# Integration of a Cryptographic API with Configurable Hardware and Software Backends in RIOT

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# Crypto Support in RIOT

- RIOT provides built-in software implementations and third party libraries
- Only pure software implementations
- Run on supported platforms, but are quite inefficient

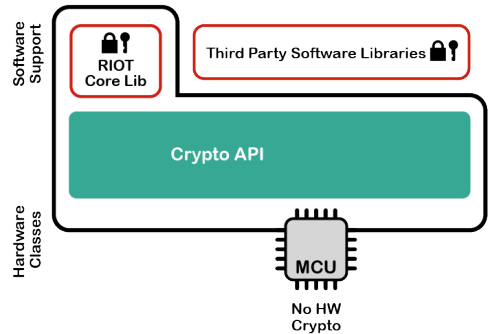
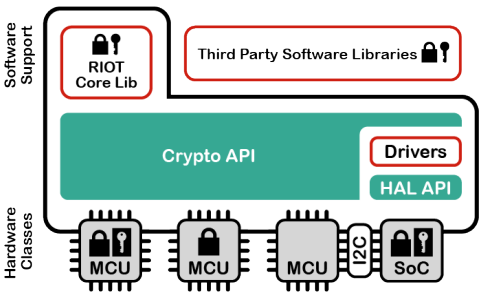



Figure: Currently supported crypto backends in RIOT

# Cryptographic Backends

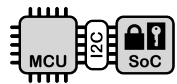




Crypto performed by software libraries

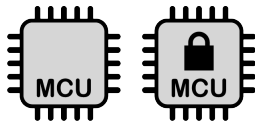

Crypto performed by hardware without key storage


Crypto performed by hardware with key storage




Crypto performed by external hardware with key storage

# Transparent Drivers for Unprotected Keys

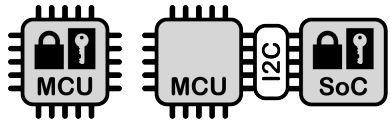



- Keys are stored in RAM or ROM
- Can be operated on by any implementation that accepts plain text key material
- User can freely choose between hardware or software implementations

**Definition**

**Transparent drivers** are software implementations and drivers that can be invoked without being dependent on the actual location of a key.

# Opaque Drivers for Protected Keys



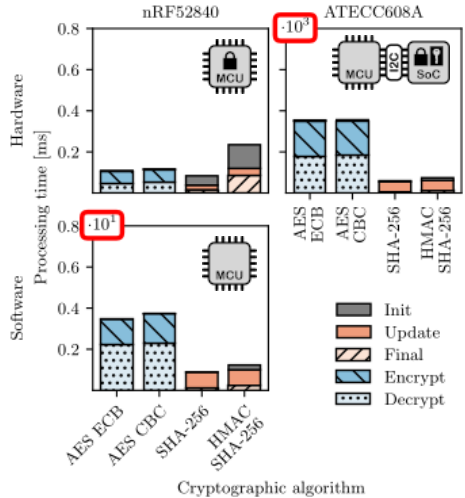

- Dedicated key storage areas (often slots)
- Only crypto processor can access key material
- Caller provides key identifier or slot number
- Only driver assigned to processor the key is located in can be invoked

**Definition**

**Opaque drivers** operate on protected keys. They are bound to a key location and can not be chosen freely.

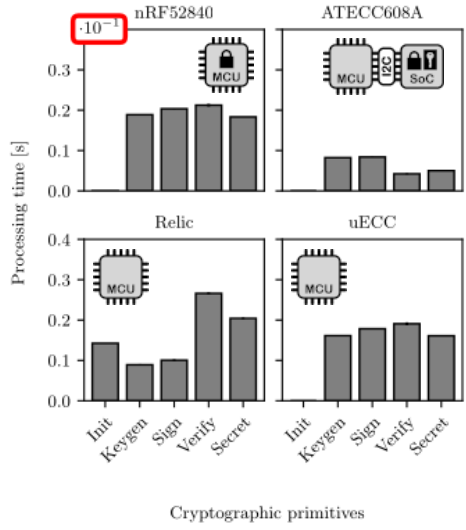
# Benefits of Hardware Crypto in Symmetric Operations

- Accelerator on nRF52840 is faster than RIOT software implementation
- Secure Element ATECC608A is less efficient, comes with benefit of protected storage



# Benefits of Hardware Crypto in Asymmetric Operations

- Secure Element ATECC608A is faster than software
- Accelerator on nRF52840 outperforms software and secure element



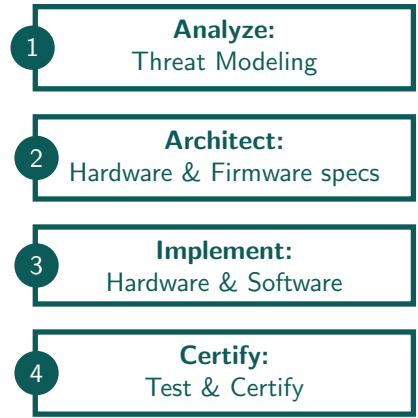
# Challenges and Solution

- Platforms with varying hardware crypto capabilities need to be supported
- Both protected and unprotected key storage need to be supported
- Hardware and software backends should be exchanged transparently beneath a unified API

**Our Solution:**
Implementing the ARM Platform Security Architecture Crypto API

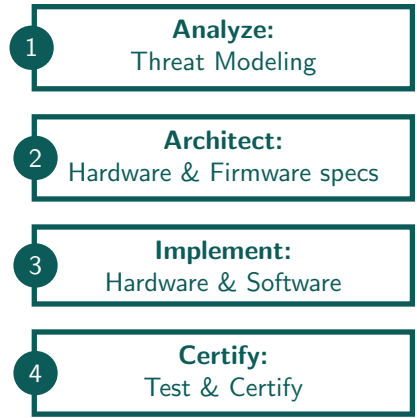
# What is PSA?

- ARM Platform Security Architecture



# What is PSA?

- ARM Platform Security Architecture
- Framework for development of secure IoT systems



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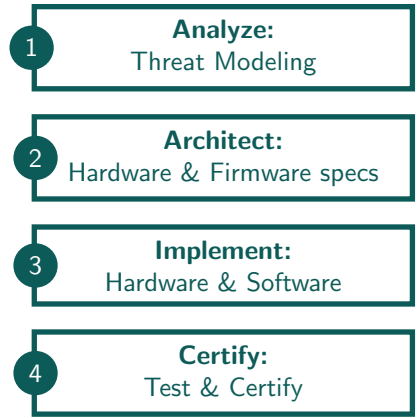
- Threat models, specifications and reference implementations



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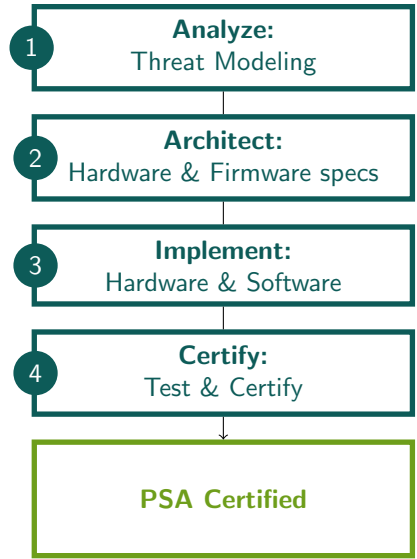
- Implementations may be certified through PSA Certified scheme



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- ARM Platform Security Architecture
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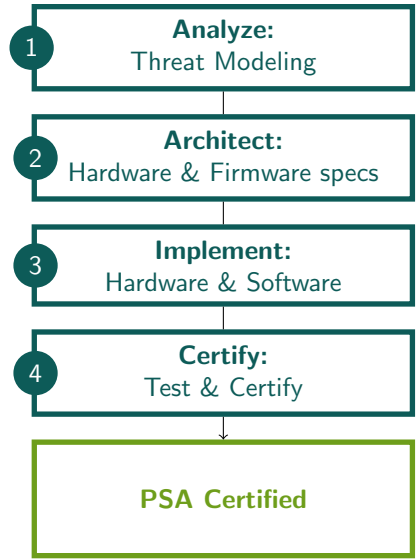
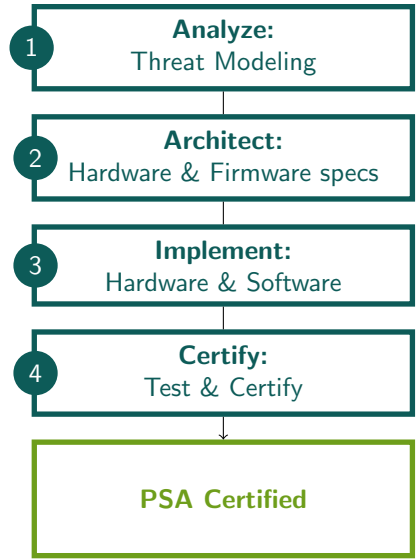
- Implementations may be certified through PSA Certified scheme
- Open source test suite for implementation verification



# What is PSA?

- Where can we find PSA Crypto?



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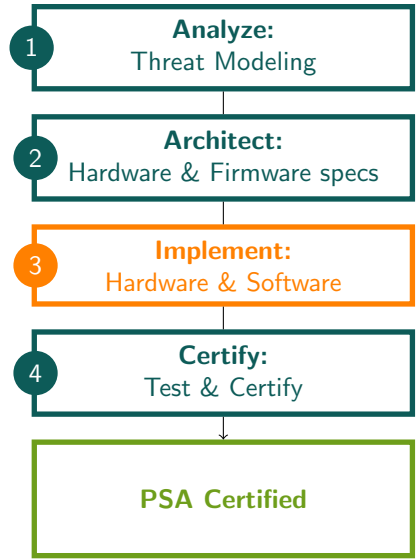

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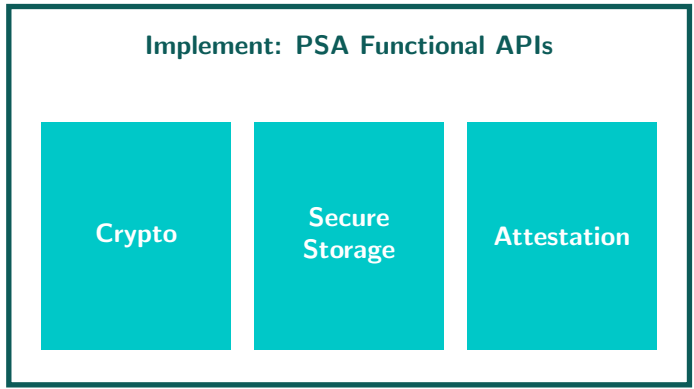

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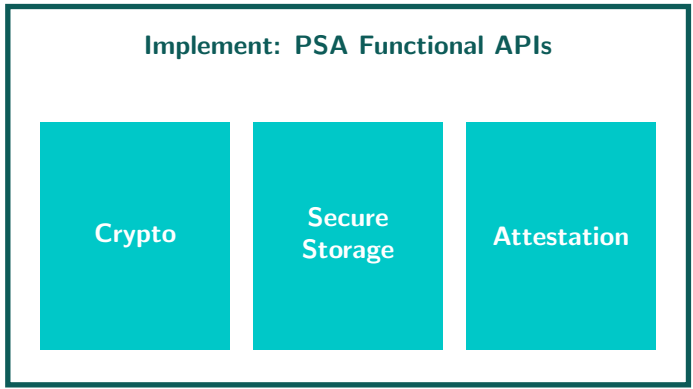


- Platform independent, suitable for IoT devices

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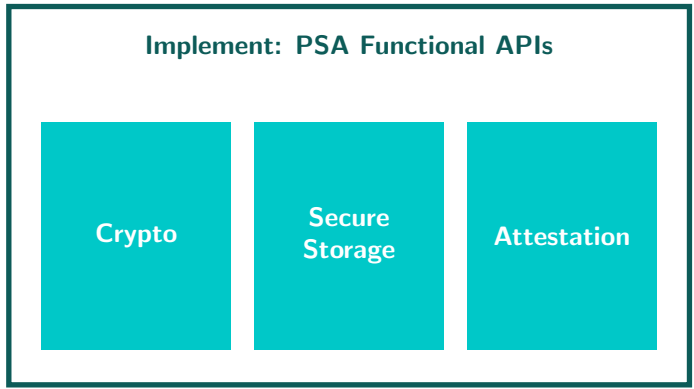


- Platform independent, suitable for IoT devices
- Designed with usability and portability in mind

# What do we get?


Complete API design specification

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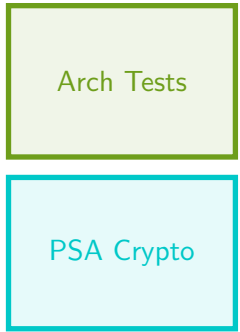

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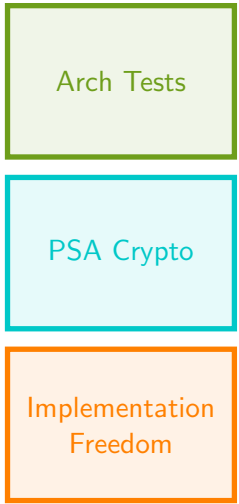
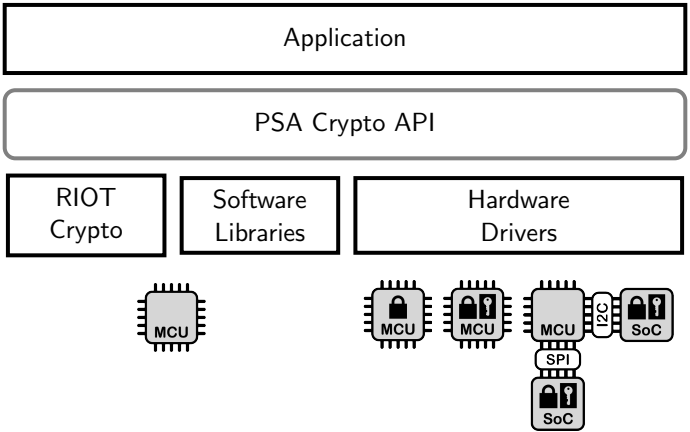


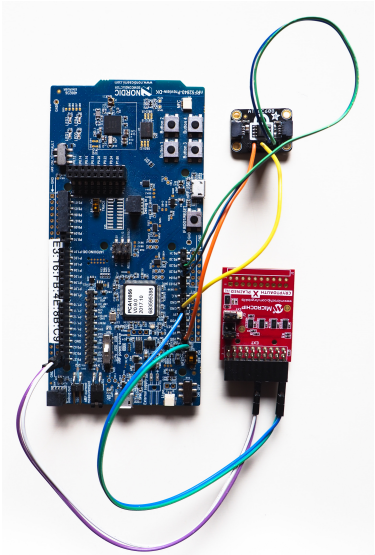
# Backend Flexibility




- Hardware agnostic application development possible
- Backends can be exchanged and combined as needed
- Use of multiple secure elements possible

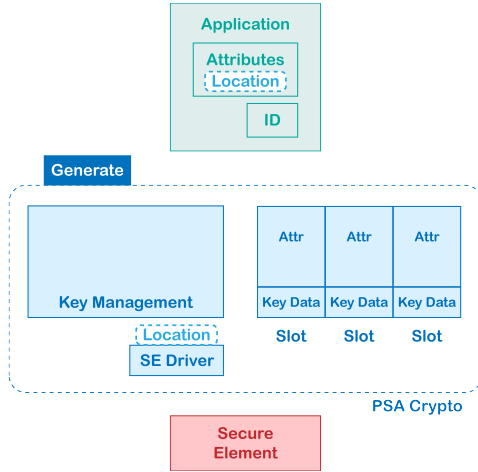
# Secure Element Handling

- Multiple SE's can be managed by a driver registry
- Calls are dispatched to appropiate driver depending on key location
- PSA Crypto reference implementation provides an API for SEs



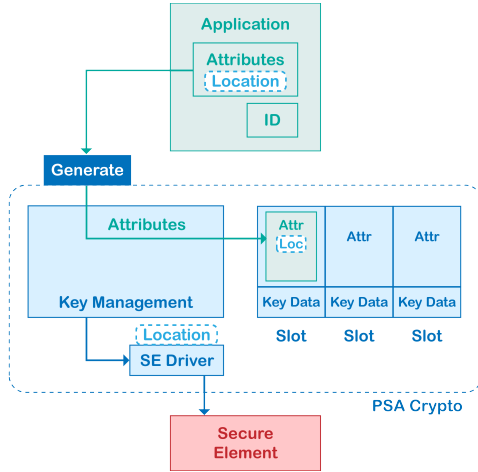
# Handling Keys in Protected Storage

1. Application provides key attributes with key location



# Handling Keys in Protected Storage

1. Application provides key attributes with key location
2. Attributes are stored and opaque SE driver is invoked



# Handling Keys in Protected Storage

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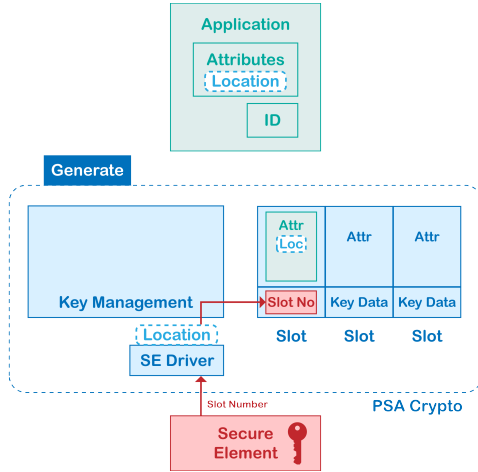
3. SE generates and stores key in free slot, returns slot number



# Handling Keys in Protected Storage

1. Application provides key attributes with key location
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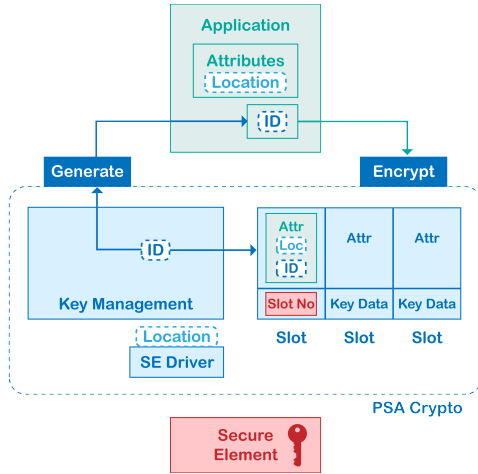
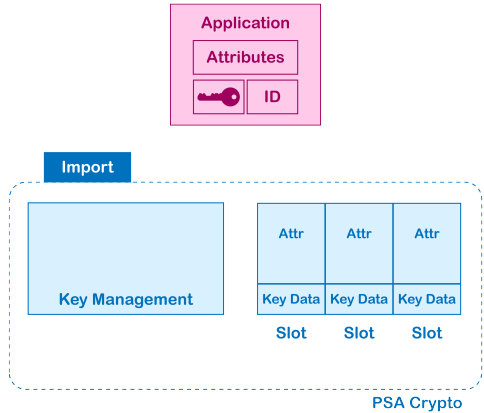
4. Key manager returns key ID to application for later use



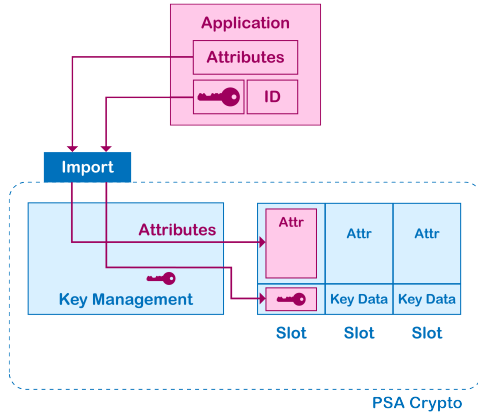
# Handling Externally Provided Keys

1. Application provides attributes and key material



# Handling Externally Provided Keys

1. Application provides attributes and key material
2. Both are stored in local memory



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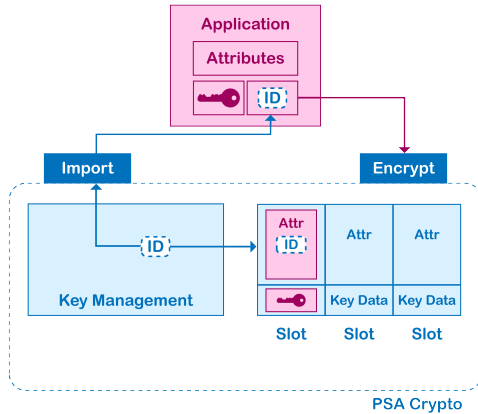


# What is mbedTLS doing?

- Working on reference implementations for PSA Functional APIs
- We're following their progress and have been in contact
- Still under construction

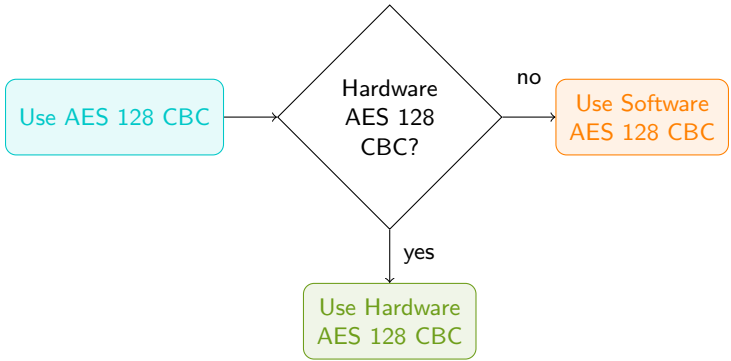
# Driver Wrapper Generation

**Support of different backends in mbedTLS**

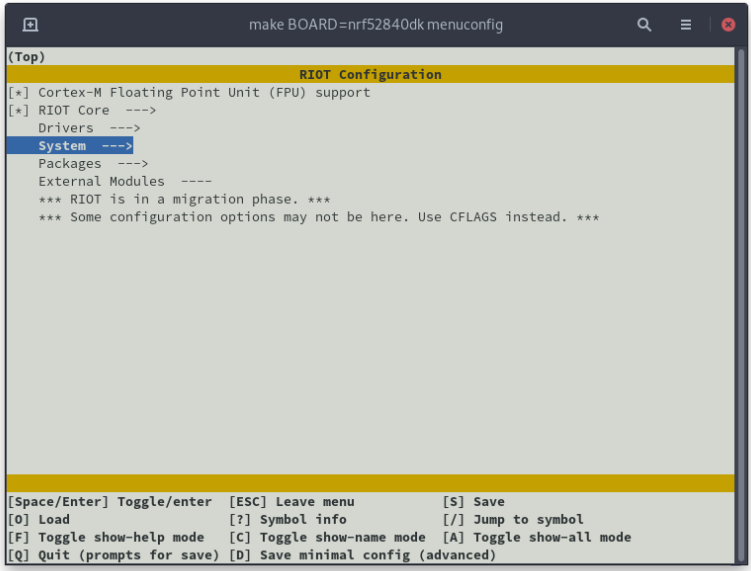
- Provide information about available drivers at compile time
- Driver description files in JSON format
- Code generator will parse descriptions and generate wrapper
- Wrapper contains calls to available drivers and software fallback
- Code generator does not exist, yet

# Configuring Crypto Backends with Kconfig

- If CPU defines symbol for hardware crypto (e.g. HAS_HW_AES_128_CBC), hardware is default backend
- User may change default configuration if desired



# Menuconfig Walkthrough



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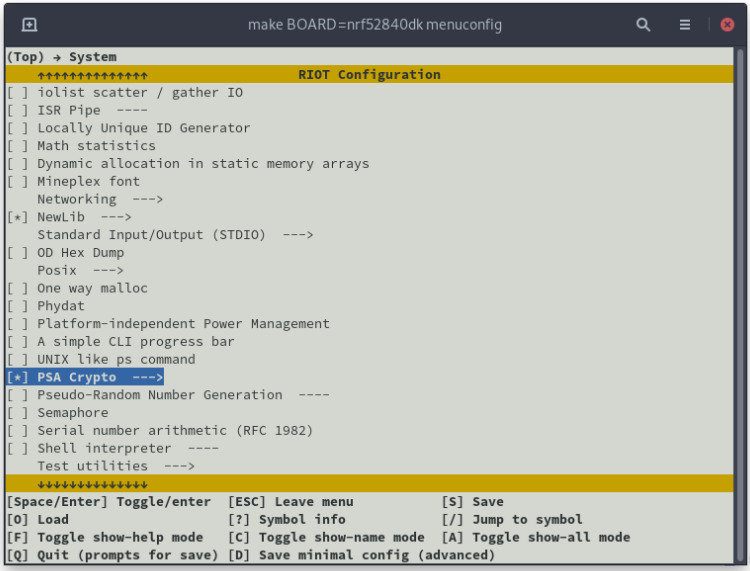

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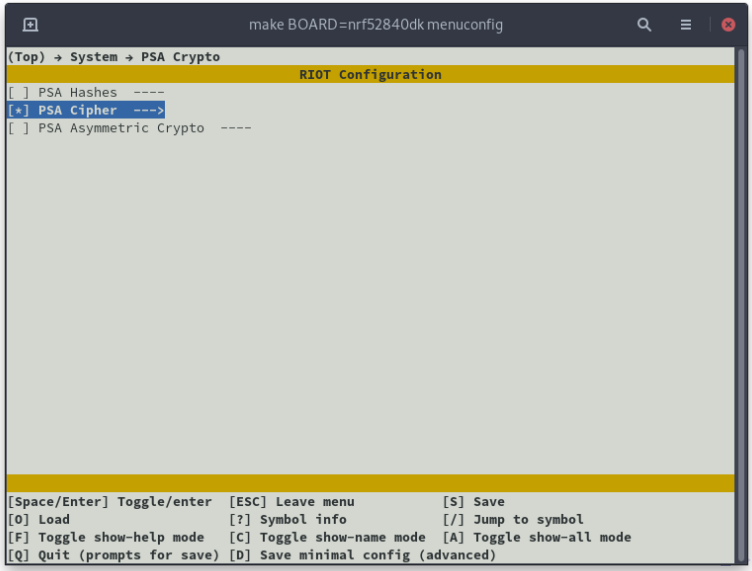

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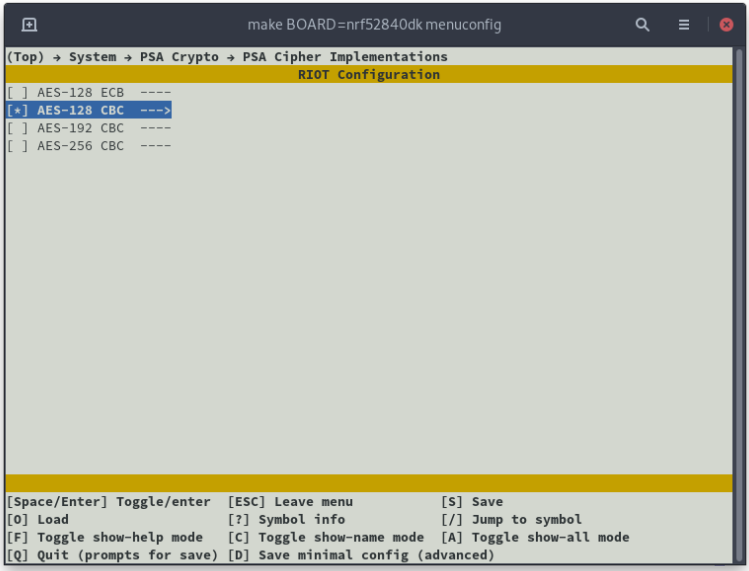

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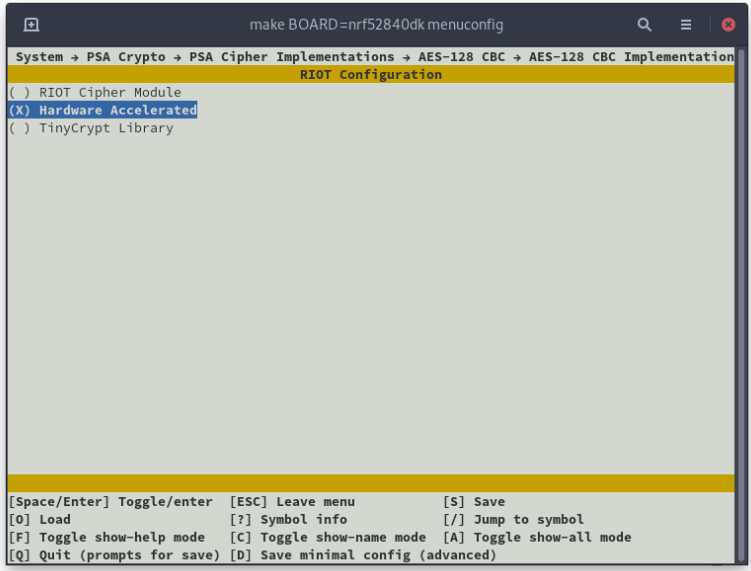

# PSA Crypto Implementation Structure

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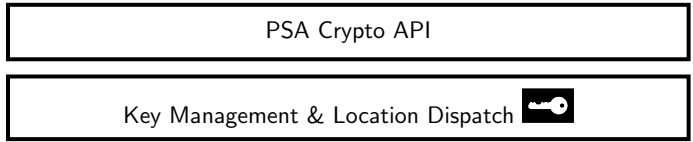

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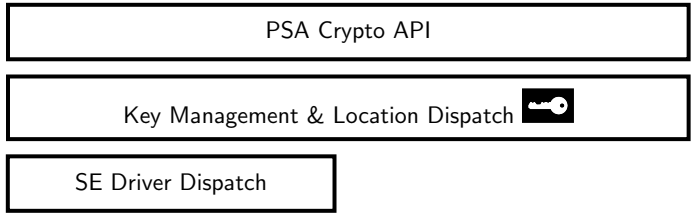

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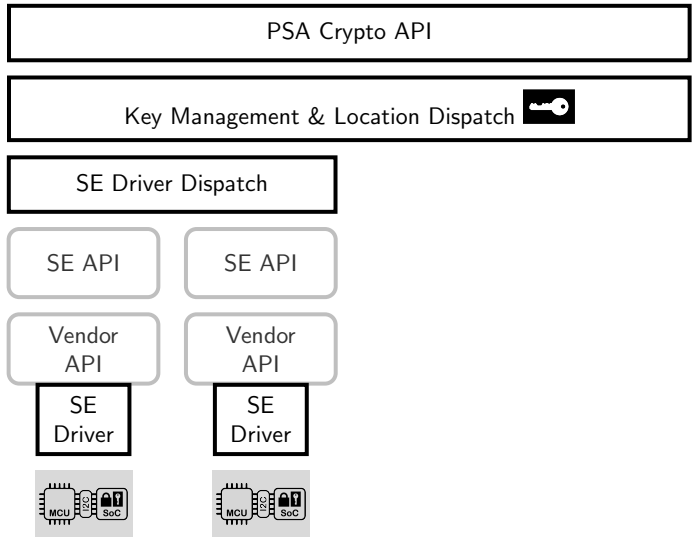

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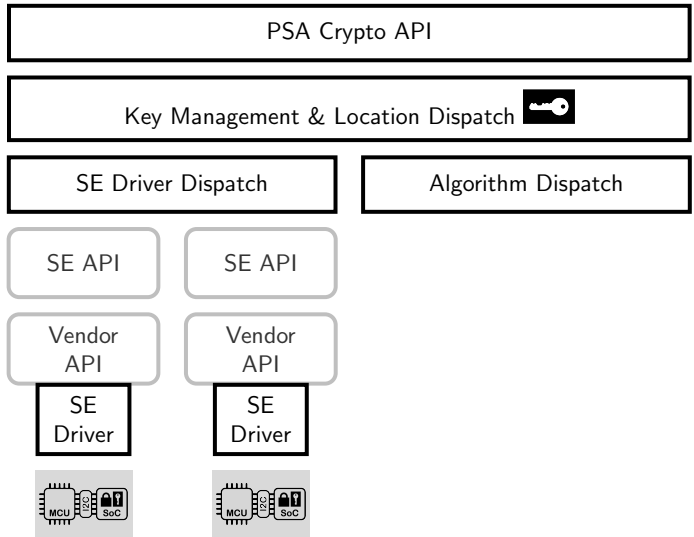

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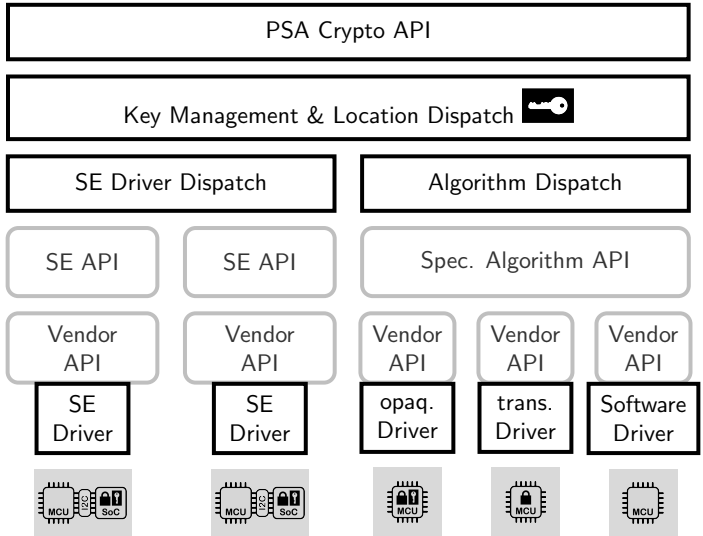

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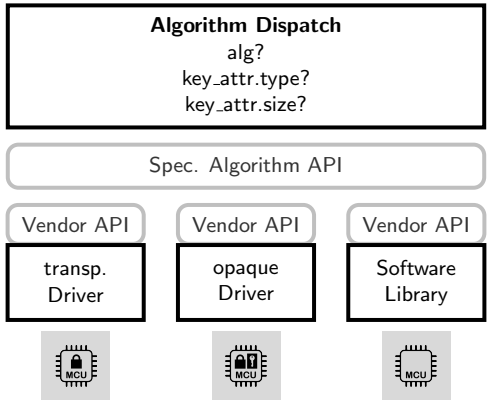

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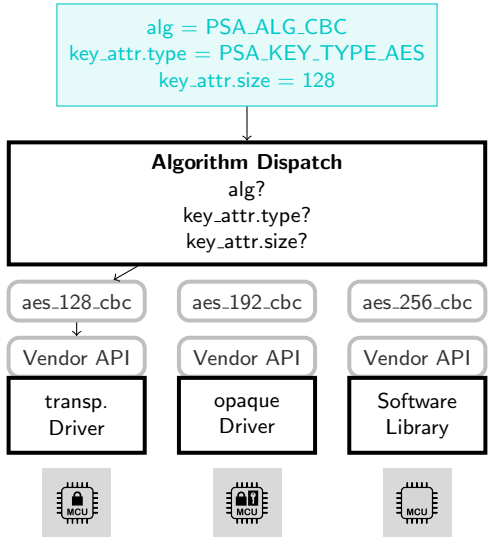

# Application Example of AES Encryption

```
uint8_t key[] = { ... };
uint8_t key_length = AES_128_KEY_LENGTH;

psa_key_id_t key_id;
psa_key_attributes_t attr = psa_key_attributes_init();

// Set key attributes
psa_key_lifetime_t lifetime = PSA_KEY_LOCATION_LOCAL_STORAGE |
                              PSA_KEY_PERSISTENCE_VOLATILE;

psa_set_key_lifetime(&attr, lifetime);
psa_set_key_algorithm(&attr, PSA_ALG_CBC_NO_PADDING);
psa_set_key_usage_flags(&attr, PSA_KEY_USAGE_ENCRYPT);
psa_set_key_type(&attr, PSA_KEY_TYPE_AES);
psa_set_key_bits(&attr, 128);

// Import key and store it as specified in lifetime
psa_import_key(&attr, key, key_length, &key_id);

// Encrypt some plaintext with key beloning to key_id
psa_cipher_encrypt(key_id, PSA_ALG_CBC_NO_PADDING, plaintext,
                   plaintext_length, output, output_size, &output_length);
```

# Implementation Status

| Component | Status | Description | Next Steps |
|---|---|---|---|
| PSA Arch Testsuite as package | ✔ | Hash tests work | Enable other algorithm tests |
| Volatile Key Management | ✔ | Volatile keys in local memory and SEs can be handled | Add support for persistent keys |
| Cryptographic Operations | ✔ | Some hashes and ciphers work | Extend support for cryptographic operations |
| Secure Element Handling | ✔ | Multiple devices can be handled | Add support for other devices |

**Outlook:** Support of operations in trusted execution environments