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Encrypted Filesystem for Applications

Master Thesis: Portable multi-key encrypted file storage

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Why encrypt in the application?

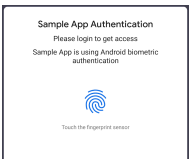
Motivation

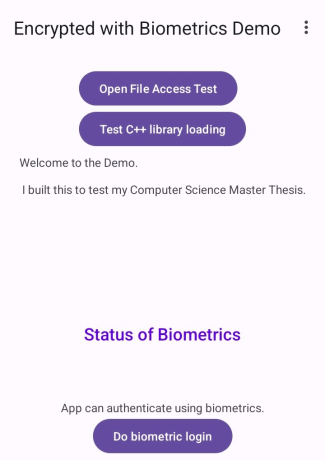
For developers:

- Manageable for an end-user
- Sync- or Migrate-able from one device to another
- Easy to use & hard to make mistakes

For users:

- Normal workflow $\rightarrow$ fast biometric
- Backup and Migration Path





Technology Decision

- Use Rust for memory safety
- No `unsafe` ← only safe rust
- Use modern key strengthening Argon2 [3]
- Replace AES with ChaCha20-Poly1305 [2]
- Embeddable for the Digidow.eu project

Technology Decision - Why replace AES?

- See L2 Cache-timing attacks on AES [1]
- See Microarchitectural exploitation and other hardware attacks[1]
- Replaces S-Boxes with `XOR`, `Integer Addition Modulo` 2^{32}, and `Integer Shift with Roll`

[1] https://github.com/codexlynx/hardware-attacks-state-of-the-art

Speed Comparison

From rfc8439

Chip	AES-128-GCM	ChaCha20-Poly1305
OMAP 4460	24.1 MB/s	75.3 MB/s
Snapdragon S4 Pro	41.5 MB/s	130.9 MB/s
Sandy Bridge Xeon (AES-NI)	900 MB/s	500 MB/s

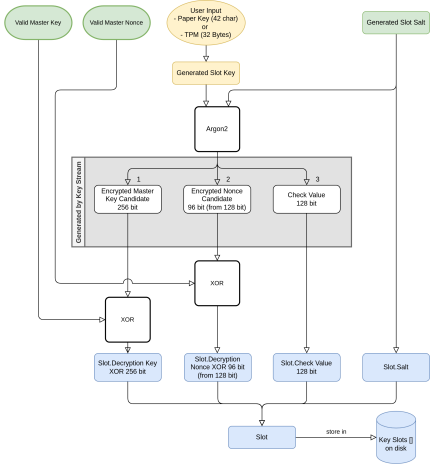
Master Key Management

Technical Decisions

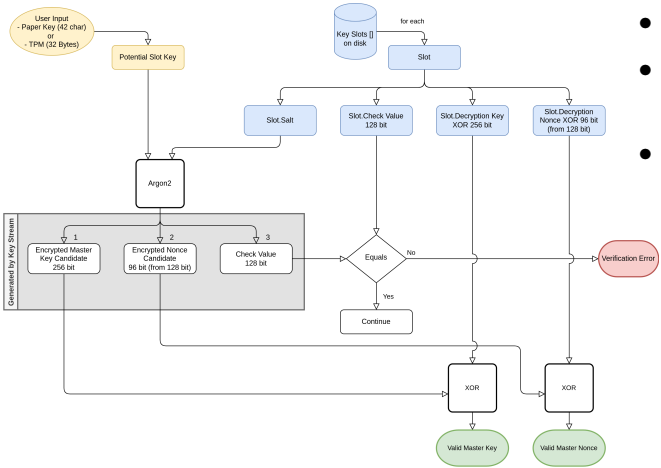
- Reduce the amount of places where the master key resides in memory
- Use the type system to keep the nonce in sync
- Lock the open files so syncing operations don't cause problems
  - Unix: `flock(file, rustix::fs::FlockOperation::LockExclusive)`
  - Windows: `lock_file(file, LOCKFILE_EXCLUSIVE_LOCK)`
- Autosave on `Drop::drop(&mut self)`

Master Key Creation

- Paper Key for user
- Add n-th key for other devices
- TPM Key for secure hardware
- Master Key only in system memory



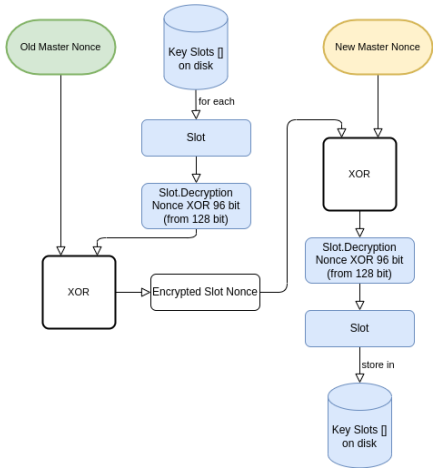
Per Slot Master Key Decryption



- Try all stored key material
- Nonce is rather predictable, few writes of the whole directory
- “If the seed used to generate the stream is secret then it is **infeasible to compute previously generated bytes** in an Argon2 key stream” Philipp Jovanovic, PhD, Associate Professor in Information Security (University College London)

Update Master Key Nonces

- Requires the Master Key for opening the vault
- Does not require the other Slot Keys
- Is done on every `Write::flush()`
- Very cheap to compute



Schneeglöggli

Schneeglöggli 21.02.2023

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File Content Encryption and Virtual Filesystem

File Content Encryption

The based on established code and practices:

- Authenticated Encryption with Associated Data (AEAD) [5]
  ChaCha20-Poly1305 [2] developed by Daniel J. Bernstein
- The `ring` crate with a safe Rust interface
- C and assembly language code in ring come from BoringSSL [6], that is derived from OpenSSL [4]

Abstraction Design Choices

The directory:

- `HashMap` with the clear path as key
- Minimal index $\rightarrow$ every change requires a full encrypt + write
- Create and access time from underlying filesystem
- Size may be reported incorrectly, AEAD TAG + Padding
- Filesystem Lock during application run

Per file:

- Loading the contents on demand to memory
- Guarding open file contents with RwLock per file
- Automatic flush on scope drop

Native Integration

Android Integration - the plan

Build system integration:

- Integrate with gradle
- Build a native toolchain with cmake and cargo

Use the Kotlin runtime for:

- Handle system permissions
- Communicate with finger print reader and KeyStore
- Handle user input for setup and recovery (Paper Key)

Artistic representation of the working environment

Dramatization incoming

Are you ready?

Artistic representation of the working environment

Source:

https://www.deviantart.com/aperture--science/art/Android-hell-137246583

Current Problems with the Android Ecosystem 1/2

- Open Android Studio
  - Update 2022.1.1 Patch 1
  - Project is broken now
- Start a new default project with Update 2022.1
  - Build fails
  - Find the project setting to upgrade gradle to 7.6
- Find the docs to get finger print sensor presence?
  - No complete sample, just snippets
  - No docs on how to store an actual key in the HSM

Current Problems with the Android Ecosystem 2/2

- How to generate FFI C include header?
  - `javah` is replaced by `javac -h`
  - Does not work with Kotlin
- How to find compiled libraries with `gradelw` or Android Studio?
  - `cmake` is completely reconfigured by multiple `compile_commands.json`
- How to compile the glue crate? (After reading the error messages)
  - Wast a lot of time building `build.rs`
  - Install `cargo-ndk` still pass the NDK path manually

Linux / Windows Integration

Build system cargo:

- Provide a Rust lib or C98 FFI staticlib interface
- TPM/vTPM communication

Runtime:

- Provide a Rust or C98 FFI interface
- Handle TPM/vTPM communication
- Handle user input for setup and recovery (Paper Key)

Lets relax

Walensee 21.02.2023

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References I

[1] Daniel J. Bernstein. 2005. Cache-timing attacks on AES. https://cr.yp.to/antiforgery/cachetiming-20050414.pdf. (2005).

[2] Daniel J. Bernstein. 2018. ChaCha20-Poly1305 is an authenticated encryption with additional data (AEAD) algorithm, RFC8439. https://datatracker.ietf.org/doc/html/rfc8439. (2018).

[3] Alex Biryukov, Daniel Dinu, and Dmitry Khovratovich. 2017. Argon2: the memory-hard function for password hashing and other applications. https://www.cryptolux.org/index.php/Argon2. (2017).

[4] OpenSSL Contributors. 1998-. OpenSSL. https://www.openssl.org/. (1998-).

References II

[5] Google Engineering. 2021. Authenticated Encryption with Associated Data. https://developers.google.com/tink/aead. (2021).

[6] Google Engineering and OpenSSL Contributors. 2014-. BoringSSL. https://boringssl.googlesource.com/boringssl/. (2014-).


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