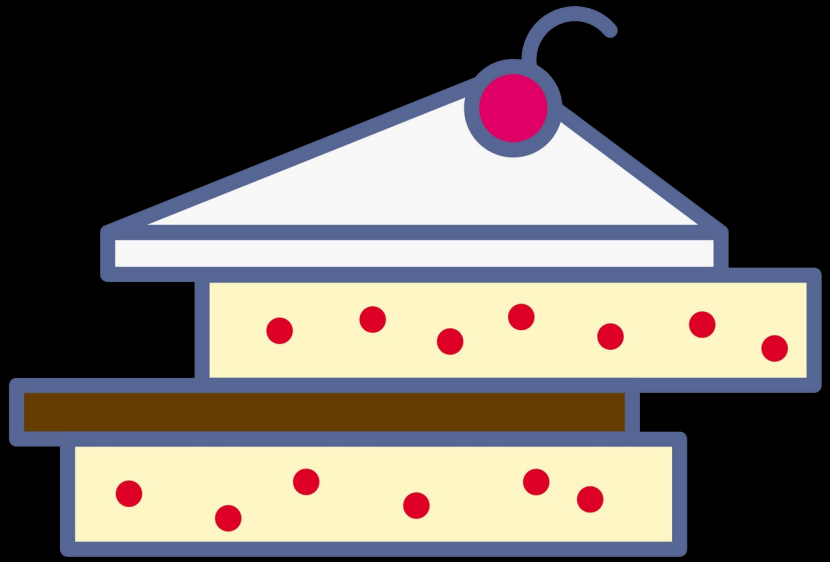

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- One device = multiple volumes (with concurrency)
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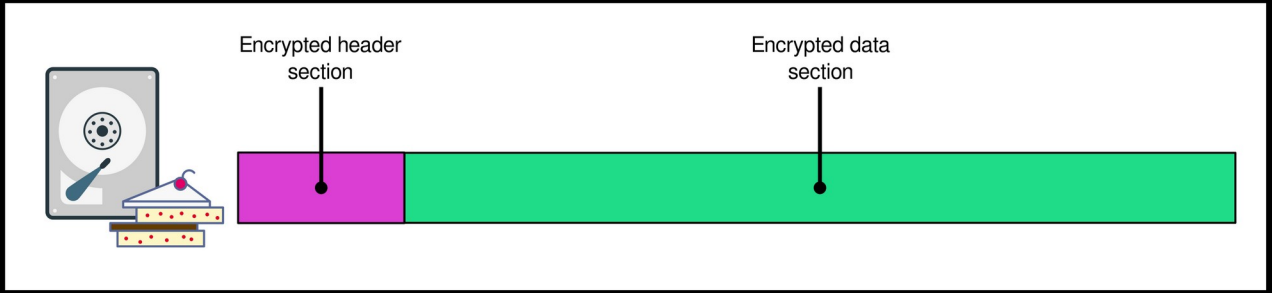
Cryptography

- Well-established schemes (AES, Argon2)
- Cryptographic security proof (single-snapshot)

Shufflecake: disk layout



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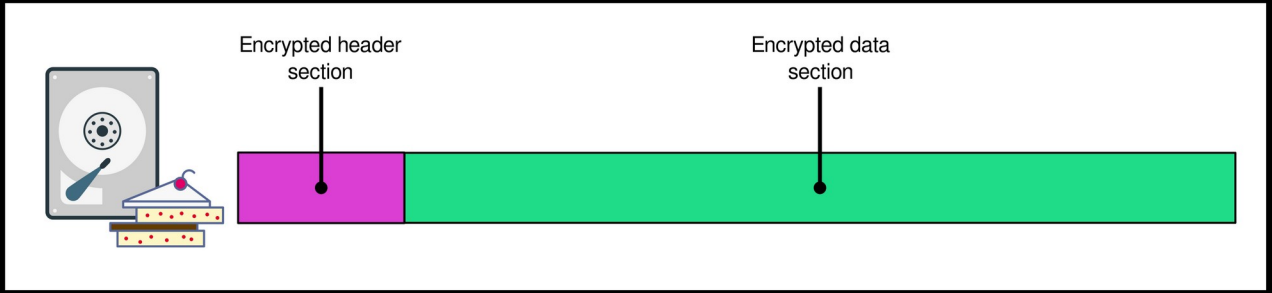

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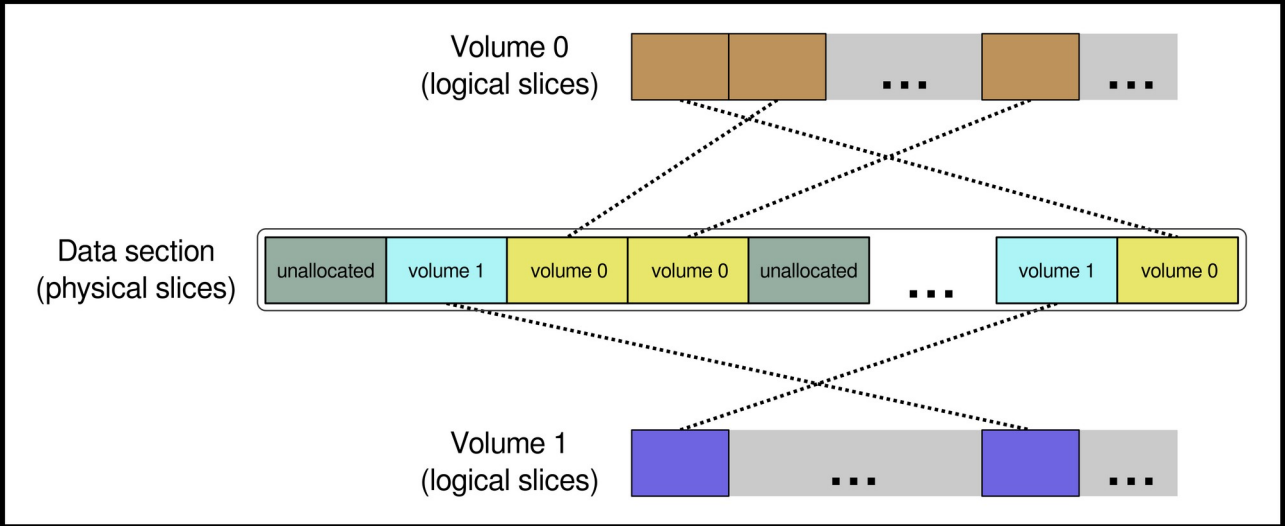

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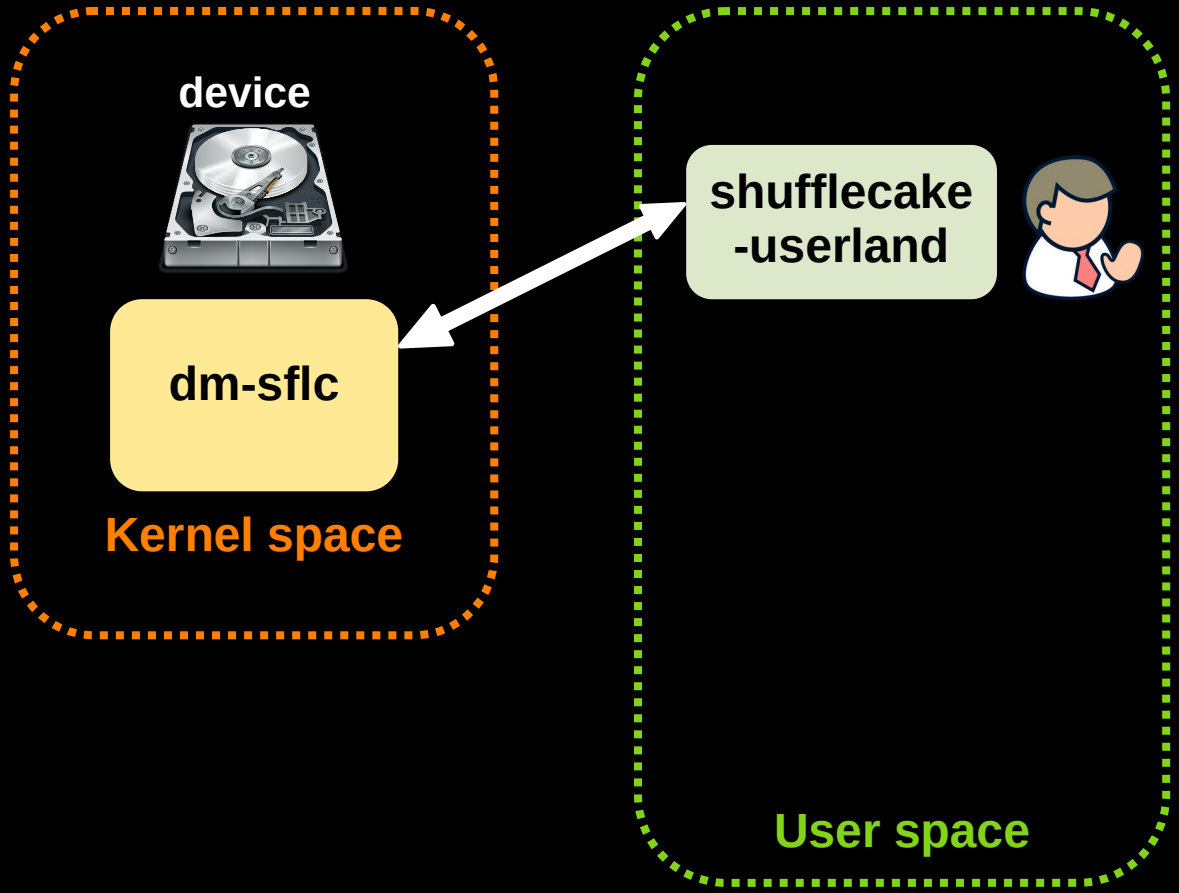

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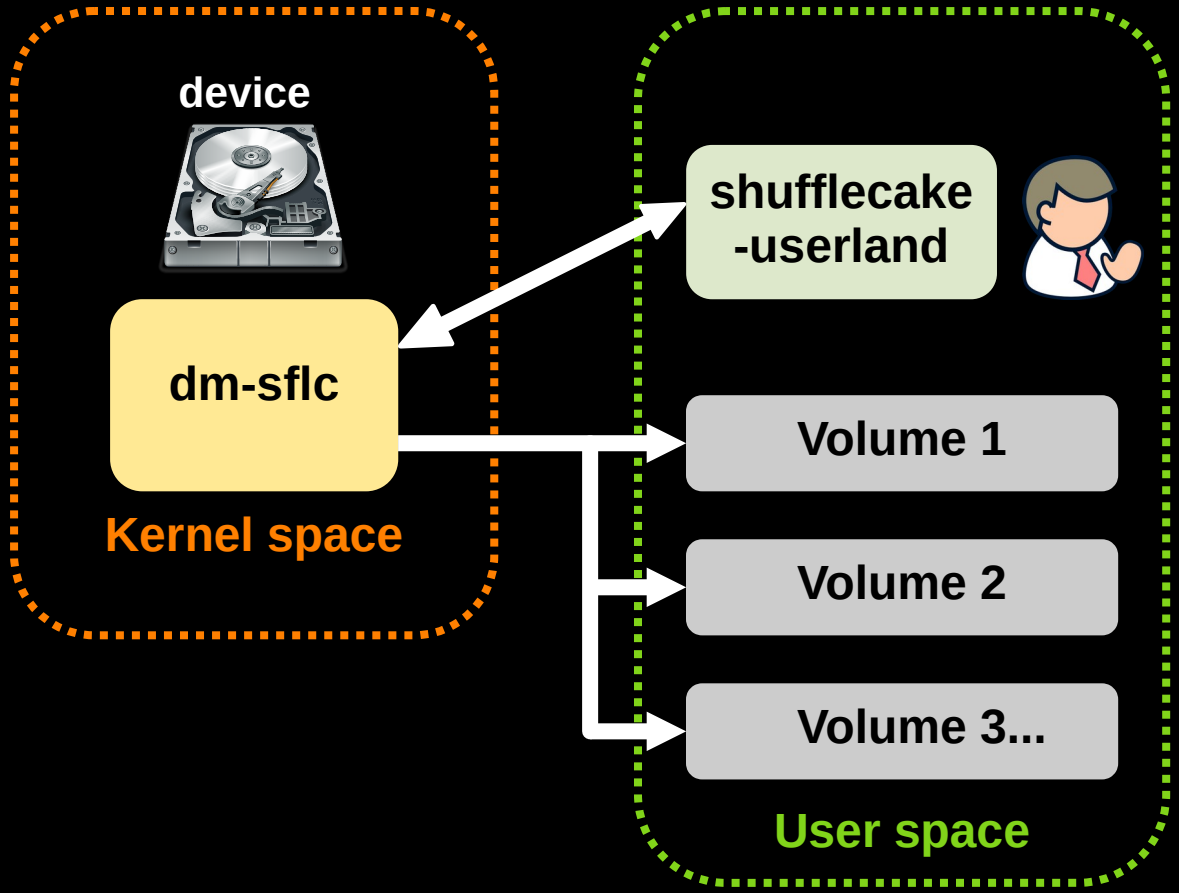

- Userspace can leverage more advanced crypto
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- Hidden volumes appear as `/dev/mapper/sflc_X_Y`
- They can be used as any other block device (formatted at wish, mounted, etc)

Let's talk about multi-snapshot

Physical volume (hard disk/partition)

Decoy data (FAT filesystem)	Empty space (?)

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"modern" solid-state drives: caching / layering / TRIM

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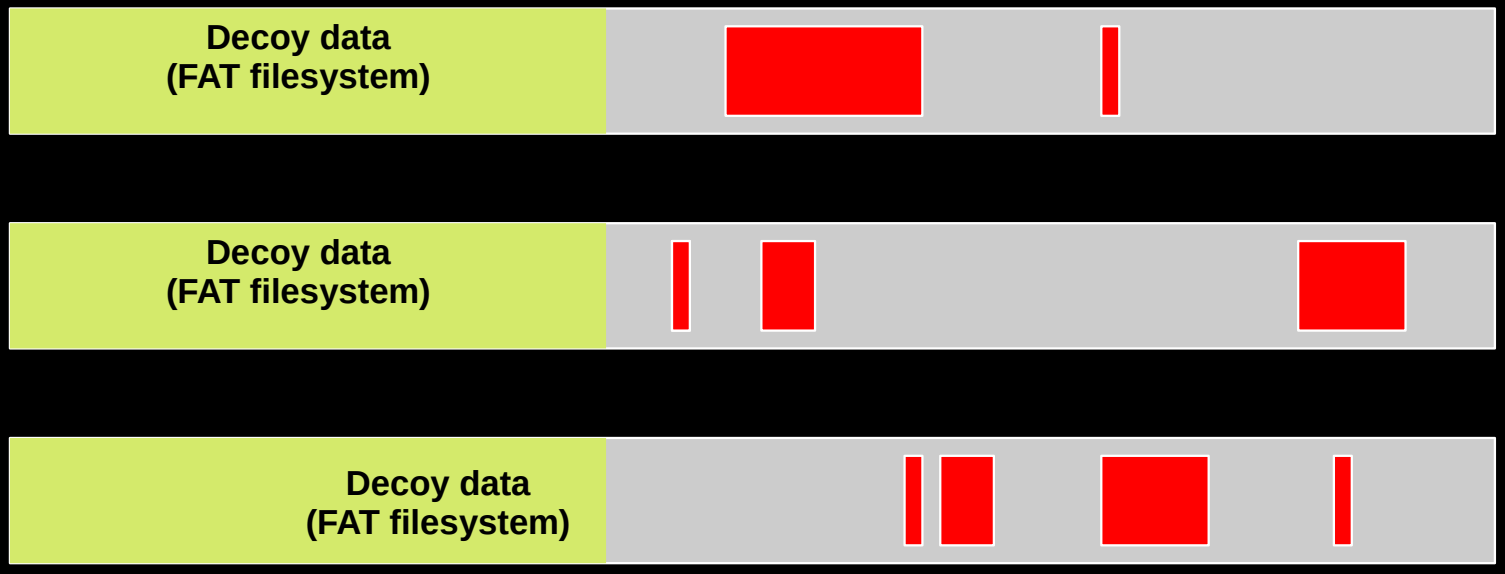

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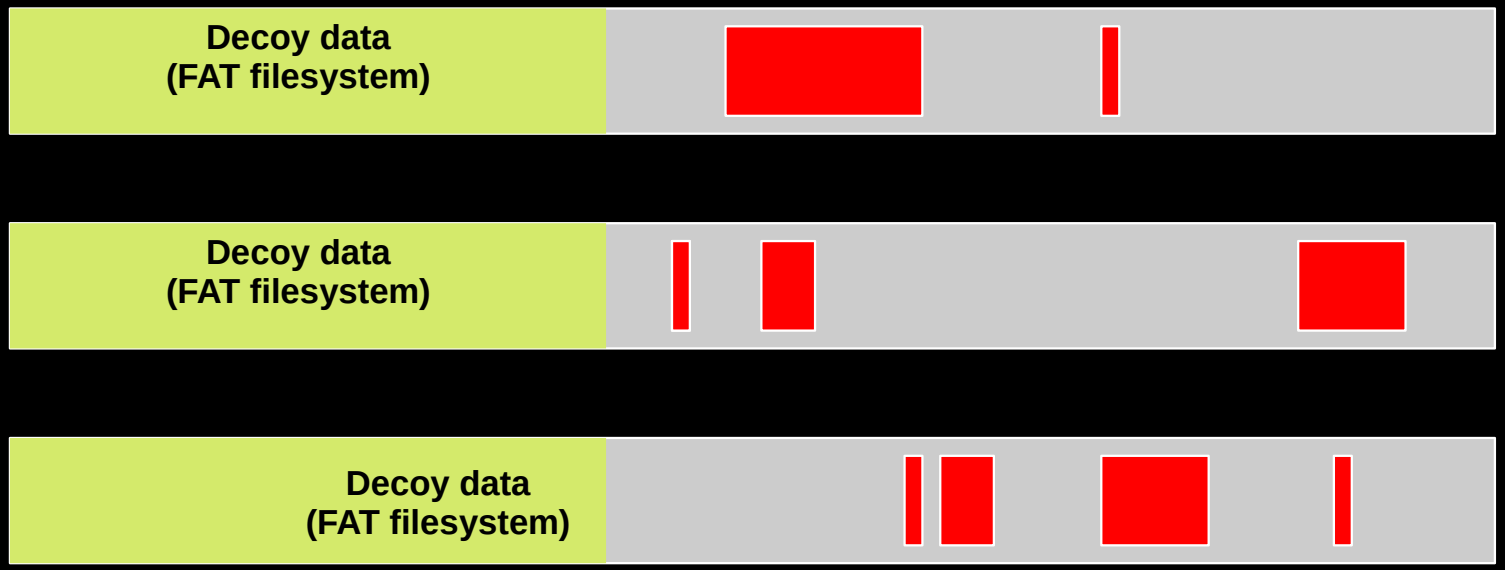

Can we do better?

- Long story short: multi-snapshot security is hard
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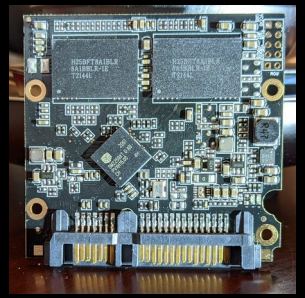

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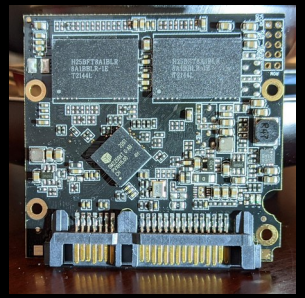

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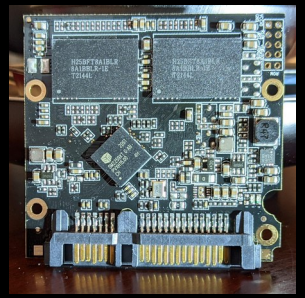

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- How about operational security?
- Are multi-snapshot attacks realistic at all? Should we care?

Shufflecake "Legacy"

- Initial design of Shufflecake scheme
- Uses AES-CTR to achieve ciphertext re-randomization
- The goal is to exploit re-randomization for multi-snapshot resistance in the future (kind of a "lightweight ORAM")
- But needs to write IVs on disk: cumbersome, corruption-prone
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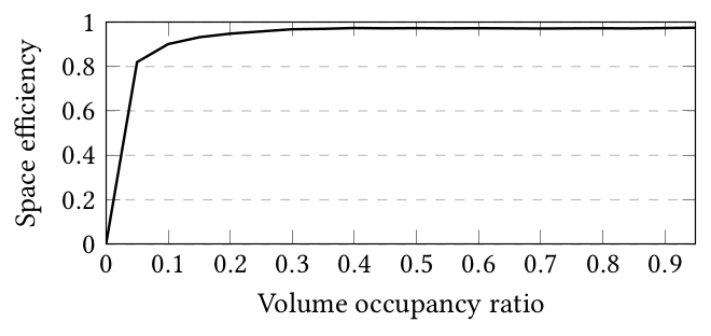
	Shufflecake	dm-crypt/LUKS	VeraCrypt
random write	26.77	38.43	39.07
random read	26.78	38.44	39.09
sequential write	176.87	247.14	247.75
sequential read	177.10	247.43	248.04

Table 1: I/O performance (in MB/s) of Shufflecake, dm-crypt/LUKS, and VeraCrypt.



- ~30% slower than LUKS/VeraCrypt
- Negligible waste of space

Shufflecake “Lite”

Shufflecake v0.5.0 introduces “Lite” scheme

- Uses AES-XTS instead of AES-CTR (like most disk encryption tools)
- As secure as Legacy (single-snapshot)
- Natively crash consistent
- Faster
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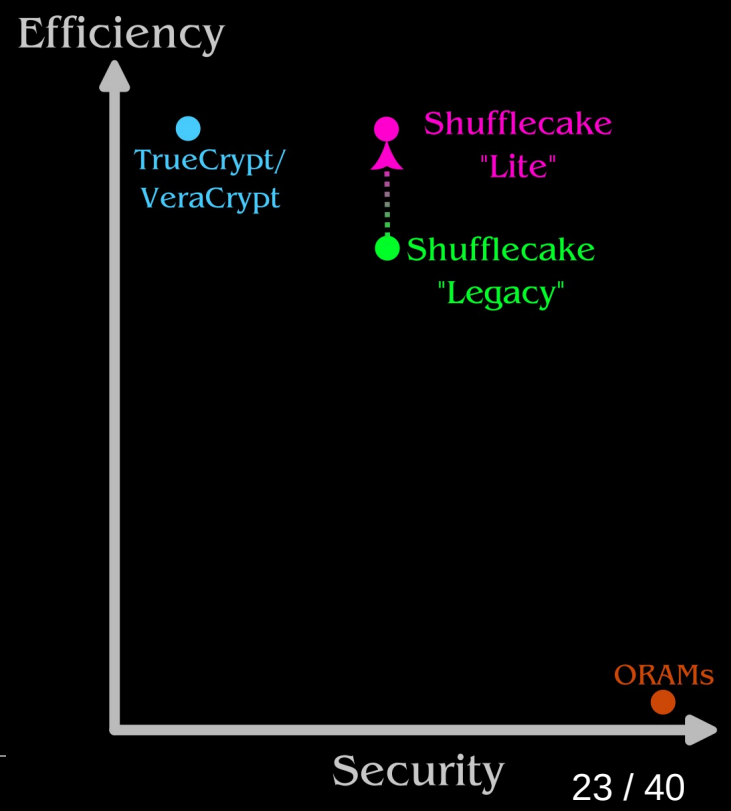

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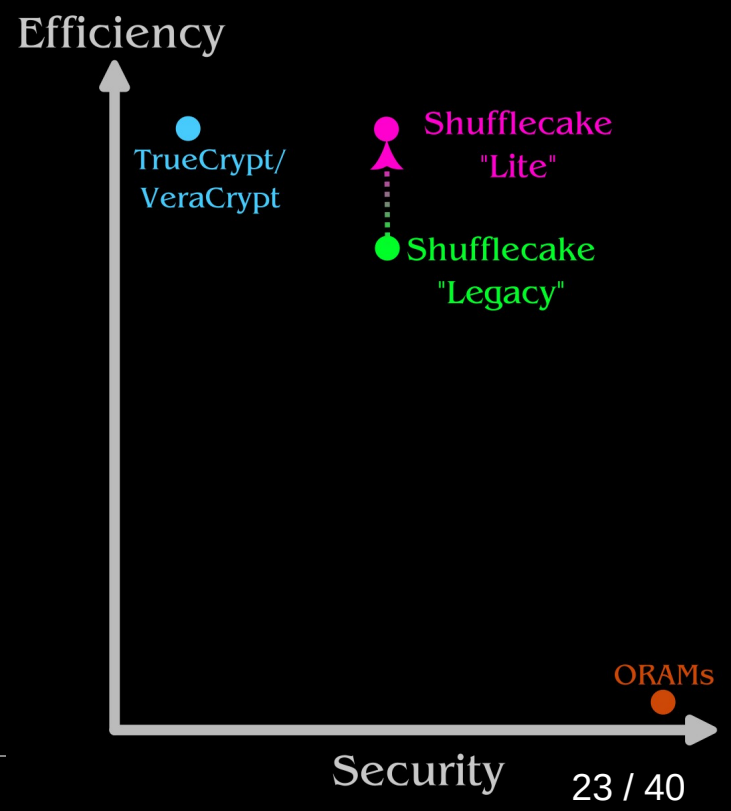
Lite as default mode, but Legacy supported for backward compatibility

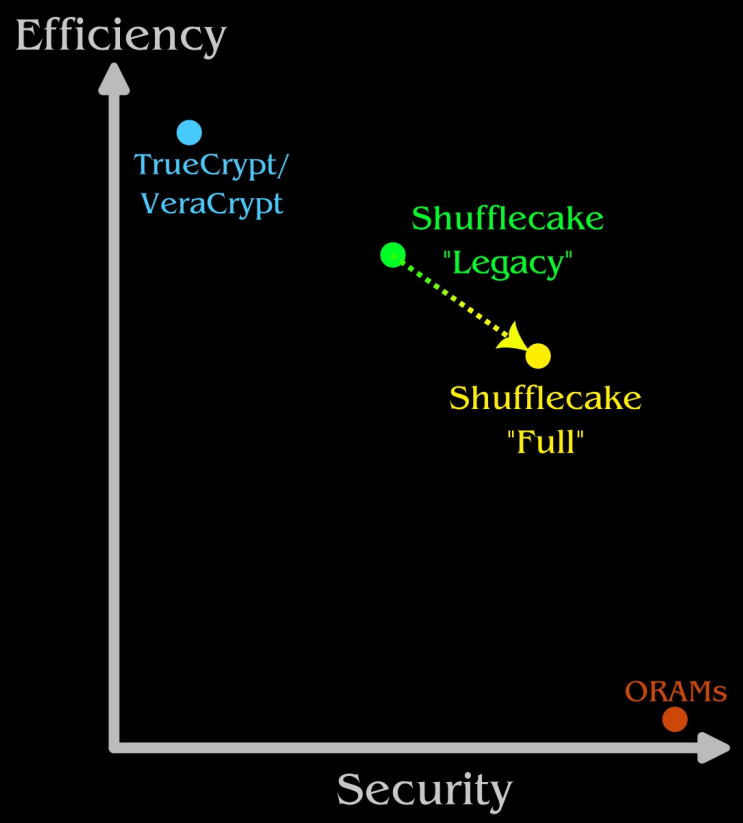
Paper and benchmarks coming soon...



Shufflecake “Full” (WIP)

Like Shufflecake “Legacy” (use of AES-CTR for ciphertext rerandomization) but with added features

- Crash consistency
- (Partial) multi-snapshot security
- “lightweight ORAM” in spirit
- Will not achieve “full” multisnapshot security
- But goal is to reach “operational” security (= “stands in court”)



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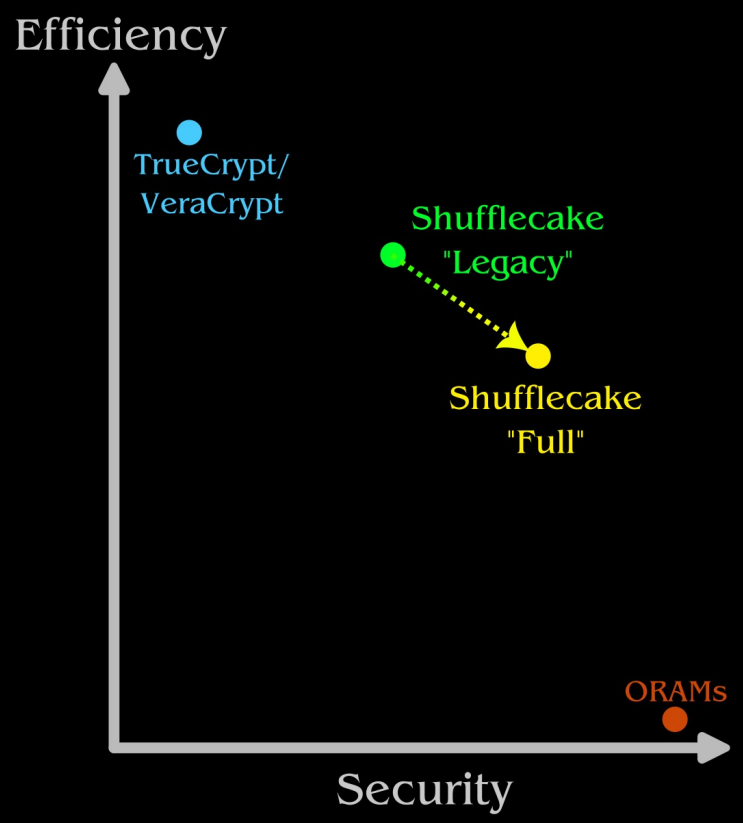
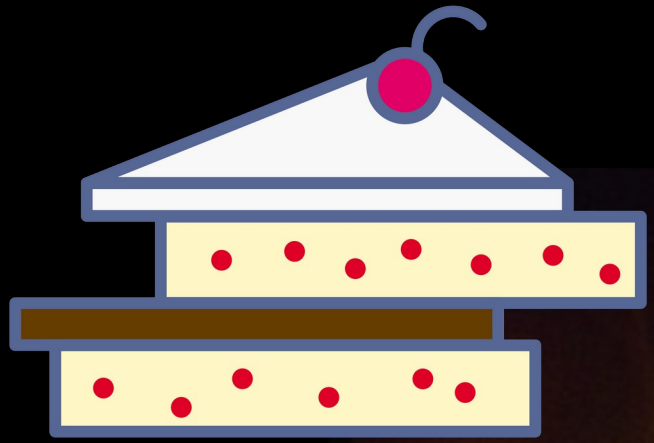
Open question: should we bother? Or is Lite enough?



Future Directions



Chores and external contribution

Shufflecake is still an experimental, very low-level tool

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- `make install`
- Distribute through DKMS
- Packetization (.deb, .rpm etc)
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- Porting to Rust?
- GUI?
- Port to Windows/iOS?

Work in progress and plans

- Shufflecake "Full"
- Full crash consistency
- Corruption resistance
- (Partial) multi-snapshot security
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- Reclaiming unused slices
- Anti-safeword: unbounded number of volumes
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  - Problem understudied: it exists in all PD solutions we are aware of.
  - Only fix: have an unbounded number of nested volumes.

Unbounded number of volumes

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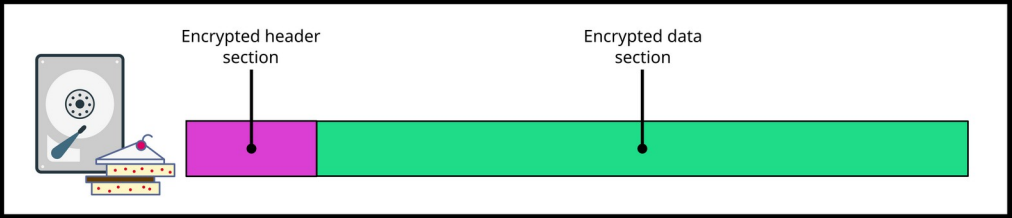

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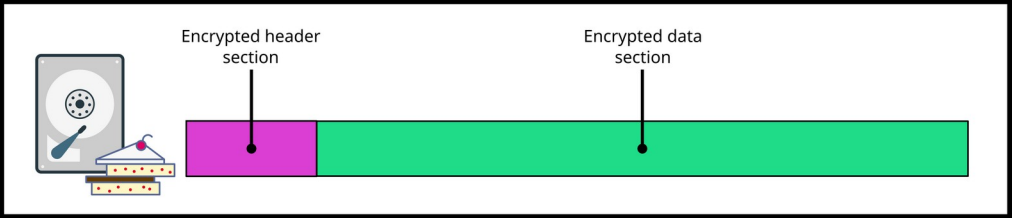

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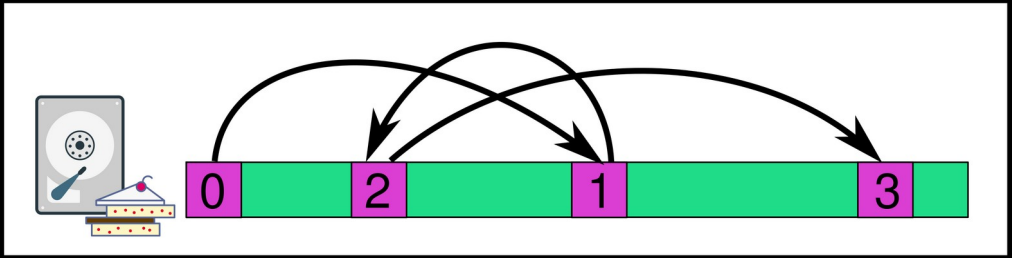

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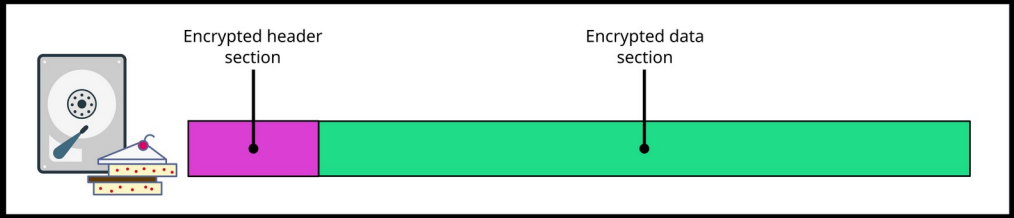

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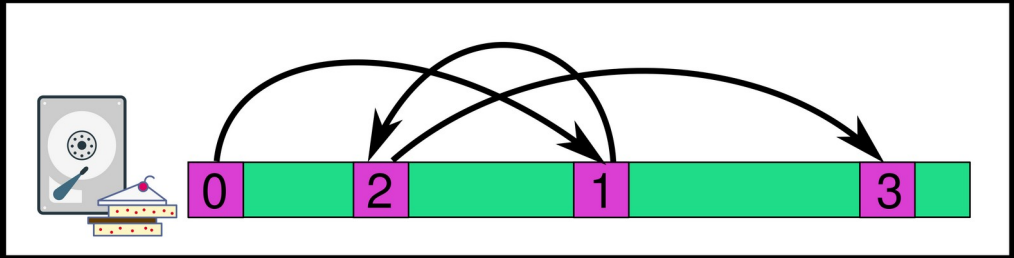

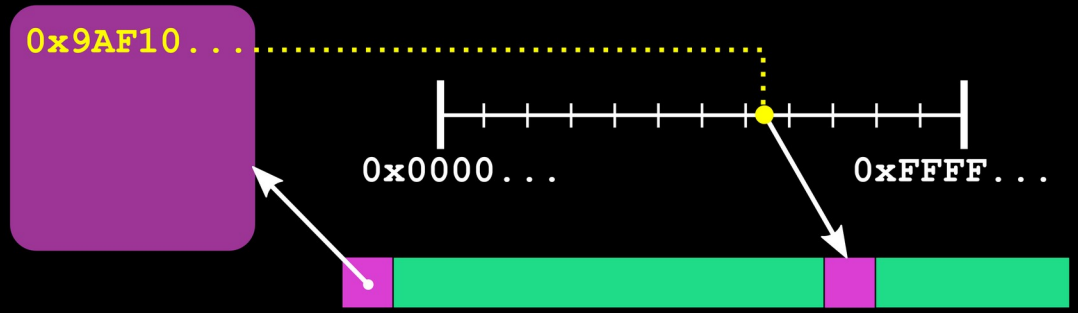

- Linked list, navigation through cleartext randomness
- Position maps split into more list nodes if too large

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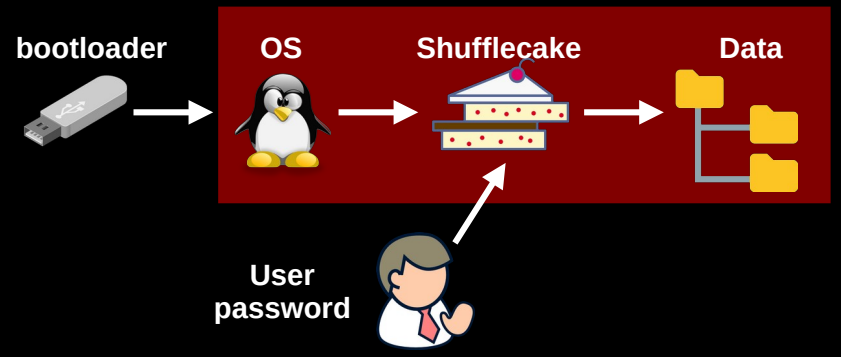

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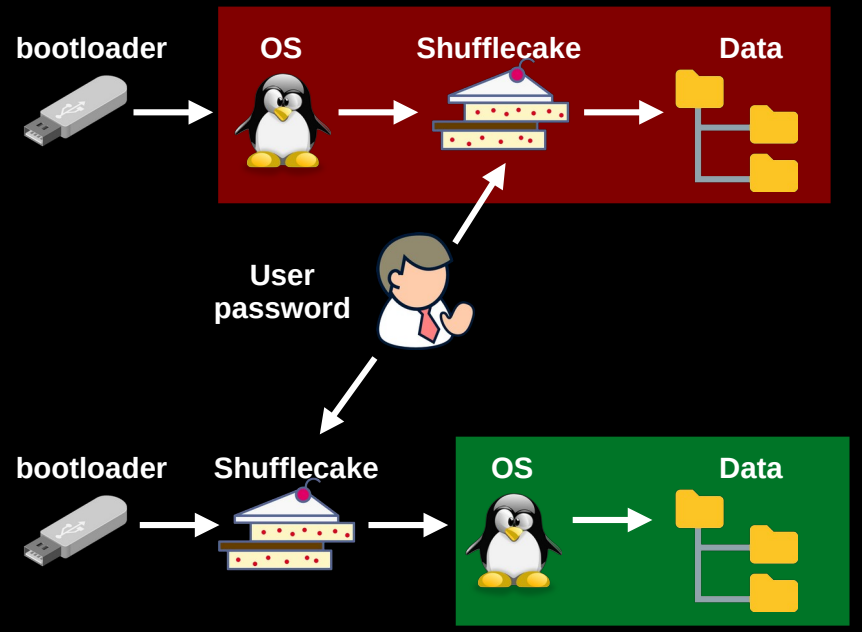

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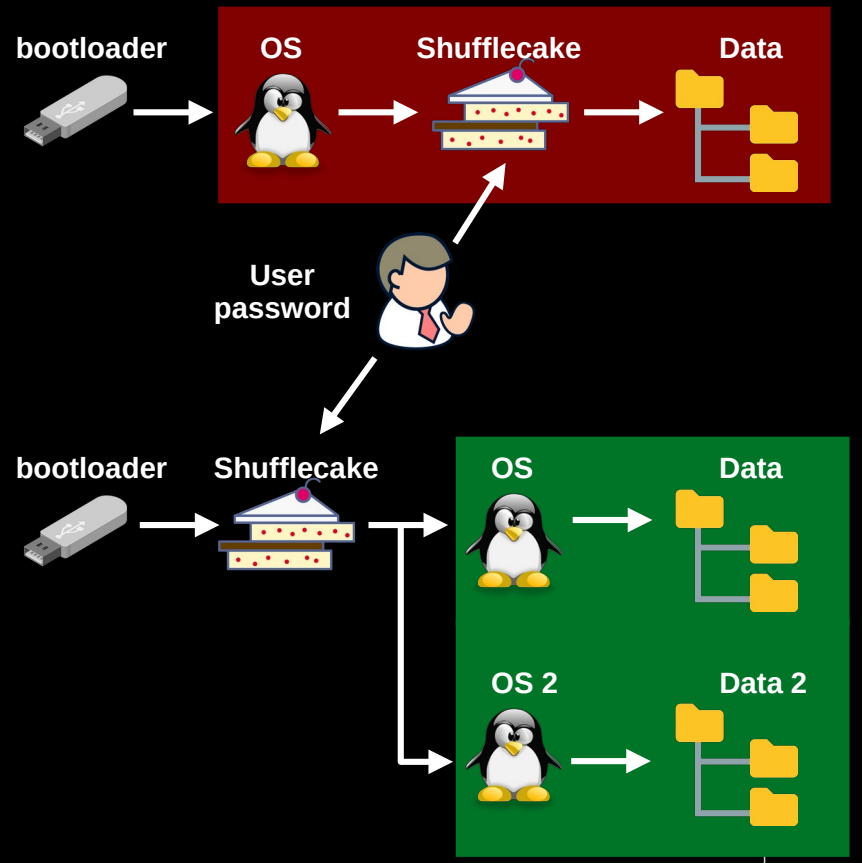

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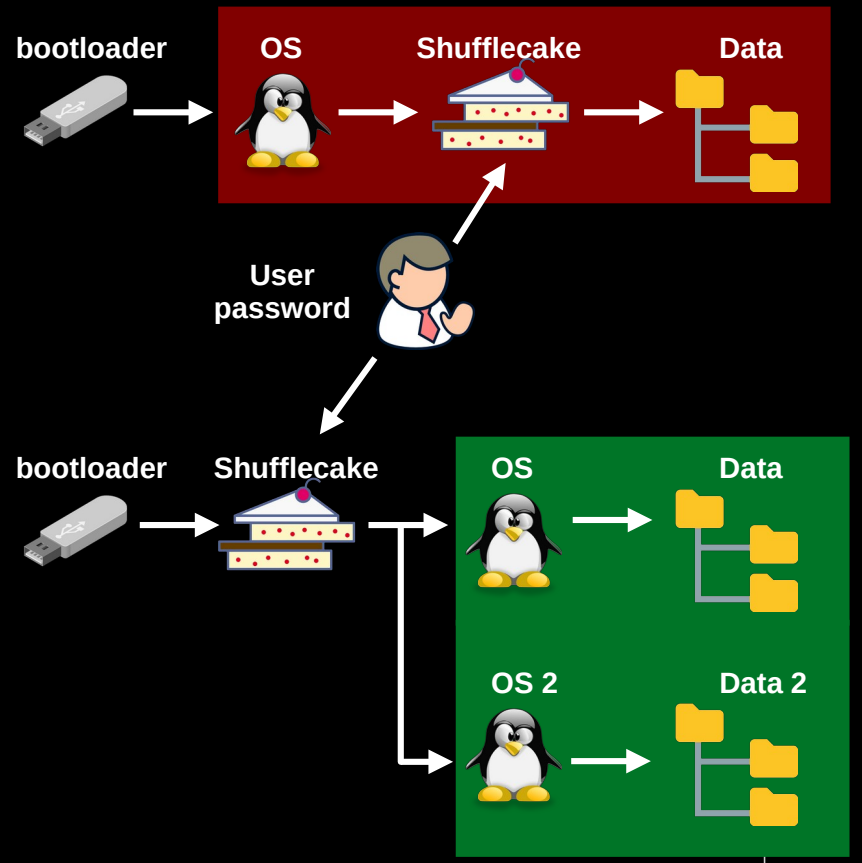

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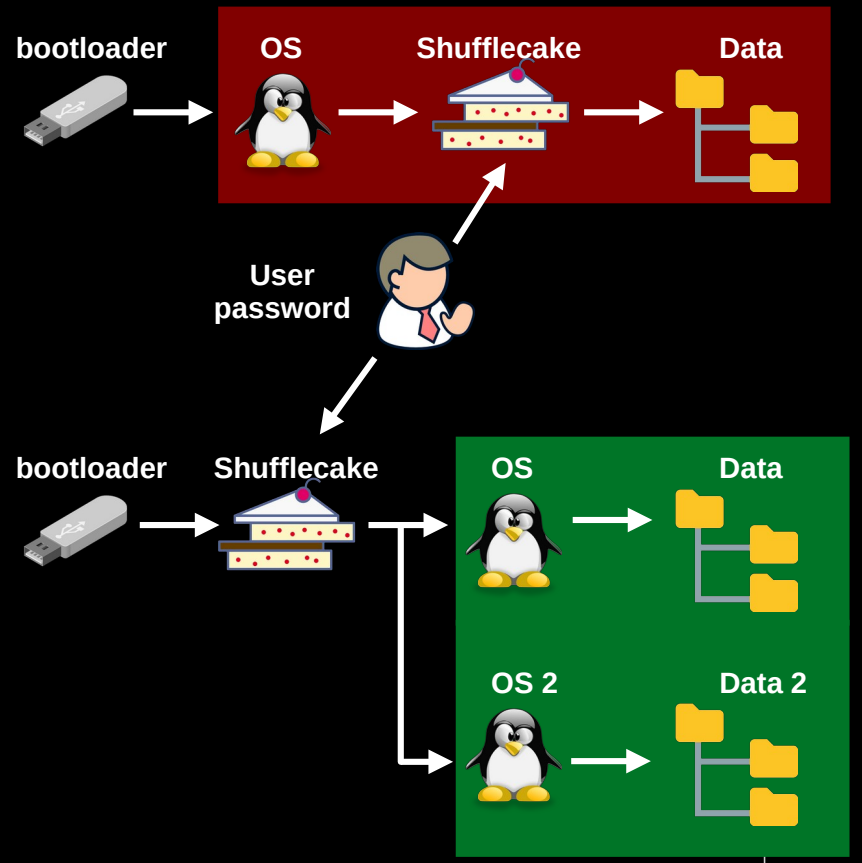

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  - All other VMs would reside in other Shufflecake volumes.

Shufflecake OS: Roadmap

1) Improve testing and performance of Shufflecake Lite — in progress

2) Implement Shufflecake primitives in a new library **`sflclib`** and have **`dm-sflc`** and **`shufflecake-userland`** depend on that — in progress

3) Patch GRUB to support Argon2 KDF and other Shufflecake tweaks — done

4) Write **`sflcdisk`** GRUB module using **`sflclib`** — done

5) Patch Qubes OS to support dom0+hypervisor in read-only mode and allow flashing from another VM — planned

6) Patch Qubes OS' installer — planned

How to contribute

- Code https://codeberg.org/shufflecake
- Mastodon @shufflecake@fosstodon.org
- Website https://shufflecake.net
- E-mail website@shufflecake.net
- Jabber xmpp:shufflecake@conference.draugr.de
- Blog: COMING SOON

Thank you for your attention!

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Option 2

- Store IV along data block and make write of block atomic
- Minimum addressable block size (on Linux): 512 bytes
- Use 9-block writes (4096 bytes data + 512 bytes IV block)
- Wastes ~11% space but faster, extra space in IV block to be used

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- Obfuscation can be delegated to a daemon (additional component)
- "Poor man's ORAM" in spirit

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- Tested with RAID (but cumbersome)
- Shufflecake reallocates corrupted slices, but recovery left to external tools
- We are implementing API to help external tools
- Open problem: how to protect not only data blocks, but also position map?

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- Example: mountpoint (and allow Shufflecake to automount)
- Example: corruption status flag
- Example: virtual quotas
  - To limit overcommitment and avoid corruption
  - Every volume's VMB has a virtual quota not for itself, but for the volume below
  - Topmost volume is assigned total space minus sum of virtual quotas

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- Need intervention from the OS for this. TRIM operation.
- Needs to intercept OS's TRIM operations for a given slice.
- Once we have this in place, Shufflecake design allows to do the rest easily.