dirlock: a tool to manage encrypted filesystems

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About me

- Software engineer at Igalia.
  - GNOME
  - Maemo / MeeGo
  - QEMU
- Debian developer.
- Currently working on SteamOS.

dirlock

A tool to manage disk encryption

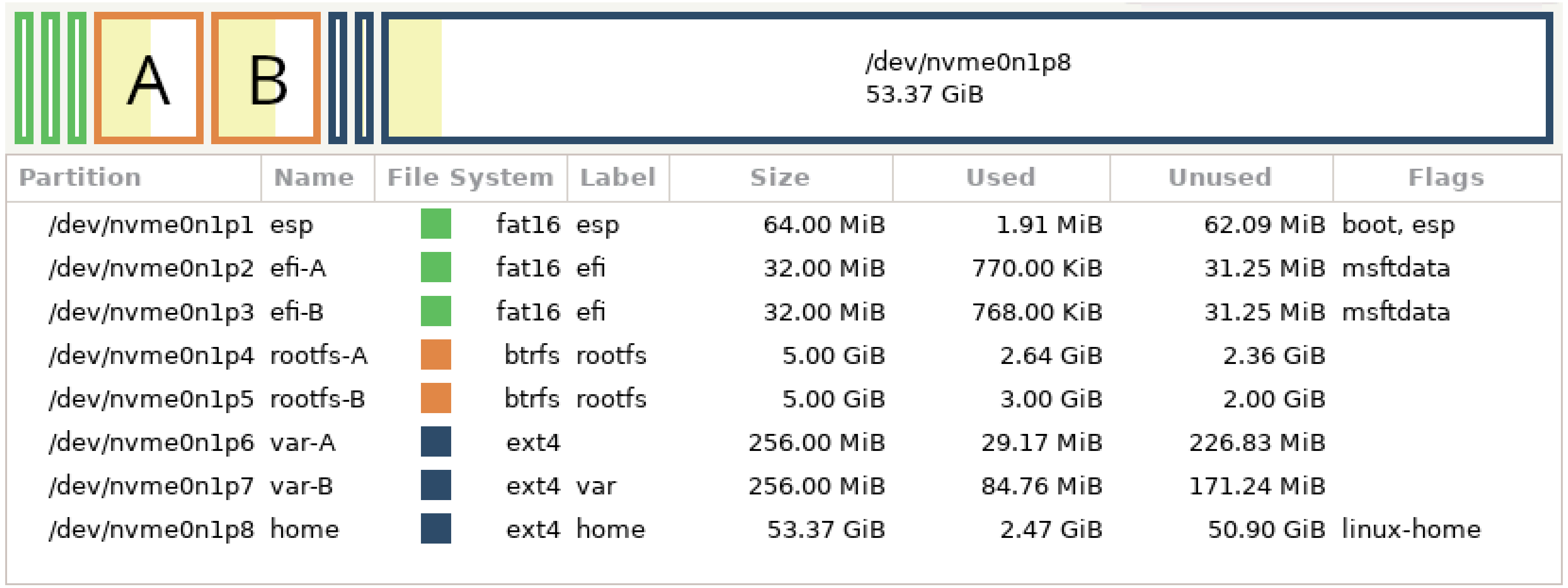
Not a new encryption system

Built on top of existing technologies

Use case: encryption for SteamOS

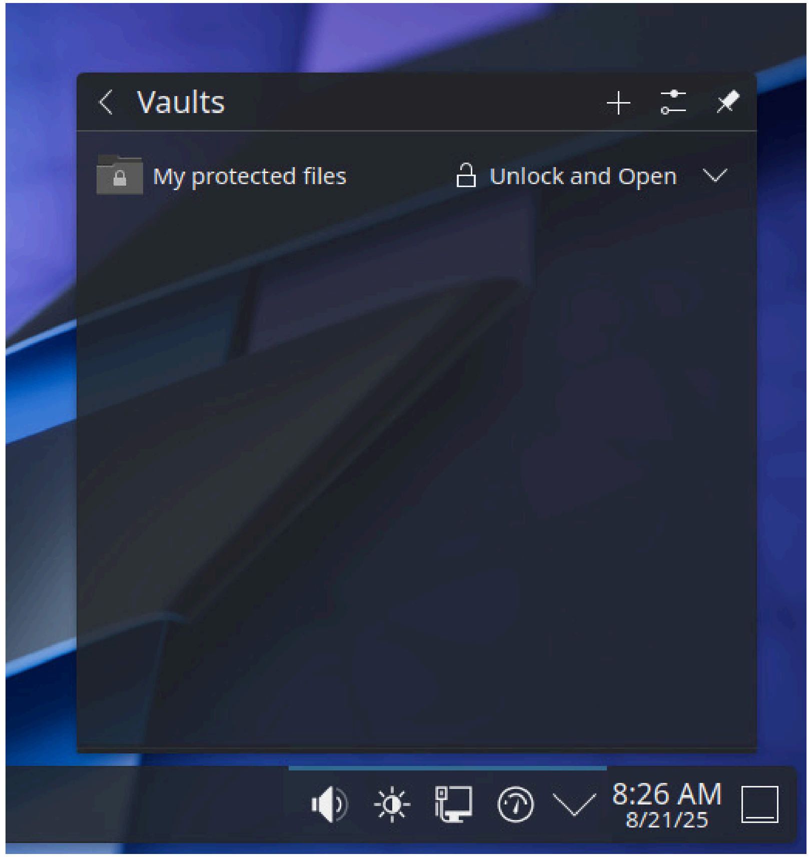
- Steam Deck and others: portable devices, easy to lose.
- No encryption at the moment.
- Not only usable for gaming.
- Anyone can read the contents of the hard drive.

Disk layout



Partition	Name	File System	Label	Size	Used	Unused	Flags
/dev/nvme0n1p1	esp	🟩 fat16	esp	64.00 MiB	1.91 MiB	62.09 MiB	boot, esp
/dev/nvme0n1p2	efi-A	🟩 fat16	efi	32.00 MiB	770.00 KiB	31.25 MiB	msftdata
/dev/nvme0n1p3	efi-B	🟩 fat16	efi	32.00 MiB	768.00 KiB	31.25 MiB	msftdata
/dev/nvme0n1p4	rootfs-A	🟧 btrfs	rootfs	5.00 GiB	2.64 GiB	2.36 GiB	
/dev/nvme0n1p5	rootfs-B	🟧 btrfs	rootfs	5.00 GiB	3.00 GiB	2.00 GiB	
/dev/nvme0n1p6	var-A	🟦 ext4		256.00 MiB	29.17 MiB	226.83 MiB	
/dev/nvme0n1p7	var-B	🟦 ext4	var	256.00 MiB	84.76 MiB	171.24 MiB	
/dev/nvme0n1p8	home	🟦 ext4	home	53.37 GiB	2.47 GiB	50.90 GiB	linux-home

Current alternative: Plasma Vaults



Our goals

- **Personal files must be unreadable if the computer is stolen.**
- `$HOME` should be be encrypted.
  - Possibility to encrypt other directories.
- Multiple users with independent encryption keys.
- Access should be authenticated.
  - PIN, password, or similar to log in.
  - Not all computers have a keyboard!
  - Support hardware-backed mechanisms.

- Enable encryption without reinstalling the OS from scratch.
  - Ideally: a simple *"Encrypt data"* button or command.
- D-Bus API.
- Reasonable performace.

Available encryption technologies

- Stacked filesystem encryption
- Block device encryption
- Native filesytem encryption

Stacked filesytem encryption

- Data is stored as (encrypted) regular files.
- Mount the encrypted directory to see the data.
- Examples: gocryptfs, EncFS
  - Implemented in user space (FUSE).
  - Used by tools like Plasma Vaults.

Block device encryption

- Encrypts blocks on disk, does not care about what's inside. (normally a filesystem but it can be anything).
- Uses raw partitions or loopback files.
- The contents are completely hidden.
- Most popular technology: LUKS.
    - The header contains the encryption keys.

Native filesystem encryption

- Files are encrypted directly at the filesystem level.
- A filesystem can contain a mix of encrypted and unencrypted directories.
- Only partial confidentiality:
  - Data is safe, but metadata, file sizes, … are not protected.
- The Linux kernel provides the *fscrypt* API:
  - Implemented by ext4, f2fs and others.
- User space is responsible for the encryption keys.

LUKS vs fscrypt

LUKS: pros and cons

- Pros:
  - Maximum confidentiality and protection.
  - Supports TPM, FIDO tokens (via systemd).
- Cons:
  - Usually unlocked early on boot.
  - No fine-grained control about what to encrypt.
  - Hard to encrypt an existing installation, it needs a new filesystem.

fscrypt: pros and cons

- Pros:
  - Easy to encrypt an existing installation, no preallocation needed.
  - Multiple directories and user accounts with different keys.
  - Easy integration with PAM.
  - Can be unlocked after booting, also remotely (ssh).
- Cons:
  - Metadata not encrypted, some information can be seen or guessed.
    - Approximate directory structure, sizes, permissions, timestamps, extended attributes.
  - Attackers can delete files.

Our choice is fscrypt

- Good confidentiality guarantees for the main use case.
- Flexible.
- It can be enabled in existing installations.
- Good performance.

But fscrypt is just a kernel API

- We need to handle the encryption keys in user space.
- Existing tools:
    - The *fscrypt* command-line application.
        - Related to, but different from the fscrypt kernel API.
    - systemd-homed

/usr/bin/fscrypt

- Reference tool to manage encrypted directories.
- Written in Go by Joe Richey and Eric Biggers.
- Simple to use, covers all essential functionalities.
- PAM support.
- Only allows passwords and raw binary keys.
  - No hardware-backed mechanisms.
- No D-Bus API.

systemd-homed

- A tool to manage *human* user accounts.
- Various storage backends, two of them encrypted:
  - LUKS (homedir inside a LUKS loopback file).
  - fscrypt (only the deprecated v1 API).
- D-Bus API, PAM and FIDO support (but no TPM).
- However: it's primarily *not* an encryption tool.
  - It encrypts `$HOME` and nothing else.
  - Own user database (no `/etc/passwd`).
  - Uses idmapped mounts, issues with podman.

dirlock

A new high-level tool that uses the fscrypt API

Overview

- Does encryption, authentication and nothing else.
- Heavily inspired by /usr/bin/fscrypt.
- Still under development.
  - PAM support working.
  - FIDO support working.
  - (basic) TPM support working.
  - D-Bus API in prototype stage.

Where to find it

- **https://gitlab.steamos.cloud/holo/dirlock/**
- Free software, BSD license.
- Written in Rust.
- Works in any Linux system.
- Available in SteamOS 3.8 as an *experimental* feature.

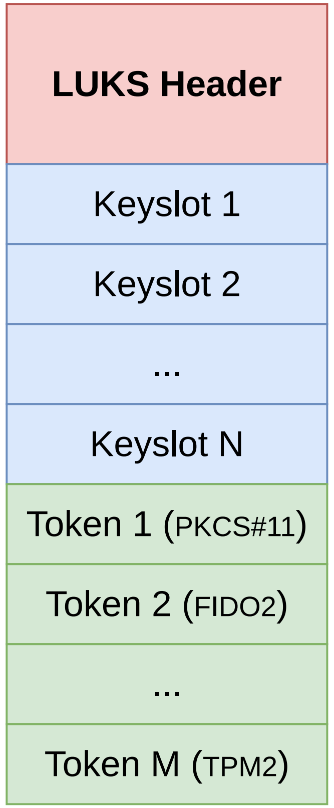
Basic architecture

Encryption policies and master keys

- An encrypted directory has an **encryption policy** (master key and various parameters).
- The master key is loaded into the kernel to *unlock* a directory and removed from the kernel to *lock* it.
- User space (e.g. `dirlock`) must manage the master key and keep it safe.

Protectors

- The master key is not used directly.
- Wrapped with intermediate keys called *protectors*.
- Different types of protectors (password, FIDO2, ...).
- Compromised protectors can be deleted without exposing the master key.
- Design taken from /usr/bin/fscrypt. Similar idea used in LUKS or BitLocker.



LUKS Header

Keyslot 1

Keyslot 2

...

Keyslot N

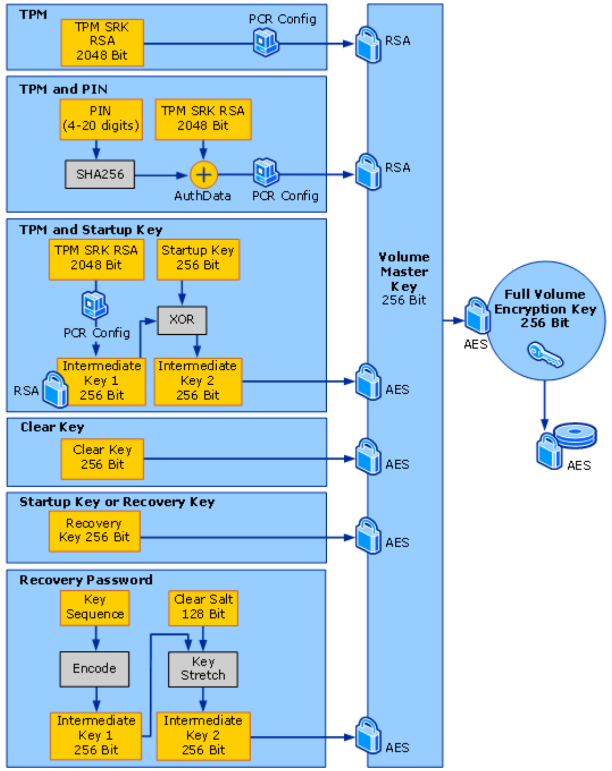
Token 1 (PKCS#11)

Token 2 (FIDO2)

...

Token M (TPM2)

bitlocker (image source)



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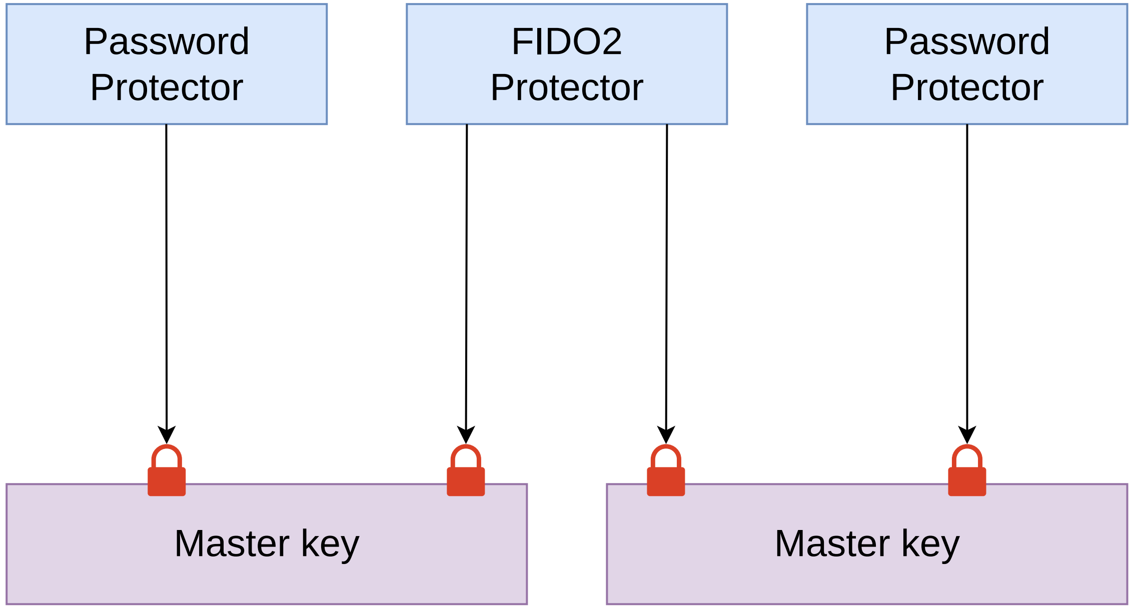
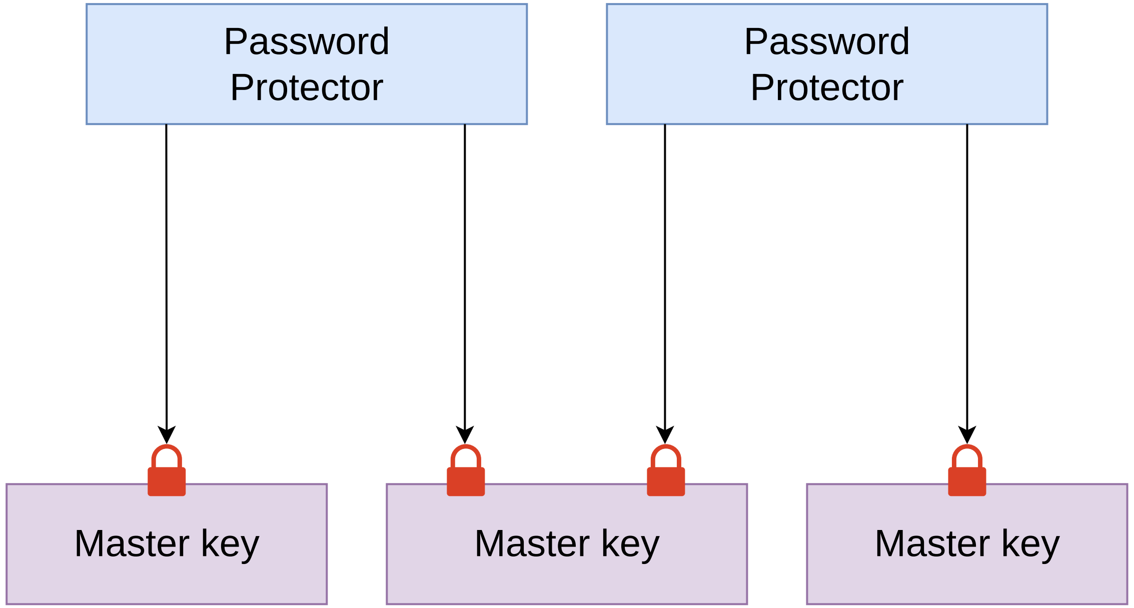
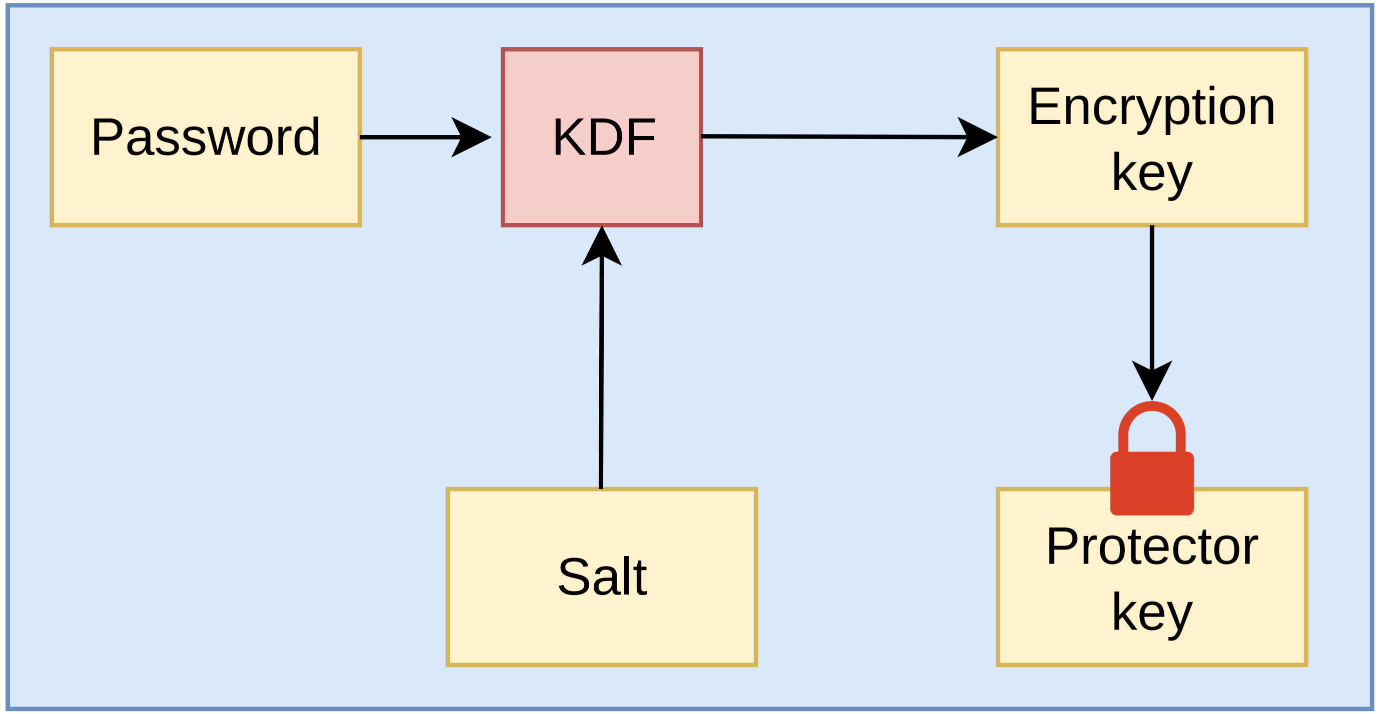

Password Protector
FIDO2 Protector
Password Protector
Master key
Master key

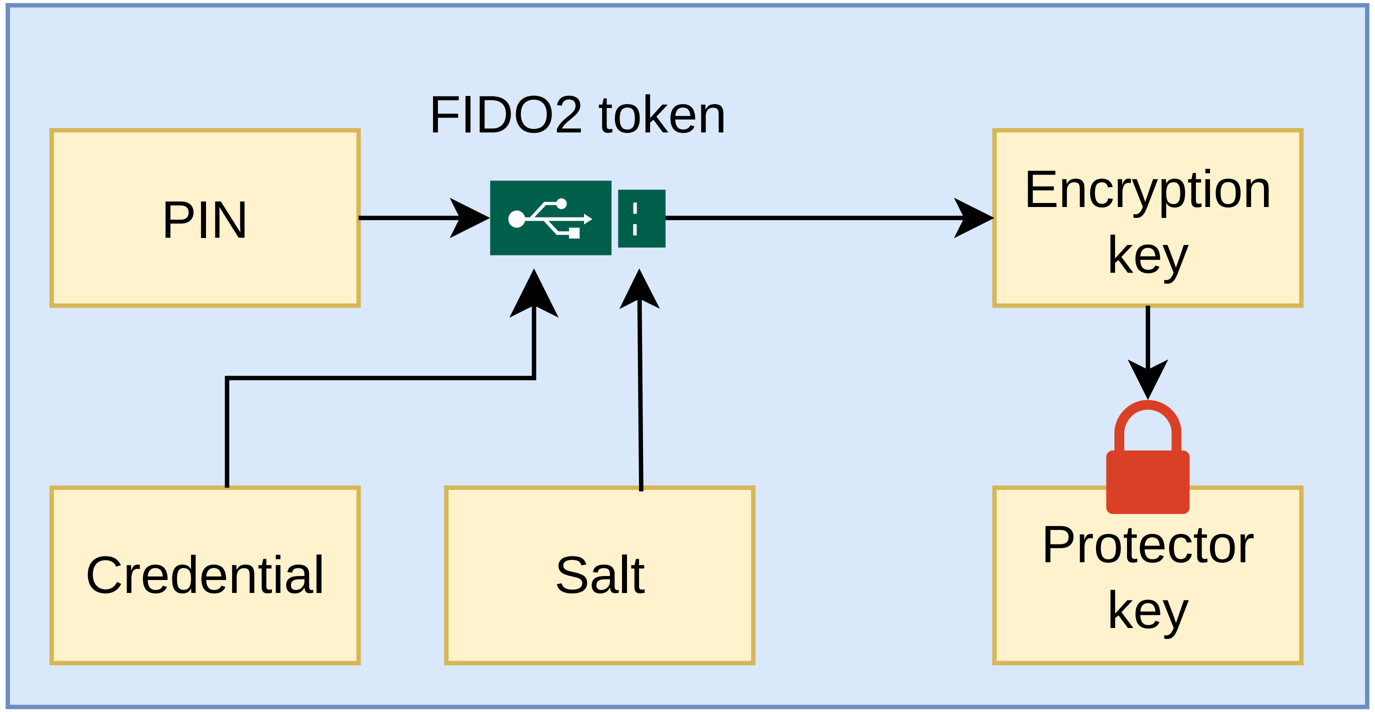
dirlock


Password Protector
Password Protector
Master key
Master key
Master key

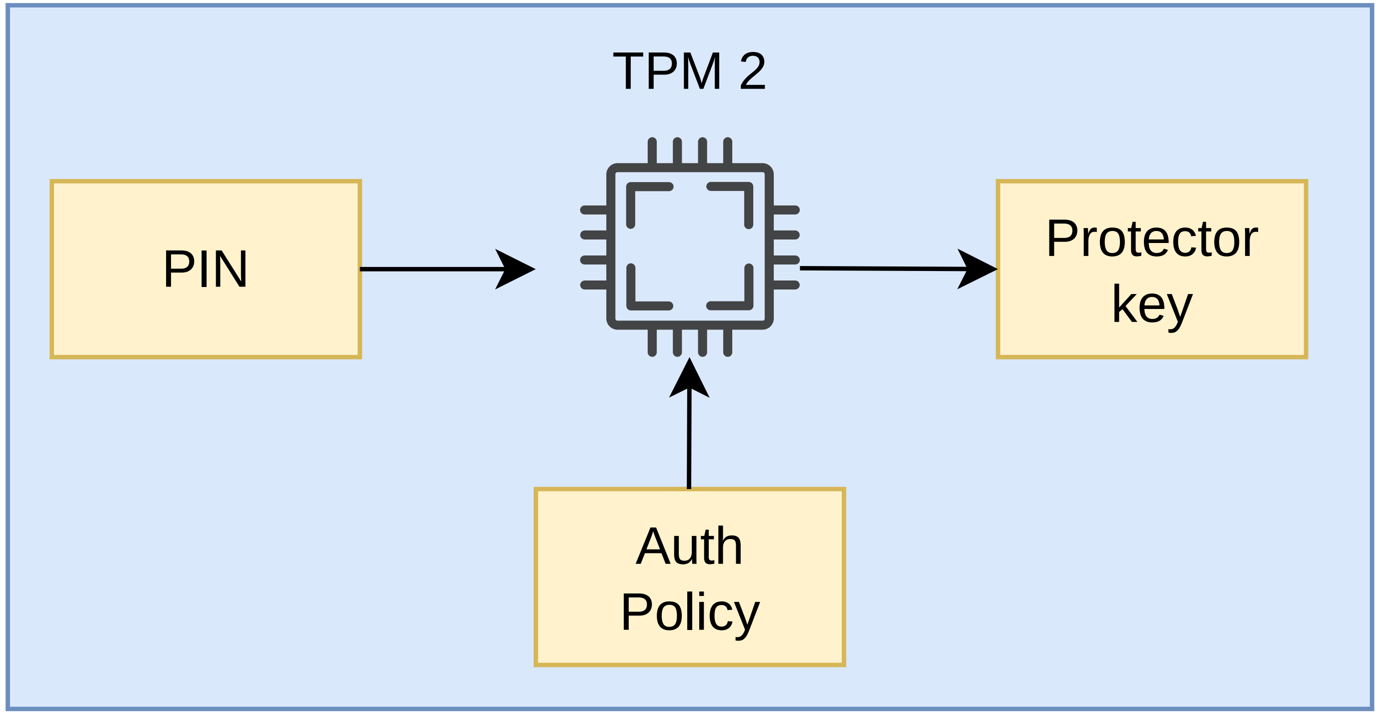
Password protector



FIDO2 protector



TPM2 protector



dirlock: basic commands

- `encrypt`: enable encryption on a directory.
  - This creates a new master key and encryption policy.
- `lock`: lock an encrypted directory.
- `unlock`: unlock an encrypted directory.
- `protector create`: create a new protector.
- `protector remove`: remove an existing protector.
- `protector change-password`: change a protector's password.
- `policy add-protector`: add a protector to an encryption policy.
- `policy remove-protector`: remove a protector from an encryption policy.

PAM integration

- PAM module available: `pam_dirlock.so`.
- No need to convert users:
  - Home directory encrypted? ⇒ handled by dirlock.
  - Otherwise ⇒ `PAM_USER_UNKNOWN` ⇒ next module.

PAM configuration

```
auth    [success=3 user_unknown=ignore default=die] pam_dirlock.so
auth    [success=2 default=ignore]  pam_systemd_home.so
auth    [success=1 default=ignore]  pam_unix.so nullok try_first_pass
auth    requisite           pam_deny.so
auth    required            pam_permit.so

session optional    pam_dirlock.so
session required    pam_unix.so

password    [success=3 user_unknown=ignore default=die] pam_dirlock.so
password    [success=2 default=ignore]  pam_systemd_home.so
password    [success=1 default=ignore]  pam_unix.so obscure yescrypt
password    requisite           pam_deny.so
password    required            pam_permit.so
```

Demo

Thanks!

igalia