

# Linux Kernel Crypto API

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by Stephan Mueller and Marek Vasut

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# Chapter 1. Kernel Crypto API Interface Specification

## Introduction

The kernel crypto API offers a rich set of cryptographic ciphers as well as other data transformation mechanisms and methods to invoke these. This document contains a description of the API and provides example code.

To understand and properly use the kernel crypto API a brief explanation of its structure is given. Based on the architecture, the API can be separated into different components. Following the architecture specification, hints to developers of ciphers are provided. Pointers to the API function call documentation are given at the end.

The kernel crypto API refers to all algorithms as "transformations". Therefore, a cipher handle variable usually has the name "tfm". Besides cryptographic operations, the kernel crypto API also knows compression transformations and handles them the same way as ciphers.

The kernel crypto API serves the following entity types:

- consumers requesting cryptographic services
- data transformation implementations (typically ciphers) that can be called by consumers using the kernel crypto API

This specification is intended for consumers of the kernel crypto API as well as for developers implementing ciphers. This API specification, however, does not discuss all API calls available to data transformation implementations (i.e. implementations of ciphers and other transformations (such as CRC or even compression algorithms) that can register with the kernel crypto API).

Note: The terms "transformation" and cipher algorithm are used interchangeably.

## Terminology

The transformation implementation is an actual code or interface to hardware which implements a certain transformation with precisely defined behavior.

The transformation object (TFM) is an instance of a transformation implementation. There can be multiple transformation objects associated with a single transformation implementation. Each of those transformation objects is held by a crypto API consumer or another transformation. Transformation object is allocated when a crypto API consumer requests a transformation implementation. The consumer is then provided with a structure, which contains a transformation object (TFM).

The structure that contains transformation objects may also be referred to as a "cipher handle". Such a cipher handle is always subject to the following phases that are reflected in the API calls applicable to such a cipher handle:

1. Initialization of a cipher handle.
2. Execution of all intended cipher operations applicable for the handle where the cipher handle must be furnished to every API call.

### 3. Destruction of a cipher handle.

When using the initialization API calls, a cipher handle is created and returned to the consumer. Therefore, please refer to all initialization API calls that refer to the data structure type a consumer is expected to receive and subsequently to use. The initialization API calls have all the same naming conventions of `crypto_alloc_*`.

The transformation context is private data associated with the transformation object.

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# Chapter 2. Kernel Crypto API Architecture

## Cipher algorithm types

The kernel crypto API provides different API calls for the following cipher types:

- Symmetric ciphers
- AEAD ciphers
- Message digest, including keyed message digest
- Random number generation
- User space interface

## Ciphers And Templates

The kernel crypto API provides implementations of single block ciphers and message digests. In addition, the kernel crypto API provides numerous "templates" that can be used in conjunction with the single block ciphers and message digests. Templates include all types of block chaining mode, the HMAC mechanism, etc.

Single block ciphers and message digests can either be directly used by a caller or invoked together with a template to form multi-block ciphers or keyed message digests.

A single block cipher may even be called with multiple templates. However, templates cannot be used without a single cipher.

See `/proc/crypto` and search for "name". For example:

- aes
- ecb(aes)
- cmac(aes)
- ccm(aes)
- rfc4106(gcm(aes))
- sha1
- hmac(sha1)
- authenc(hmac(sha1),cbc(aes))

In these examples, "aes" and "sha1" are the ciphers and all others are the templates.

## Synchronous And Asynchronous Operation

The kernel crypto API provides synchronous and asynchronous API operations.

When using the synchronous API operation, the caller invokes a cipher operation which is performed synchronously by the kernel crypto API. That means, the caller waits until the cipher operation completes. Therefore, the kernel crypto API calls work like regular function calls. For synchronous operation, the set of API calls is small and conceptually similar to any other crypto library.

Asynchronous operation is provided by the kernel crypto API which implies that the invocation of a cipher operation will complete almost instantly. That invocation triggers the cipher operation but it does not signal its completion. Before invoking a cipher operation, the caller must provide a callback function the kernel crypto API can invoke to signal the completion of the cipher operation. Furthermore, the caller must ensure it can handle such asynchronous events by applying appropriate locking around its data. The kernel crypto API does not perform any special serialization operation to protect the caller's data integrity.

## Crypto API Cipher References And Priority

A cipher is referenced by the caller with a string. That string has the following semantics:

```
template(single block cipher)
```

where "template" and "single block cipher" is the aforementioned template and single block cipher, respectively. If applicable, additional templates may enclose other templates, such as

```
template1(template2(single block cipher)))
```

The kernel crypto API may provide multiple implementations of a template or a single block cipher. For example, AES on newer Intel hardware has the following implementations: AES-NI, assembler implementation, or straight C. Now, when using the string "aes" with the kernel crypto API, which cipher implementation is used? The answer to that question is the priority number assigned to each cipher implementation by the kernel crypto API. When a caller uses the string to refer to a cipher during initialization of a cipher handle, the kernel crypto API looks up all implementations providing an implementation with that name and selects the implementation with the highest priority.

Now, a caller may have the need to refer to a specific cipher implementation and thus does not want to rely on the priority-based selection. To accommodate this scenario, the kernel crypto API allows the cipher implementation to register a unique name in addition to common names. When using that unique name, a caller is therefore always sure to refer to the intended cipher implementation.

The list of available ciphers is given in `/proc/crypto`. However, that list does not specify all possible permutations of templates and ciphers. Each block listed in `/proc/crypto` may contain the following information -- if one of the components listed as follows are not applicable to a cipher, it is not displayed:

- name: the generic name of the cipher that is subject to the priority-based selection -- this name can be used by the cipher allocation API calls (all names listed above are examples for such generic names)
- driver: the unique name of the cipher -- this name can be used by the cipher allocation API calls
- module: the kernel module providing the cipher implementation (or "kernel" for statically linked ciphers)
- priority: the priority value of the cipher implementation
- refcnt: the reference count of the respective cipher (i.e. the number of current consumers of this cipher)

- selftest: specification whether the self test for the cipher passed
- type:
  - blkcipher for synchronous block ciphers
  - ablkcipher for asynchronous block ciphers
  - cipher for single block ciphers that may be used with an additional template
  - shash for synchronous message digest
  - ahash for asynchronous message digest
  - aead for AEAD cipher type
  - compression for compression type transformations
  - rng for random number generator
  - givcipher for cipher with associated IV generator (see the geniv entry below for the specification of the IV generator type used by the cipher implementation)
- blocksize: blocksize of cipher in bytes
- keysize: key size in bytes
- ivsize: IV size in bytes
- seedsize: required size of seed data for random number generator
- digestsiz: output size of the message digest
- geniv: IV generation type:
  - eseqiv for encrypted sequence number based IV generation
  - seqiv for sequence number based IV generation
  - chainiv for chain iv generation
  - <builtin> is a marker that the cipher implements IV generation and handling as it is specific to the given cipher

## Key Sizes

When allocating a cipher handle, the caller only specifies the cipher type. Symmetric ciphers, however, typically support multiple key sizes (e.g. AES-128 vs. AES-192 vs. AES-256). These key sizes are determined with the length of the provided key. Thus, the kernel crypto API does not provide a separate way to select the particular symmetric cipher key size.

## Cipher Allocation Type And Masks

The different cipher handle allocation functions allow the specification of a type and mask flag. Both parameters have the following meaning (and are therefore not covered in the subsequent sections).



The type flag specifies the type of the cipher algorithm. The caller usually provides a 0 when the caller wants the default handling. Otherwise, the caller may provide the following selections which match the the aforementioned cipher types:

- CRYPTO\_ALG\_TYPE\_CIPHER Single block cipher
- CRYPTO\_ALG\_TYPE\_COMPRESS Compression
- CRYPTO\_ALG\_TYPE\_AEAD Authenticated Encryption with Associated Data (MAC)
- CRYPTO\_ALG\_TYPE\_BLKCIPHER Synchronous multi-block cipher
- CRYPTO\_ALG\_TYPE\_ABLKCIPHER Asynchronous multi-block cipher
- CRYPTO\_ALG\_TYPE\_GIVCIPHER Asynchronous multi-block cipher packed together with an IV generator (see `geniv` field in the `/proc/crypto` listing for the known IV generators)
- CRYPTO\_ALG\_TYPE\_DIGEST Raw message digest
- CRYPTO\_ALG\_TYPE\_HASH Alias for CRYPTO\_ALG\_TYPE\_DIGEST
- CRYPTO\_ALG\_TYPE\_SHASH Synchronous multi-block hash
- CRYPTO\_ALG\_TYPE\_AHASH Asynchronous multi-block hash
- CRYPTO\_ALG\_TYPE\_RNG Random Number Generation
- CRYPTO\_ALG\_TYPE\_PCOMPRESS Enhanced version of CRYPTO\_ALG\_TYPE\_COMPRESS allowing for segmented compression / decompression instead of performing the operation on one segment only. CRYPTO\_ALG\_TYPE\_PCOMPRESS is intended to replace CRYPTO\_ALG\_TYPE\_COMPRESS once existing consumers are converted.

The mask flag restricts the type of cipher. The only allowed flag is CRYPTO\_ALG\_ASYNC to restrict the cipher lookup function to asynchronous ciphers. Usually, a caller provides a 0 for the mask flag.

When the caller provides a mask and type specification, the caller limits the search the kernel crypto API can perform for a suitable cipher implementation for the given cipher name. That means, even when a caller uses a cipher name that exists during its initialization call, the kernel crypto API may not select it due to the used type and mask field.

---

# Chapter 3. Developing Cipher Algorithms

## Registering And Unregistering Transformation

There are three distinct types of registration functions in the Crypto API. One is used to register a generic cryptographic transformation, while the other two are specific to HASH transformations and COMPRESSion. We will discuss the latter two in a separate chapter, here we will only look at the generic ones.

Before discussing the register functions, the data structure to be filled with each, struct crypto\_alg, must be considered -- see below for a description of this data structure.

The generic registration functions can be found in include/linux/crypto.h and their definition can be seen below. The former function registers a single transformation, while the latter works on an array of transformation descriptions. The latter is useful when registering transformations in bulk.

```
int crypto_register_alg(struct crypto_alg *alg);
int crypto_register_algs(struct crypto_alg *algs, int count);
```

The counterparts to those functions are listed below.

```
int crypto_unregister_alg(struct crypto_alg *alg);
int crypto_unregister_algs(struct crypto_alg *algs, int count);
```

Notice that both registration and unregistration functions do return a value, so make sure to handle errors. A return code of zero implies success. Any return code < 0 implies an error.

The bulk registration / unregistration functions require that struct crypto\_alg is an array of count size. These functions simply loop over that array and register / unregister each individual algorithm. If an error occurs, the loop is terminated at the offending algorithm definition. That means, the algorithms prior to the offending algorithm are successfully registered. Note, the caller has no way of knowing which cipher implementations have successfully registered. If this is important to know, the caller should loop through the different implementations using the single instance \*\_alg functions for each individual implementation.

## Single-Block Symmetric Ciphers [CIPHER]

Example of transformations: aes, arc4, ...

This section describes the simplest of all transformation implementations, that being the CIPHER type used for symmetric ciphers. The CIPHER type is used for transformations which operate on exactly one block at a time and there are no dependencies between blocks at all.

### Registration specifics

The registration of [CIPHER] algorithm is specific in that struct crypto\_alg field .cra\_type is empty. The .cra\_u.cipher has to be filled in with proper callbacks to implement this transformation.

See struct cipher\_alg below.

## Cipher Definition With struct cipher\_alg

Struct cipher\_alg defines a single block cipher.

Here are schematics of how these functions are called when operated from other part of the kernel. Note that the .cia\_setkey() call might happen before or after any of these schematics happen, but must not happen during any of these are in-flight.

```

KEY ---.      PLAINTEXT ---.
  v              v
.cia_setkey() -> .cia_encrypt()
                  |
                  '-----> CIPHERTEXT

```

Please note that a pattern where .cia\_setkey() is called multiple times is also valid:

```

KEY1 --.      PLAINTEXT1 --.      KEY2 --.      PLAINTEXT2 --.
  v              v              v              v
.cia_setkey() -> .cia_encrypt() -> .cia_setkey() -> .cia_encrypt()
                  |                               |
                  '----> CIPHERTEXT1             '----> CIPHERTEXT2

```

## Multi-Block Ciphers [BLKCIPHER] [ABLKIPHER]

Example of transformations: cbc(aes), ecb(arc4), ...

This section describes the multi-block cipher transformation implementations for both synchronous [BLKCIPHER] and asynchronous [ABLKIPHER] case. The multi-block ciphers are used for transformations which operate on scatterlists of data supplied to the transformation functions. They output the result into a scatterlist of data as well.

## Registration Specifics

The registration of [BLKCIPHER] or [ABLKIPHER] algorithms is one of the most standard procedures throughout the crypto API.

Note, if a cipher implementation requires a proper alignment of data, the caller should use the functions of crypto\_blkcipher\_alignmask() or crypto\_ablkcipher\_alignmask() respectively to identify a memory alignment mask. The kernel crypto API is able to process requests that are unaligned. This implies, however, additional overhead as the kernel crypto API needs to perform the realignment of the data which may imply moving of data.

## Cipher Definition With struct blkcipher\_alg and ablkcipher\_alg

Struct blkcipher\_alg defines a synchronous block cipher whereas struct ablkcipher\_alg defines an asynchronous block cipher.

Please refer to the single block cipher description for schematics of the block cipher usage. The usage patterns are exactly the same for [ABLKIPHER] and [BLKIPHER] as they are for plain [CIPHER].

## Specifics Of Asynchronous Multi-Block Cipher

There are a couple of specifics to the [ABLKIPHER] interface.

First of all, some of the drivers will want to use the Generic ScatterWalk in case the hardware needs to be fed separate chunks of the scatterlist which contains the plaintext and will contain the ciphertext. Please refer to the ScatterWalk interface offered by the Linux kernel scatter / gather list implementation.

## Hashing [HASH]

Example of transformations: crc32, md5, sha1, sha256,...

## Registering And Unregistering The Transformation

There are multiple ways to register a HASH transformation, depending on whether the transformation is synchronous [SHASH] or asynchronous [AHASH] and the amount of HASH transformations we are registering. You can find the prototypes defined in include/crypto/internal/hash.h:

```
int crypto_register_ahash(struct ahash_alg *alg);

int crypto_register_shash(struct shash_alg *alg);
int crypto_register_shashes(struct shash_alg *algs, int count);
```

The respective counterparts for unregistering the HASH transformation are as follows:

```
int crypto_unregister_ahash(struct ahash_alg *alg);

int crypto_unregister_shash(struct shash_alg *alg);
int crypto_unregister_shashes(struct shash_alg *algs, int count);
```

## Cipher Definition With struct shash\_alg and ahash\_alg

Here are schematics of how these functions are called when operated from other part of the kernel. Note that the .setkey() call might happen before or after any of these schematics happen, but must not happen during any of these are in-flight. Please note that calling .init() followed immediately by .finish() is also a perfectly valid transformation.

```
I)  DATA -----
      v
      .init() -> .update() -> .final()      ! .update() might not be called
      ^         |         |                at all in this scenario.
      '-----'         '----> HASH

II) DATA -----
      v                     v
```

```

        .init() -> .update() -> .finup()      ! .update() may not be called
            ^   |           |                at all in this scenario.
            '----'         '----> HASH

III) DATA -----
      v
      .digest()                      ! The entire process is handled
      |                             by the .digest() call.
      '-----> HASH

```

Here is a schematic of how the .export()/import() functions are called when used from another part of the kernel.

```

KEY--.          DATA--.
  v            v
.setkey() -> .init() -> .update() -> .export()  ! .update() may not be called
            ^   |           |                at all in this scenario.
            '----'         '----> PARTIAL_HASH

----- other transformations happen here -----

PARTIAL_HASH--.  DATA1--.
      v          v
      .import -> .update() -> .final()      ! .update() may not be called
            ^   |           |                at all in this scenario.
            '----'         '----> HASH1

PARTIAL_HASH--.  DATA2--.
      v          v
      .import -> .finup()
            |
            '-----> HASH2

```

## Specifics Of Asynchronous HASH Transformation

Some of the drivers will want to use the Generic ScatterWalk in case the implementation needs to be fed separate chunks of the scatterlist which contains the input data. The buffer containing the resulting hash will always be properly aligned to .cra\_alignmask so there is no need to worry about this.

---

# **Chapter 4. Programming Interface**

## **Block Cipher Context Data Structures**

These data structures define the operating context for each block cipher type.

## Name

struct aead\_request — AEAD request

## Synopsis

```
struct aead_request {
    struct crypto_async_request base;
    unsigned int assoclen;
    unsigned int cryptlen;
    u8 * iv;
    struct scatterlist * assoc;
    struct scatterlist * src;
    struct scatterlist * dst;
    void * __ctx[] CRYPTO_MINALIGN_ATTR;
};
```

## Members

base	Common attributes for async crypto requests
assoclen	Length in bytes of associated data for authentication
cryptlen	Length of data to be encrypted or decrypted
iv	Initialisation vector
assoc	Associated data
src	Source data
dst	Destination data
__ctx[] CRYPTO_MINALIGN_ATTR	Start of private context data

## Block Cipher Algorithm Definitions

These data structures define modular crypto algorithm implementations, managed via `crypto_register_alg` and `crypto_unregister_alg`.

## Name

struct crypto\_alg — definition of a cryptographic cipher algorithm

## Synopsis

```
struct crypto_alg {
    struct list_head cra_list;
    struct list_head cra_users;
    u32 cra_flags;
    unsigned int cra_blocksize;
    unsigned int cra_ctxsize;
    unsigned int cra_alignmask;
    int cra_priority;
    atomic_t cra_refcnt;
    char cra_name[CRYPTO_MAX_ALG_NAME];
    char cra_driver_name[CRYPTO_MAX_ALG_NAME];
    const struct crypto_type * cra_type;
    union cra_u;
    int (* cra_init) (struct crypto_tfm *tfm);
    void (* cra_exit) (struct crypto_tfm *tfm);
    void (* cra_destroy) (struct crypto_alg *alg);
    struct module * cra_module;
};
```

## Members

cra_list	internally used
cra_users	internally used
cra_flags	Flags describing this transformation. See include/linux/crypto.h CRYPTO_ALG_* flags for the flags which go in here. Those are used for fine-tuning the description of the transformation algorithm.
cra_blocksize	Minimum block size of this transformation. The size in bytes of the smallest possible unit which can be transformed with this algorithm. The users must respect this value. In case of HASH transformation, it is possible for a smaller block than <i>cra_blocksize</i> to be passed to the crypto API for transformation, in case of any other transformation type, an error will be returned upon any attempt to transform smaller than <i>cra_blocksize</i> chunks.
cra_ctxsize	Size of the operational context of the transformation. This value informs the kernel crypto API about the memory size needed to be allocated for the transformation context.
cra_alignmask	Alignment mask for the input and output data buffer. The data buffer containing the input data for the algorithm must be aligned to this alignment mask. The data buffer for the output data must be aligned to this alignment mask. Note that the Crypto API will do the re-alignment in software, but only under special conditions and there is a performance hit. The re-alignment happens at these occasions for different



<code>cra_priority</code>	Priority of this transformation implementation. In case multiple transformations with same <code>cra_name</code> are available to the Crypto API, the kernel will use the one with highest <code>cra_priority</code> .
<code>cra_refcnt</code>	internally used
<code>cra_name[CRYPTO_MAX_ALG_NAME]</code>	Generic name (usable by multiple implementations) of the transformation algorithm. This is the name of the transformation itself. This field is used by the kernel when looking up the providers of particular transformation.
<code>cra_driver_name[CRYPTO_MAX_ALG_NAME]</code>	Unique name of the transformation provider. This is the name of the provider of the transformation. This can be any arbitrary value, but in the usual case, this contains the name of the chip or provider and the name of the transformation algorithm.
<code>cra_type</code>	Type of the cryptographic transformation. This is a pointer to struct <code>crypto_type</code> , which implements callbacks common for all transformation types. There are multiple options: <code>crypto_blkcipher_type</code> , <code>crypto_ablkcipher_type</code> , <code>crypto_ahash_type</code> , <code>crypto_aead_type</code> , <code>crypto_rng_type</code> . This field might be empty. In that case, there are no common callbacks. This is the case for: cipher, compress, shash.
<code>cra_u</code>	Callbacks implementing the transformation. This is a union of multiple structures. Depending on the type of transformation selected by <code>cra_type</code> and <code>cra_flags</code> above, the associated structure must be filled with callbacks. This field might be empty. This is the case for ahash, shash.
<code>cra_init</code>	Initialize the cryptographic transformation object. This function is used to initialize the cryptographic transformation object. This function is called only once at the instantiation time, right after the transformation context was allocated. In case the cryptographic hardware has some special requirements which need to be handled by software, this function shall check for the precise requirement of the transformation and put any software fallbacks in place.
<code>cra_exit</code>	Deinitialize the cryptographic transformation object. This is a counterpart to <code>cra_init</code> , used to remove various changes set in <code>cra_init</code> .
<code>cra_destroy</code>	internally used
<code>cra_module</code>	Owner of this transformation implementation. Set to <code>THIS_MODULE</code>

## Description

The struct `crypto_alg` describes a generic Crypto API algorithm and is common for all of the transformations. Any variable not documented here shall not be used by a cipher implementation as it is internal to the Crypto API.

## Name

struct ablkcipher\_alg — asynchronous block cipher definition

## Synopsis

```
struct ablkcipher_alg {
    int (* setkey) (struct crypto_ablkcipher *tfm, const u8 *key, unsigned int keylen);
    int (* encrypt) (struct ablkcipher_request *req);
    int (* decrypt) (struct ablkcipher_request *req);
    int (* givencrypt) (struct skcipher_givcrypt_request *req);
    int (* givdecrypt) (struct skcipher_givcrypt_request *req);
    const char * geniv;
    unsigned int min_keysize;
    unsigned int max_keysize;
    unsigned int ivsize;
};
```

## Members

setkey	Set key for the transformation. This function is used to either program a supplied key into the hardware or store the key in the transformation context for programming it later. Note that this function does modify the transformation context. This function can be called multiple times during the existence of the transformation object, so one must make sure the key is properly reprogrammed into the hardware. This function is also responsible for checking the key length for validity. In case a software fallback was put in place in the <i>cra_init</i> call, this function might need to use the fallback if the algorithm doesn't support all of the key sizes.
encrypt	Encrypt a scatterlist of blocks. This function is used to encrypt the supplied scatterlist containing the blocks of data. The crypto API consumer is responsible for aligning the entries of the scatterlist properly and making sure the chunks are correctly sized. In case a software fallback was put in place in the <i>cra_init</i> call, this function might need to use the fallback if the algorithm doesn't support all of the key sizes. In case the key was stored in transformation context, the key might need to be re-programmed into the hardware in this function. This function shall not modify the transformation context, as this function may be called in parallel with the same transformation object.
decrypt	Decrypt a single block. This is a reverse counterpart to <i>encrypt</i> and the conditions are exactly the same.
givencrypt	Update the IV for encryption. With this function, a cipher implementation may provide the function on how to update the IV for encryption.
givdecrypt	Update the IV for decryption. This is the reverse of <i>givencrypt</i> .
geniv	The transformation implementation may use an “IV generator” provided by the kernel crypto API. Several use cases have a predefined approach how IVs are to be updated. For such use cases, the kernel crypto API provides ready-to-use implementations that can be referenced with this variable.
min_keysize	Minimum key size supported by the transformation. This is the smallest key length supported by this transformation algorithm. This must be set to one of the pre-defined values as this is not hardware specific. Possible values for this field can be found via <code>git grep “_MIN_KEY_SIZE” include/crypto/</code>

max_keysize	Maximum key size supported by the transformation. This is the largest key length supported by this transformation algorithm. This must be set to one of the pre-defined values as this is not hardware specific. Possible values for this field can be found via <code>git grep "_MAX_KEY_SIZE" include/crypto/</code>
ivsize	IV size applicable for transformation. The consumer must provide an IV of exactly that size to perform the encrypt or decrypt operation.

## Description

All fields except *givencrypt*, *givdecrypt*, *geniv* and *ivsize* are mandatory and must be filled.

## Name

struct aead\_alg — AEAD cipher definition

## Synopsis

```
struct aead_alg {
    int (* setkey) (struct crypto_aead *tfm, const u8 *key, unsigned int keylen);
    int (* setauthsize) (struct crypto_aead *tfm, unsigned int authsize);
    int (* encrypt) (struct aead_request *req);
    int (* decrypt) (struct aead_request *req);
    int (* givencrypt) (struct aead_givcrypt_request *req);
    int (* givdecrypt) (struct aead_givcrypt_request *req);
    const char * geniv;
    unsigned int ivsize;
    unsigned int maxauthsize;
};
```

## Members

setkey	see struct ablkcipher_alg
setauthsize	Set authentication size for the AEAD transformation. This function is used to specify the consumer requested size of the authentication tag to be either generated by the transformation during encryption or the size of the authentication tag to be supplied during the decryption operation. This function is also responsible for checking the authentication tag size for validity.
encrypt	see struct ablkcipher_alg
decrypt	see struct ablkcipher_alg
givencrypt	see struct ablkcipher_alg
givdecrypt	see struct ablkcipher_alg
geniv	see struct ablkcipher_alg
ivsize	see struct ablkcipher_alg
maxauthsize	Set the maximum authentication tag size supported by the transformation. A transformation may support smaller tag sizes. As the authentication tag is a message digest to ensure the integrity of the encrypted data, a consumer typically wants the largest authentication tag possible as defined by this variable.

## Description

All fields except *givencrypt*, *givdecrypt*, *geniv* and *ivsize* are mandatory and must be filled.

## Name

struct blkcipher\_alg — synchronous block cipher definition

## Synopsis

```
struct blkcipher_alg {  
    int (* setkey) (struct crypto_tfm *tfm, const u8 *key, unsigned int keylen);  
    int (* encrypt) (struct blkcipher_desc *desc, struct scatterlist *dst, struct sca  
    int (* decrypt) (struct blkcipher_desc *desc, struct scatterlist *dst, struct sca  
    const char * geniv;  
    unsigned int min_keysize;  
    unsigned int max_keysize;  
    unsigned int ivsize;  
};
```

## Members

setkey	see struct ablkcipher_alg
encrypt	see struct ablkcipher_alg
decrypt	see struct ablkcipher_alg
geniv	see struct ablkcipher_alg
min_keysize	see struct ablkcipher_alg
max_keysize	see struct ablkcipher_alg
ivsize	see struct ablkcipher_alg

## Description

All fields except *geniv* and *ivsize* are mandatory and must be filled.

## Name

struct cipher\_alg — single-block symmetric ciphers definition

## Synopsis

```
struct cipher_alg {
    unsigned int cia_min_keysize;
    unsigned int cia_max_keysize;
    int (* cia_setkey) (struct crypto_tfm *tfm, const u8 *key, unsigned int keylen);
    void (* cia_encrypt) (struct crypto_tfm *tfm, u8 *dst, const u8 *src);
    void (* cia_decrypt) (struct crypto_tfm *tfm, u8 *dst, const u8 *src);
};
```

## Members

<code>cia_min_keysize</code>	Minimum key size supported by the transformation. This is the smallest key length supported by this transformation algorithm. This must be set to one of the pre-defined values as this is not hardware specific. Possible values for this field can be found via <code>git grep "_MIN_KEY_SIZE" include/crypto/</code>
<code>cia_max_keysize</code>	Maximum key size supported by the transformation. This is the largest key length supported by this transformation algorithm. This must be set to one of the pre-defined values as this is not hardware specific. Possible values for this field can be found via <code>git grep "_MAX_KEY_SIZE" include/crypto/</code>
<code>cia_setkey</code>	Set key for the transformation. This function is used to either program a supplied key into the hardware or store the key in the transformation context for programming it later. Note that this function does modify the transformation context. This function can be called multiple times during the existence of the transformation object, so one must make sure the key is properly reprogrammed into the hardware. This function is also responsible for checking the key length for validity.
<code>cia_encrypt</code>	Encrypt a single block. This function is used to encrypt a single block of data, which must be <code>cra_blocksize</code> big. This always operates on a full <code>cra_blocksize</code> and it is not possible to encrypt a block of smaller size. The supplied buffers must therefore also be at least of <code>cra_blocksize</code> size. Both the input and output buffers are always aligned to <code>cra_alignmask</code> . In case either of the input or output buffer supplied by user of the crypto API is not aligned to <code>cra_alignmask</code> , the crypto API will re-align the buffers. The re-alignment means that a new buffer will be allocated, the data will be copied into the new buffer, then the processing will happen on the new buffer, then the data will be copied back into the original buffer and finally the new buffer will be freed. In case a software fallback was put in place in the <code>cra_init</code> call, this function might need to use the fallback if the algorithm doesn't support all of the key sizes. In case the key was stored in transformation context, the key might need to be re-programmed into the hardware in this function. This function shall not modify the transformation context, as this function may be called in parallel with the same transformation object.
<code>cia_decrypt</code>	Decrypt a single block. This is a reverse counterpart to <code>cia_encrypt</code> , and the conditions are exactly the same.

## Description

All fields are mandatory and must be filled.

## Name

struct rng\_alg — random number generator definition

## Synopsis

```
struct rng_alg {
    int (* rng_make_random) (struct crypto_rng *tfm, u8 *rdata, unsigned int dlen);
    int (* rng_reset) (struct crypto_rng *tfm, u8 *seed, unsigned int slen);
    unsigned int seedsize;
};
```

## Members

rng_make_random	The function defined by this variable obtains a random number. The random number generator transform must generate the random number out of the context provided with this call.
rng_reset	Reset of the random number generator by clearing the entire state. With the invocation of this function call, the random number generator shall completely reinitialize its state. If the random number generator requires a seed for setting up a new state, the seed must be provided by the consumer while invoking this function. The required size of the seed is defined with <i>seedsize</i> .
seedsize	The seed size required for a random number generator initialization defined with this variable. Some random number generators like the SP800-90A DRBG does not require a seed as the seeding is implemented internally without the need of support by the consumer. In this case, the seed size is set to zero.

# Asynchronous Block Cipher API

Asynchronous block cipher API is used with the ciphers of type CRYPTO\_ALG\_TYPE\_ABLKCIPHER (listed as type “ablkcipher” in /proc/crypto).

Asynchronous cipher operations imply that the function invocation for a cipher request returns immediately before the completion of the operation. The cipher request is scheduled as a separate kernel thread and therefore load-balanced on the different CPUs via the process scheduler. To allow the kernel crypto API to inform the caller about the completion of a cipher request, the caller must provide a callback function. That function is invoked with the cipher handle when the request completes.

To support the asynchronous operation, additional information than just the cipher handle must be supplied to the kernel crypto API. That additional information is given by filling in the ablkcipher\_request data structure.

For the asynchronous block cipher API, the state is maintained with the tfm cipher handle. A single tfm can be used across multiple calls and in parallel. For asynchronous block cipher calls, context data supplied and only used by the caller can be referenced the request data structure in addition to the IV used for the cipher request. The maintenance of such state information would be important for a crypto driver implementer to have, because when calling the callback function upon completion of the cipher operation, that callback function may need some information about which operation just finished if it invoked multiple in parallel. This state information is unused by the kernel crypto API.



## Name

`crypto_alloc_ablkcipher` — allocate asynchronous block cipher handle

## Synopsis

```
struct crypto_ablkcipher * crypto_alloc_ablkcipher (const char *  
alg_name, u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the ablkcipher cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for an ablkcipher. The returned struct `crypto_ablkcipher` is the cipher handle that is required for any subsequent API invocation for that ablkcipher.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`crypto_free_ablkcipher` — zeroize and free cipher handle

## Synopsis

```
void crypto_free_ablkcipher (struct crypto_ablkcipher * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_has_ahlkcipher` — Search for the availability of an ahlkcipher.

## Synopsis

```
int crypto_has_ahlkcipher (const char * alg_name, u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the ahlkcipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Return

true when the ahlkcipher is known to the kernel crypto API; false otherwise

## Name

`crypto_ablkcipher_ivsize` — obtain IV size

## Synopsis

```
unsigned int crypto_ablkcipher_ivsize (struct crypto_ablkcipher * tfm);
```

## Arguments

*tfm*   cipher handle

## Description

The size of the IV for the ablkcipher referenced by the cipher handle is returned. This IV size may be zero if the cipher does not need an IV.

## Return

IV size in bytes

## Name

`crypto_ablkcipher_blocksize` — obtain block size of cipher

## Synopsis

```
unsigned int crypto_ablkcipher_blocksize (struct crypto_ablkcipher *  
    tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the ablkcipher referenced with the cipher handle is returned. The caller may use that information to allocate appropriate memory for the data returned by the encryption or decryption operation

## Return

block size of cipher

## Name

`crypto_ablkcipher_setkey` — set key for cipher

## Synopsis

```
int crypto_ablkcipher_setkey (struct crypto_ablkcipher * tfm, const u8  
* key, unsigned int keylen);
```

## Arguments

<i>tfm</i>	cipher handle
<i>key</i>	buffer holding the key
<i>keylen</i>	length of the key in bytes

## Description

The caller provided key is set for the ablkcipher referenced by the cipher handle.

Note, the key length determines the cipher type. Many block ciphers implement different cipher modes depending on the key size, such as AES-128 vs AES-192 vs. AES-256. When providing a 16 byte key for an AES cipher handle, AES-128 is performed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_ablkcipher_reqtfm` — obtain cipher handle from request

## Synopsis

```
struct    crypto_ablkcipher    *    crypto_ablkcipher_reqtfm    (struct  
ablkcipher_request * req);
```

## Arguments

*req* ablkcipher\_request out of which the cipher handle is to be obtained

## Description

Return the `crypto_ablkcipher` handle when furnishing an `ablkcipher_request` data structure.

## Return

`crypto_ablkcipher` handle

## Name

`crypto_ablkcipher_encrypt` — encrypt plaintext

## Synopsis

```
int crypto_ablkcipher_encrypt (struct ablkcipher_request * req);
```

## Arguments

*req* reference to the `ablkcipher_request` handle that holds all information needed to perform the cipher operation

## Description

Encrypt plaintext data using the `ablkcipher_request` handle. That data structure and how it is filled with data is discussed with the `ablkcipher_request_*` functions.

## Return

0 if the cipher operation was successful; < 0 if an error occurred



## Name

crypto\_ablkcipher\_decrypt — decrypt ciphertext

## Synopsis

```
int crypto_ablkcipher_decrypt (struct ablkcipher_request * req);
```

## Arguments

*req* reference to the `ablkcipher_request` handle that holds all information needed to perform the cipher operation

## Description

Decrypt ciphertext data using the `ablkcipher_request` handle. That data structure and how it is filled with data is discussed with the `ablkcipher_request_*` functions.

## Return

0 if the cipher operation was successful; < 0 if an error occurred

# Asynchronous Cipher Request Handle

The `ablkcipher_request` data structure contains all pointers to data required for the asynchronous cipher operation. This includes the cipher handle (which can be used by multiple `ablkcipher_request` instances), pointer to plaintext and ciphertext, asynchronous callback function, etc. It acts as a handle to the `ablkcipher_request_*` API calls in a similar way as `ablkcipher` handle to the `crypto_ablkcipher_*` API calls.

## Name

`crypto_ablkcipher_reqsize` — obtain size of the request data structure

## Synopsis

```
unsigned int crypto_ablkcipher_reqsize (struct crypto_ablkcipher * tfm);
```

## Arguments

*tfm*   cipher handle

## Return

number of bytes

## Name

`ablkcipher_request_set_tfm` — update cipher handle reference in request

## Synopsis

```
void ablkcipher_request_set_tfm (struct ablkcipher_request * req, struct  
crypto_ablkcipher * tfm);
```

## Arguments

*req* request handle to be modified

*tfm* cipher handle that shall be added to the request handle

## Description

Allow the caller to replace the existing ablkcipher handle in the request data structure with a different one.

## Name

`ablkcipher_request_alloc` — allocate request data structure

## Synopsis

```
struct    ablkcipher_request    *    ablkcipher_request_alloc    (struct  
crypto_ablkcipher * tfm, gfp_t gfp);
```

## Arguments

*tfm* cipher handle to be registered with the request

*gfp* memory allocation flag that is handed to `kmalloc` by the API call.

## Description

Allocate the request data structure that must be used with the `ablkcipher` encrypt and decrypt API calls. During the allocation, the provided `ablkcipher` handle is registered in the request data structure.

## Return

allocated request handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`ablkcipher_request_free` — zeroize and free request data structure

## Synopsis

```
void ablkcipher_request_free (struct ablkcipher_request * req);
```

## Arguments

*req* request data structure cipher handle to be freed

## Name

`ablkcipher_request_set_callback` — set asynchronous callback function

## Synopsis

```
void ablkcipher_request_set_callback (struct ablkcipher_request * req,
u32 flags, crypto_completion_t compl, void * data);
```

## Arguments

<i>req</i>	request handle
<i>flags</i>	specify zero or an ORing of the flags <code>CRYPTO_TFM_REQ_MAY_BACKLOG</code> the request queue may back log and increase the wait queue beyond the initial maximum size; <code>CRYPTO_TFM_REQ_MAY_SLEEP</code> the request processing may sleep
<i>compl</i>	callback function pointer to be registered with the request handle
<i>data</i>	The data pointer refers to memory that is not used by the kernel crypto API, but provided to the callback function for it to use. Here, the caller can provide a reference to memory the callback function can operate on. As the callback function is invoked asynchronously to the related functionality, it may need to access data structures of the related functionality which can be referenced using this pointer. The callback function can access the memory via the “data” field in the <code>crypto_async_request</code> data structure provided to the callback function.

## Description

This function allows setting the callback function that is triggered once the cipher operation completes.

The callback function is registered with the `ablkcipher_request` handle and must comply with the following template

```
void callback_function(struct crypto_async_request *req, int error)
```

## Name

`ablkcipher_request_set_crypt` — set data buffers

## Synopsis

```
void ablkcipher_request_set_crypt (struct ablkcipher_request * req,
struct scatterlist * src, struct scatterlist * dst, unsigned int nbytes,
void * iv);
```

## Arguments

<i>req</i>	request handle
<i>src</i>	source scatter / gather list
<i>dst</i>	destination scatter / gather list
<i>nbytes</i>	number of bytes to process from <i>src</i>
<i>iv</i>	IV for the cipher operation which must comply with the IV size defined by <code>crypto_ablkcipher_ivsize</code>

## Description

This function allows setting of the source data and destination data scatter / gather lists.

For encryption, the source is treated as the plaintext and the destination is the ciphertext. For a decryption operation, the use is reversed - the source is the ciphertext and the destination is the plaintext.

# Authenticated Encryption With Associated Data (AEAD) Cipher API

The AEAD cipher API is used with the ciphers of type `CRYPTO_ALG_TYPE_AEAD` (listed as type “`aead`” in `/proc/crypto`)

The most prominent examples for this type of encryption is GCM and CCM. However, the kernel supports other types of AEAD ciphers which are defined with the following cipher string:

`authenc(keyed message digest, block cipher)`

For example: `authenc(hmac(sha256), cbc(aes))`

The example code provided for the asynchronous block cipher operation applies here as well. Naturally all `*ablkcipher*` symbols must be exchanged the `*aead*` pendants discussed in the following. In addition, for the AEAD operation, the `aead_request_set_assoc` function must be used to set the pointer to the associated data memory location before performing the encryption or decryption operation. In case of an encryption, the associated data memory is filled during the encryption operation. For decryption, the associated data memory must contain data that is used to verify the integrity of the decrypted data. Another deviation from the asynchronous block cipher operation is that the caller should explicitly check for `-EBADMSG` of the `crypto_aead_decrypt`. That error indicates an authentication error, i.e. a breach in the integrity of the message. In essence, that `-EBADMSG` error code is the key bonus an AEAD cipher has over “standard” block chaining modes.

## Name

`crypto_alloc_aead` — allocate AEAD cipher handle

## Synopsis

```
struct crypto_aead * crypto_alloc_aead (const char * alg_name, u32 type,  
u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the AEAD cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for an AEAD. The returned struct `crypto_aead` is the cipher handle that is required for any subsequent API invocation for that AEAD.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.



## Name

`crypto_free_aead` — zeroize and free aead handle

## Synopsis

```
void crypto_free_aead (struct crypto_aead * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_aead_ivsize` — obtain IV size

## Synopsis

```
unsigned int crypto_aead_ivsize (struct crypto_aead * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size of the IV for the aead referenced by the cipher handle is returned. This IV size may be zero if the cipher does not need an IV.

## Return

IV size in bytes

## Name

`crypto_aead_authsize` — obtain maximum authentication data size

## Synopsis

```
unsigned int crypto_aead_authsize (struct crypto_aead * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The maximum size of the authentication data for the AEAD cipher referenced by the AEAD cipher handle is returned. The authentication data size may be zero if the cipher implements a hard-coded maximum.

The authentication data may also be known as “tag value”.

## Return

authentication data size / tag size in bytes

## Name

`crypto_aead_blocksize` — obtain block size of cipher

## Synopsis

```
unsigned int crypto_aead_blocksize (struct crypto_aead * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the AEAD referenced with the cipher handle is returned. The caller may use that information to allocate appropriate memory for the data returned by the encryption or decryption operation

## Return

block size of cipher

## Name

`crypto_aead_setkey` — set key for cipher

## Synopsis

```
int crypto_aead_setkey (struct crypto_aead * tfm, const u8 * key,  
unsigned int keylen);
```

## Arguments

*tfm*       cipher handle

*key*       buffer holding the key

*keylen*   length of the key in bytes

## Description

The caller provided key is set for the AEAD referenced by the cipher handle.

Note, the key length determines the cipher type. Many block ciphers implement different cipher modes depending on the key size, such as AES-128 vs AES-192 vs. AES-256. When providing a 16 byte key for an AES cipher handle, AES-128 is performed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_aead_setauthsize` — set authentication data size

## Synopsis

```
int crypto_aead_setauthsize (struct crypto_aead * tfm, unsigned int
    authsize);
```

## Arguments

*tfm*            cipher handle

*authsize*    size of the authentication data / tag in bytes

## Description

Set the authentication data size / tag size. AEAD requires an authentication tag (or MAC) in addition to the associated data.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_aead_encrypt` — encrypt plaintext

## Synopsis

```
int crypto_aead_encrypt (struct aead_request * req);
```

## Arguments

*req* reference to the `aead_request` handle that holds all information needed to perform the cipher operation

## Description

Encrypt plaintext data using the `aead_request` handle. That data structure and how it is filled with data is discussed with the `aead_request_*` functions.

**IMPORTANT NOTE** The encryption operation creates the authentication data / tag. That data is concatenated with the created ciphertext. The ciphertext memory size is therefore the given number of block cipher blocks + the size defined by the `crypto_aead_setauthsize` invocation. The caller must ensure that sufficient memory is available for the ciphertext and the authentication tag.

## Return

0 if the cipher operation was successful; < 0 if an error occurred

## Name

`crypto_aead_decrypt` — decrypt ciphertext

## Synopsis

```
int crypto_aead_decrypt (struct aead_request * req);
```

## Arguments

*req* reference to the `ablkcipher_request` handle that holds all information needed to perform the cipher operation

## Description

Decrypt ciphertext data using the `aead_request` handle. That data structure and how it is filled with data is discussed with the `aead_request_*` functions.

**IMPORTANT NOTE** The caller must concatenate the ciphertext followed by the authentication data / tag. That authentication data / tag must have the size defined by the `crypto_aead_setauthsize` invocation.

## Return

0 if the cipher operation was successful; `-EBADMSG`: The AEAD cipher operation performs the authentication of the data during the decryption operation. Therefore, the function returns this error if the authentication of the ciphertext was unsuccessful (i.e. the integrity of the ciphertext or the associated data was violated); `< 0` if an error occurred.

# Asynchronous AEAD Request Handle

The `aead_request` data structure contains all pointers to data required for the AEAD cipher operation. This includes the cipher handle (which can be used by multiple `aead_request` instances), pointer to plaintext and ciphertext, asynchronous callback function, etc. It acts as a handle to the `aead_request_*` API calls in a similar way as AEAD handle to the `crypto_aead_*` API calls.



## Name

`crypto_aead_reqsize` — obtain size of the request data structure

## Synopsis

```
unsigned int crypto_aead_reqsize (struct crypto_aead * tfm);
```

## Arguments

*tfm* cipher handle

## Return

number of bytes

## Name

`aead_request_set_tfm` — update cipher handle reference in request

## Synopsis

```
void aead_request_set_tfm (struct aead_request * req, struct crypto_aead  
* tfm);
```

## Arguments

*req* request handle to be modified

*tfm* cipher handle that shall be added to the request handle

## Description

Allow the caller to replace the existing aead handle in the request data structure with a different one.

## Name

`aead_request_alloc` — allocate request data structure

## Synopsis

```
struct aead_request * aead_request_alloc (struct crypto_aead * tfm,  
gfp_t gfp);
```

## Arguments

*tfm* cipher handle to be registered with the request

*gfp* memory allocation flag that is handed to `kmalloc` by the API call.

## Description

Allocate the request data structure that must be used with the AEAD encrypt and decrypt API calls. During the allocation, the provided aead handle is registered in the request data structure.

## Return

allocated request handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`aead_request_free` — zeroize and free request data structure

## Synopsis

```
void aead_request_free (struct aead_request * req);
```

## Arguments

*req* request data structure cipher handle to be freed

## Name

`aead_request_set_callback` — set asynchronous callback function

## Synopsis

```
void aead_request_set_callback (struct aead_request * req, u32 flags,
crypto_completion_t compl, void * data);
```

## Arguments

<i>req</i>	request handle
<i>flags</i>	specify zero or an ORing of the flags <code>CRYPTO_TFM_REQ_MAY_BACKLOG</code> the request queue may back log and increase the wait queue beyond the initial maximum size; <code>CRYPTO_TFM_REQ_MAY_SLEEP</code> the request processing may sleep
<i>compl</i>	callback function pointer to be registered with the request handle
<i>data</i>	The data pointer refers to memory that is not used by the kernel crypto API, but provided to the callback function for it to use. Here, the caller can provide a reference to memory the callback function can operate on. As the callback function is invoked asynchronously to the related functionality, it may need to access data structures of the related functionality which can be referenced using this pointer. The callback function can access the memory via the “data” field in the <code>crypto_async_request</code> data structure provided to the callback function.

## Description

Setting the callback function that is triggered once the cipher operation completes

The callback function is registered with the `aead_request` handle and must comply with the following template

```
void callback_function(struct crypto_async_request *req, int error)
```

## Name

`aead_request_set_crypt` — set data buffers

## Synopsis

```
void aead_request_set_crypt (struct aead_request * req, struct
scatterlist * src, struct scatterlist * dst, unsigned int cryptlen,
u8 * iv);
```

## Arguments

<i>req</i>	request handle
<i>src</i>	source scatter / gather list
<i>dst</i>	destination scatter / gather list
<i>cryptlen</i>	number of bytes to process from <i>src</i>
<i>iv</i>	IV for the cipher operation which must comply with the IV size defined by <code>crypto_aead_ivsize</code>

## Description

Setting the source data and destination data scatter / gather lists.

For encryption, the source is treated as the plaintext and the destination is the ciphertext. For a decryption operation, the use is reversed - the source is the ciphertext and the destination is the plaintext.

IMPORTANT NOTE AEAD requires an authentication tag (MAC). For decryption, the caller must concatenate the ciphertext followed by the authentication tag and provide the entire data stream to the decryption operation (i.e. the data length used for the initialization of the scatterlist and the data length for the decryption operation is identical). For encryption, however, the authentication tag is created while encrypting the data. The destination buffer must hold sufficient space for the ciphertext and the authentication tag while the encryption invocation must only point to the plaintext data size. The following code snippet illustrates the memory usage `buffer = kmalloc(ptbuflen + (enc ? authsize : 0)); sg_init_one(sg, buffer, ptbuflen + (enc ? authsize : 0)); aead_request_set_crypt(req, sg, sg, ptbuflen, iv);`

## Name

`aead_request_set_assoc` — set the associated data scatter / gather list

## Synopsis

```
void aead_request_set_assoc (struct aead_request * req, struct
scatterlist * assoc, unsigned int assoclen);
```

## Arguments

<i>req</i>	request handle
<i>assoc</i>	associated data scatter / gather list
<i>assoclen</i>	number of bytes to process from <i>assoc</i>

## Description

For encryption, the memory is filled with the associated data. For decryption, the memory must point to the associated data.

# Synchronous Block Cipher API

The synchronous block cipher API is used with the ciphers of type `CRYPTO_ALG_TYPE_BLKCIPHER` (listed as type “blkcipher” in `/proc/crypto`)

Synchronous calls, have a context in the tfm. But since a single tfm can be used in multiple calls and in parallel, this info should not be changeable (unless a lock is used). This applies, for example, to the symmetric key. However, the IV is changeable, so there is an `iv` field in `blkcipher_tfm` structure for synchronous blkcipher api. So, its the only state info that can be kept for synchronous calls without using a big lock across a tfm.

The block cipher API allows the use of a complete cipher, i.e. a cipher consisting of a template (a block chaining mode) and a single block cipher primitive (e.g. AES).

The plaintext data buffer and the ciphertext data buffer are pointed to by using scatter/gather lists. The cipher operation is performed on all segments of the provided scatter/gather lists.

The kernel crypto API supports a cipher operation “in-place” which means that the caller may provide the same scatter/gather list for the plaintext and cipher text. After the completion of the cipher operation, the plaintext data is replaced with the ciphertext data in case of an encryption and vice versa for a decryption. The caller must ensure that the scatter/gather lists for the output data point to sufficiently large buffers, i.e. multiples of the block size of the cipher.

## Name

`crypto_alloc_blkcipher` — allocate synchronous block cipher handle

## Synopsis

```
struct crypto_blkcipher * crypto_alloc_blkcipher (const char * alg_name,  
u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the blkcipher cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for a block cipher. The returned struct `crypto_blkcipher` is the cipher handle that is required for any subsequent API invocation for that block cipher.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.



## Name

`crypto_free_blkcipher` — zeroize and free the block cipher handle

## Synopsis

```
void crypto_free_blkcipher (struct crypto_blkcipher * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_has_blkcipher` — Search for the availability of a block cipher

## Synopsis

```
int crypto_has_blkcipher (const char * alg_name, u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the block cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Return

true when the block cipher is known to the kernel crypto API; false otherwise

## Name

`crypto_blkcipher_name` — return the name / `cra_name` from the cipher handle

## Synopsis

```
const char * crypto_blkcipher_name (struct crypto_blkcipher * tfm);
```

## Arguments

*tfm* cipher handle

## Return

The character string holding the name of the cipher

## Name

`crypto_blkcipher_ivsize` — obtain IV size

## Synopsis

```
unsigned int crypto_blkcipher_ivsize (struct crypto_blkcipher * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size of the IV for the block cipher referenced by the cipher handle is returned. This IV size may be zero if the cipher does not need an IV.

## Return

IV size in bytes

## Name

`crypto_blkcipher_blocksize` — obtain block size of cipher

## Synopsis

```
unsigned int crypto_blkcipher_blocksize (struct crypto_blkcipher * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the block cipher referenced with the cipher handle is returned. The caller may use that information to allocate appropriate memory for the data returned by the encryption or decryption operation.

## Return

block size of cipher

## Name

`crypto_blkcipher_setkey` — set key for cipher

## Synopsis

```
int crypto_blkcipher_setkey (struct crypto_blkcipher * tfm, const u8 *  
key, unsigned int keylen);
```

## Arguments

<i>tfm</i>	cipher handle
<i>key</i>	buffer holding the key
<i>keylen</i>	length of the key in bytes

## Description

The caller provided key is set for the block cipher referenced by the cipher handle.

Note, the key length determines the cipher type. Many block ciphers implement different cipher modes depending on the key size, such as AES-128 vs AES-192 vs. AES-256. When providing a 16 byte key for an AES cipher handle, AES-128 is performed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_blkcipher_encrypt` — encrypt plaintext

## Synopsis

```
int crypto_blkcipher_encrypt (struct blkcipher_desc * desc, struct
scatterlist * dst, struct scatterlist * src, unsigned int nbytes);
```

## Arguments

*desc*      reference to the block cipher handle with meta data

*dst*        scatter/gather list that is filled by the cipher operation with the ciphertext

*src*        scatter/gather list that holds the plaintext

*nbytes*    number of bytes of the plaintext to encrypt.

## Description

Encrypt plaintext data using the IV set by the caller with a preceding call of `crypto_blkcipher_set_iv`.

The `blkcipher_desc` data structure must be filled by the caller and can reside on the stack. The caller must fill `desc` as follows: `desc.tfm` is filled with the block cipher handle; `desc.flags` is filled with either `CRYPTO_TFM_REQ_MAY_SLEEP` or 0.

## Return

0 if the cipher operation was successful; < 0 if an error occurred

## Name

`crypto_blkcipher_encrypt_iv` — encrypt plaintext with dedicated IV

## Synopsis

```
int crypto_blkcipher_encrypt_iv (struct blkcipher_desc * desc, struct
scatterlist * dst, struct scatterlist * src, unsigned int nbytes);
```

## Arguments

*desc*      reference to the block cipher handle with meta data

*dst*        scatter/gather list that is filled by the cipher operation with the ciphertext

*src*        scatter/gather list that holds the plaintext

*nbytes*    number of bytes of the plaintext to encrypt.

## Description

Encrypt plaintext data with the use of an IV that is solely used for this cipher operation. Any previously set IV is not used.

The `blkcipher_desc` data structure must be filled by the caller and can reside on the stack. The caller must fill `desc` as follows: `desc.tfm` is filled with the block cipher handle; `desc.info` is filled with the IV to be used for the current operation; `desc.flags` is filled with either `CRYPTO_TFM_REQ_MAY_SLEEP` or 0.

## Return

0 if the cipher operation was successful; < 0 if an error occurred



## Name

`crypto_blkcipher_decrypt` — decrypt ciphertext

## Synopsis

```
int crypto_blkcipher_decrypt (struct blkcipher_desc * desc, struct
scatterlist * dst, struct scatterlist * src, unsigned int nbytes);
```

## Arguments

*desc*      reference to the block cipher handle with meta data

*dst*        scatter/gather list that is filled by the cipher operation with the plaintext

*src*        scatter/gather list that holds the ciphertext

*nbytes*    number of bytes of the ciphertext to decrypt.

## Description

Decrypt ciphertext data using the IV set by the caller with a preceding call of `crypto_blkcipher_set_iv`.

The `blkcipher_desc` data structure must be filled by the caller as documented for the `crypto_blkcipher_encrypt` call above.

## Return

0 if the cipher operation was successful; < 0 if an error occurred

## Name

`crypto_blkcipher_decrypt_iv` — decrypt ciphertext with dedicated IV

## Synopsis

```
int crypto_blkcipher_decrypt_iv (struct blkcipher_desc * desc, struct scatterlist * dst, struct scatterlist * src, unsigned int nbytes);
```

## Arguments

<i>desc</i>	reference to the block cipher handle with meta data
<i>dst</i>	scatter/gather list that is filled by the cipher operation with the plaintext
<i>src</i>	scatter/gather list that holds the ciphertext
<i>nbytes</i>	number of bytes of the ciphertext to decrypt.

## Description

Decrypt ciphertext data with the use of an IV that is solely used for this cipher operation. Any previously set IV is not used.

The `blkcipher_desc` data structure must be filled by the caller as documented for the `crypto_blkcipher_encrypt_iv` call above.

## Return

0 if the cipher operation was successful; < 0 if an error occurred

## Name

`crypto_blkcipher_set_iv` — set IV for cipher

## Synopsis

```
void crypto_blkcipher_set_iv (struct crypto_blkcipher * tfm, const u8  
* src, unsigned int len);
```

## Arguments

*tfm* cipher handle

*src* buffer holding the IV

*len* length of the IV in bytes

## Description

The caller provided IV is set for the block cipher referenced by the cipher handle.

## Name

`crypto_blkcipher_get_iv` — obtain IV from cipher

## Synopsis

```
void crypto_blkcipher_get_iv (struct crypto_blkcipher * tfm, u8 * dst,  
unsigned int len);
```

## Arguments

*tfm* cipher handle

*dst* buffer filled with the IV

*len* length of the buffer *dst*

## Description

The caller can obtain the IV set for the block cipher referenced by the cipher handle and store it into the user-provided buffer. If the buffer has an insufficient space, the IV is truncated to fit the buffer.

# Single Block Cipher API

The single block cipher API is used with the ciphers of type `CRYPTO_ALG_TYPE_CIPHER` (listed as type “cipher” in `/proc/crypto`).

Using the single block cipher API calls, operations with the basic cipher primitive can be implemented. These cipher primitives exclude any block chaining operations including IV handling.

The purpose of this single block cipher API is to support the implementation of templates or other concepts that only need to perform the cipher operation on one block at a time. Templates invoke the underlying cipher primitive block-wise and process either the input or the output data of these cipher operations.

## Name

`crypto_alloc_cipher` — allocate single block cipher handle

## Synopsis

```
struct crypto_cipher * crypto_alloc_cipher (const char * alg_name, u32
type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the single block cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for a single block cipher. The returned struct `crypto_cipher` is the cipher handle that is required for any subsequent API invocation for that single block cipher.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`crypto_free_cipher` — zeroize and free the single block cipher handle

## Synopsis

```
void crypto_free_cipher (struct crypto_cipher * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_has_cipher` — Search for the availability of a single block cipher

## Synopsis

```
int crypto_has_cipher (const char * alg_name, u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the single block cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Return

true when the single block cipher is known to the kernel crypto API; false otherwise

## Name

`crypto_cipher_blocksize` — obtain block size for cipher

## Synopsis

```
unsigned int crypto_cipher_blocksize (struct crypto_cipher * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the single block cipher referenced with the cipher handle *tfm* is returned. The caller may use that information to allocate appropriate memory for the data returned by the encryption or decryption operation

## Return

block size of cipher



## Name

`crypto_cipher_setkey` — set key for cipher

## Synopsis

```
int crypto_cipher_setkey (struct crypto_cipher * tfm, const u8 * key,  
unsigned int keylen);
```

## Arguments

<i>tfm</i>	cipher handle
<i>key</i>	buffer holding the key
<i>keylen</i>	length of the key in bytes

## Description

The caller provided key is set for the single block cipher referenced by the cipher handle.

Note, the key length determines the cipher type. Many block ciphers implement different cipher modes depending on the key size, such as AES-128 vs AES-192 vs. AES-256. When providing a 16 byte key for an AES cipher handle, AES-128 is performed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_cipher_encrypt_one` — encrypt one block of plaintext

## Synopsis

```
void crypto_cipher_encrypt_one (struct crypto_cipher * tfm, u8 * dst,  
const u8 * src);
```

## Arguments

*tfm* cipher handle

*dst* points to the buffer that will be filled with the ciphertext

*src* buffer holding the plaintext to be encrypted

## Description

Invoke the encryption operation of one block. The caller must ensure that the plaintext and ciphertext buffers are at least one block in size.

## Name

`crypto_cipher_decrypt_one` — decrypt one block of ciphertext

## Synopsis

```
void crypto_cipher_decrypt_one (struct crypto_cipher * tfm, u8 * dst,  
const u8 * src);
```

## Arguments

*tfm* cipher handle

*dst* points to the buffer that will be filled with the plaintext

*src* buffer holding the ciphertext to be decrypted

## Description

Invoke the decryption operation of one block. The caller must ensure that the plaintext and ciphertext buffers are at least one block in size.

# Synchronous Message Digest API

The synchronous message digest API is used with the ciphers of type `CRYPTO_ALG_TYPE_HASH` (listed as type “hash” in `/proc/crypto`)

## Name

`crypto_alloc_hash` — allocate synchronous message digest handle

## Synopsis

```
struct crypto_hash * crypto_alloc_hash (const char * alg_name, u32 type,  
u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the message digest cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for a message digest. The returned struct `crypto_hash` is the cipher handle that is required for any subsequent API invocation for that message digest.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`crypto_free_hash` — zeroize and free message digest handle

## Synopsis

```
void crypto_free_hash (struct crypto_hash * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_has_hash` — Search for the availability of a message digest

## Synopsis

```
int crypto_has_hash (const char * alg_name, u32 type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the message digest cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Return

true when the message digest cipher is known to the kernel crypto API; false otherwise

## Name

`crypto_hash_blocksize` — obtain block size for message digest

## Synopsis

```
unsigned int crypto_hash_blocksize (struct crypto_hash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the message digest cipher referenced with the cipher handle is returned.

## Return

block size of cipher

## Name

`crypto_hash_digestsize` — obtain message digest size

## Synopsis

```
unsigned int crypto_hash_digestsize (struct crypto_hash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size for the message digest created by the message digest cipher referenced with the cipher handle is returned.

## Return

message digest size



## Name

`crypto_hash_init` — (re)initialize message digest handle

## Synopsis

```
int crypto_hash_init (struct hash_desc * desc);
```

## Arguments

*desc* cipher request handle that to be filled by caller -- `desc.tfm` is filled with the hash cipher handle; `desc.flags` is filled with either `CRYPTO_TFM_REQ_MAY_SLEEP` or 0.

## Description

The call (re-)initializes the message digest referenced by the hash cipher request handle. Any potentially existing state created by previous operations is discarded.

## Return

0 if the message digest initialization was successful; < 0 if an error occurred

## Name

`crypto_hash_update` — add data to message digest for processing

## Synopsis

```
int crypto_hash_update (struct hash_desc * desc, struct scatterlist *  
sg, unsigned int nbytes);
```

## Arguments

*desc*      cipher request handle

*sg*          scatter / gather list pointing to the data to be added to the message digest

*nbytes*    number of bytes to be processed from *sg*

## Description

Updates the message digest state of the cipher handle pointed to by the hash cipher request handle with the input data pointed to by the scatter/gather list.

## Return

0 if the message digest update was successful; < 0 if an error occurred

## Name

`crypto_hash_final` — calculate message digest

## Synopsis

```
int crypto_hash_final (struct hash_desc * desc, u8 * out);
```

## Arguments

*desc* cipher request handle

*out* message digest output buffer -- The caller must ensure that the out buffer has a sufficient size (e.g. by using the `crypto_hash_digestsize` function).

## Description

Finalize the message digest operation and create the message digest based on all data added to the cipher handle. The message digest is placed into the output buffer.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_hash_digest` — calculate message digest for a buffer

## Synopsis

```
int crypto_hash_digest (struct hash_desc * desc, struct scatterlist *  
sg, unsigned int nbytes, u8 * out);
```

## Arguments

<i>desc</i>	see <code>crypto_hash_final</code>
<i>sg</i>	see <code>crypto_hash_update</code>
<i>nbytes</i>	see <code>crypto_hash_update</code>
<i>out</i>	see <code>crypto_hash_final</code>

## Description

This function is a “short-hand” for the function calls of `crypto_hash_init`, `crypto_hash_update` and `crypto_hash_final`. The parameters have the same meaning as discussed for those separate three functions.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_hash_setkey` — set key for message digest

## Synopsis

```
int crypto_hash_setkey (struct crypto_hash * hash, const u8 * key,  
unsigned int keylen);
```

## Arguments

*hash*      cipher handle

*key*        buffer holding the key

*keylen*    length of the key in bytes

## Description

The caller provided key is set for the message digest cipher. The cipher handle must point to a keyed hash in order for this function to succeed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

# Message Digest Algorithm Definitions

These data structures define modular message digest algorithm implementations, managed via `crypto_register_ahash`, `crypto_register_shash`, `crypto_unregister_ahash` and `crypto_unregister_shash`.

## Name

struct hash\_alg\_common — define properties of message digest

## Synopsis

```
struct hash_alg_common {  
    unsigned int digestsize;  
    unsigned int statesize;  
    struct crypto_alg base;  
};
```

## Members

digestsize	Size of the result of the transformation. A buffer of this size must be available to the <i>final</i> and <i>finup</i> calls, so they can store the resulting hash into it. For various predefined sizes, search include/crypto/ using <code>git grep _DIGEST_SIZE include/crypto</code> .
statesize	Size of the block for partial state of the transformation. A buffer of this size must be passed to the <i>export</i> function as it will save the partial state of the transformation into it. On the other side, the <i>import</i> function will load the state from a buffer of this size as well.
base	Start of data structure of cipher algorithm. The common data structure of <code>crypto_alg</code> contains information common to all ciphers. The <code>hash_alg_common</code> data structure now adds the hash-specific information.

## Name

struct ahash\_alg — asynchronous message digest definition

## Synopsis

```
struct ahash_alg {
    int (* init) (struct ahash_request *req);
    int (* update) (struct ahash_request *req);
    int (* final) (struct ahash_request *req);
    int (* finup) (struct ahash_request *req);
    int (* digest) (struct ahash_request *req);
    int (* export) (struct ahash_request *req, void *out);
    int (* import) (struct ahash_request *req, const void *in);
    int (* setkey) (struct crypto_ahash *tfm, const u8 *key, unsigned int keylen);
    struct hash_alg_common halg;
};
```

## Members

init	Initialize the transformation context. Intended only to initialize the state of the HASH transformation at the begining. This shall fill in the internal structures used during the entire duration of the whole transformation. No data processing happens at this point.
update	Push a chunk of data into the driver for transformation. This function actually pushes blocks of data from upper layers into the driver, which then passes those to the hardware as seen fit. This function must not finalize the HASH transformation by calculating the final message digest as this only adds more data into the transformation. This function shall not modify the transformation context, as this function may be called in parallel with the same transformation object. Data processing can happen synchronously [SHASH] or asynchronously [AHASH] at this point.
final	Retrieve result from the driver. This function finalizes the transformation and retrieves the resulting hash from the driver and pushes it back to upper layers. No data processing happens at this point.
finup	Combination of <i>update</i> and <i>final</i> . This function is effectively a combination of <i>update</i> and <i>final</i> calls issued in sequence. As some hardware cannot do <i>update</i> and <i>final</i> separately, this callback was added to allow such hardware to be used at least by IPsec. Data processing can happen synchronously [SHASH] or asynchronously [AHASH] at this point.
digest	Combination of <i>init</i> and <i>update</i> and <i>final</i> . This function effectively behaves as the entire chain of operations, <i>init</i> , <i>update</i> and <i>final</i> issued in sequence. Just like <i>finup</i> , this was added for hardware which cannot do even the <i>finup</i> , but can only do the whole transformation in one run. Data processing can happen synchronously [SHASH] or asynchronously [AHASH] at this point.
export	Export partial state of the transformation. This function dumps the entire state of the ongoing transformation into a provided block of data so it can be <i>import</i> 'ed back later on. This is useful in case you want to save partial result of the transformation after processing certain amount of data and reload this partial result multiple times later on for multiple re-use. No data processing happens at this point.

<code>import</code>	Import partial state of the transformation. This function loads the entire state of the ongoing transformation from a provided block of data so the transformation can continue from this point onward. No data processing happens at this point.
<code>setkey</code>	Set optional key used by the hashing algorithm. Intended to push optional key used by the hashing algorithm from upper layers into the driver. This function can store the key in the transformation context or can outright program it into the hardware. In the former case, one must be careful to program the key into the hardware at appropriate time and one must be careful that <code>.setkey</code> can be called multiple times during the existence of the transformation object. Not all hashing algorithms do implement this function as it is only needed for keyed message digests. <code>SHAx/MDx/CRCx</code> do NOT implement this function. <code>HMAC(MDx)/HMAC(SHAx)/CMAC(AES)</code> do implement this function. This function must be called before any other of the <i>init</i> , <i>update</i> , <i>final</i> , <i>finup</i> , <i>digest</i> is called. No data processing happens at this point.
<code>halg</code>	see struct <code>hash_alg_common</code>



## Name

struct shash\_alg — synchronous message digest definition

## Synopsis

```
struct shash_alg {
    int (* init) (struct shash_desc *desc);
    int (* update) (struct shash_desc *desc, const u8 *data,unsigned int len);
    int (* final) (struct shash_desc *desc, u8 *out);
    int (* finup) (struct shash_desc *desc, const u8 *data,unsigned int len, u8 *out);
    int (* digest) (struct shash_desc *desc, const u8 *data,unsigned int len, u8 *out);
    int (* export) (struct shash_desc *desc, void *out);
    int (* import) (struct shash_desc *desc, const void *in);
    int (* setkey) (struct crypto_shash *tfm, const u8 *key,unsigned int keylen);
    unsigned int descsize;
    unsigned int statesize;
    struct crypto_alg base;
};
```

## Members

init	see struct ahash_alg
update	see struct ahash_alg
final	see struct ahash_alg
finup	see struct ahash_alg
digest	see struct ahash_alg
export	see struct ahash_alg
import	see struct ahash_alg
setkey	see struct ahash_alg
descsize	Size of the operational state for the message digest. This state size is the memory size that needs to be allocated for shash_desc.__ctx
statesize	see struct ahash_alg
base	internally used

# Asynchronous Message Digest API

The asynchronous message digest API is used with the ciphers of type CRYPTO\_ALG\_TYPE\_AHASH (listed as type “ahash” in /proc/crypto)

The asynchronous cipher operation discussion provided for the CRYPTO\_ALG\_TYPE\_ABLKCIPHER API applies here as well.

## Name

`crypto_alloc_ahash` — allocate ahash cipher handle

## Synopsis

```
struct crypto_ahash * crypto_alloc_ahash (const char * alg_name, u32
type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the ahash cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for an ahash. The returned struct `crypto_ahash` is the cipher handle that is required for any subsequent API invocation for that ahash.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`crypto_free_ahash` — zeroize and free the ahash handle

## Synopsis

```
void crypto_free_ahash (struct crypto_ahash * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_ahash_init` — (re)initialize message digest handle

## Synopsis

```
int crypto_ahash_init (struct ahash_request * req);
```

## Arguments

*req* ahash\_request handle that already is initialized with all necessary data using the ahash\_request\_\* API functions

## Description

The call (re-)initializes the message digest referenced by the ahash\_request handle. Any potentially existing state created by previous operations is discarded.

## Return

0 if the message digest initialization was successful; < 0 if an error occurred

## Name

`crypto_ahash_digestsize` — obtain message digest size

## Synopsis

```
unsigned int crypto_ahash_digestsize (struct crypto_ahash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size for the message digest created by the message digest cipher referenced with the cipher handle is returned.

## Return

message digest size of cipher

## Name

`crypto_ahash_reqtfm` — obtain cipher handle from request

## Synopsis

```
struct crypto_ahash * crypto_ahash_reqtfm (struct ahash_request * req);
```

## Arguments

*req* asynchronous request handle that contains the reference to the ahash cipher handle

## Description

Return the ahash cipher handle that is registered with the asynchronous request handle `ahash_request`.

## Return

ahash cipher handle

## Name

`crypto_ahash_reqsize` — obtain size of the request data structure

## Synopsis

```
unsigned int crypto_ahash_reqsize (struct crypto_ahash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

Return the size of the ahash state size. With the `crypto_ahash_export` function, the caller can export the state into a buffer whose size is defined with this function.

## Return

size of the ahash state

## Name

`crypto_ahash_setkey` — set key for cipher handle

## Synopsis

```
int crypto_ahash_setkey (struct crypto_ahash * tfm, const u8 * key,  
unsigned int keylen);
```

## Arguments

<i>tfm</i>	cipher handle
<i>key</i>	buffer holding the key
<i>keylen</i>	length of the key in bytes

## Description

The caller provided key is set for the ahash cipher. The cipher handle must point to a keyed hash in order for this function to succeed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred



## Name

`crypto_ahash_finup` — update and finalize message digest

## Synopsis

```
int crypto_ahash_finup (struct ahash_request * req);
```

## Arguments

*req* reference to the `ahash_request` handle that holds all information needed to perform the cipher operation

## Description

This function is a “short-hand” for the function calls of `crypto_ahash_update` and `crypto_shash_final`. The parameters have the same meaning as discussed for those separate functions.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_ahash_final` — calculate message digest

## Synopsis

```
int crypto_ahash_final (struct ahash_request * req);
```

## Arguments

*req* reference to the `ahash_request` handle that holds all information needed to perform the cipher operation

## Description

Finalize the message digest operation and create the message digest based on all data added to the cipher handle. The message digest is placed into the output buffer registered with the `ahash_request` handle.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_ahash_digest` — calculate message digest for a buffer

## Synopsis

```
int crypto_ahash_digest (struct ahash_request * req);
```

## Arguments

*req* reference to the `ahash_request` handle that holds all information needed to perform the cipher operation

## Description

This function is a “short-hand” for the function calls of `crypto_ahash_init`, `crypto_ahash_update` and `crypto_ahash_final`. The parameters have the same meaning as discussed for those separate three functions.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_ahash_export` — extract current message digest state

## Synopsis

```
int crypto_ahash_export (struct ahash_request * req, void * out);
```

## Arguments

*req* reference to the `ahash_request` handle whose state is exported

*out* output buffer of sufficient size that can hold the hash state

## Description

This function exports the hash state of the `ahash_request` handle into the caller-allocated output buffer `out` which must have sufficient size (e.g. by calling `crypto_ahash_reqsize`).

## Return

0 if the export was successful; < 0 if an error occurred

## Name

`crypto_ahash_import` — import message digest state

## Synopsis

```
int crypto_ahash_import (struct ahash_request * req, const void * in);
```

## Arguments

*req* reference to ahash\_request handle the state is imported into

*in* buffer holding the state

## Description

This function imports the hash state into the ahash\_request handle from the input buffer. That buffer should have been generated with the `crypto_ahash_export` function.

## Return

0 if the import was successful; < 0 if an error occurred

# Asynchronous Hash Request Handle

The ahash\_request data structure contains all pointers to data required for the asynchronous cipher operation. This includes the cipher handle (which can be used by multiple ahash\_request instances), pointer to plaintext and the message digest output buffer, asynchronous callback function, etc. It acts as a handle to the ahash\_request\_\* API calls in a similar way as ahash handle to the crypto\_ahash\_\* API calls.

## Name

`ahash_request_set_tfm` — update cipher handle reference in request

## Synopsis

```
void ahash_request_set_tfm (struct ahash_request * req, struct  
crypto_ahash * tfm);
```

## Arguments

*req* request handle to be modified

*tfm* cipher handle that shall be added to the request handle

## Description

Allow the caller to replace the existing ahash handle in the request data structure with a different one.

## Name

`ahash_request_alloc` — allocate request data structure

## Synopsis

```
struct ahash_request * ahash_request_alloc (struct crypto_ahash * tfm,  
gfp_t gfp);
```

## Arguments

*tfm* cipher handle to be registered with the request

*gfp* memory allocation flag that is handed to `kmalloc` by the API call.

## Description

Allocate the request data structure that must be used with the ahash message digest API calls. During the allocation, the provided ahash handle is registered in the request data structure.

## Return

allocated request handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`ahash_request_free` — zeroize and free the request data structure

## Synopsis

```
void ahash_request_free (struct ahash_request * req);
```

## Arguments

*req* request data structure cipher handle to be freed



## Name

`ahash_request_set_callback` — set asynchronous callback function

## Synopsis

```
void ahash_request_set_callback (struct ahash_request * req, u32 flags,
crypto_completion_t compl, void * data);
```

## Arguments

<i>req</i>	request handle
<i>flags</i>	specify zero or an ORing of the flags <code>CRYPTO_TFM_REQ_MAY_BACKLOG</code> the request queue may back log and increase the wait queue beyond the initial maximum size; <code>CRYPTO_TFM_REQ_MAY_SLEEP</code> the request processing may sleep
<i>compl</i>	callback function pointer to be registered with the request handle
<i>data</i>	The data pointer refers to memory that is not used by the kernel crypto API, but provided to the callback function for it to use. Here, the caller can provide a reference to memory the callback function can operate on. As the callback function is invoked asynchronously to the related functionality, it may need to access data structures of the related functionality which can be referenced using this pointer. The callback function can access the memory via the “data” field in the <code>crypto_async_request</code> data structure provided to the callback function.

## Description

This function allows setting the callback function that is triggered once the cipher operation completes.

The callback function is registered with the `ahash_request` handle and must comply with the following template

```
void callback_function(struct crypto_async_request *req, int error)
```

## Name

`ahash_request_set_crypt` — set data buffers

## Synopsis

```
void ahash_request_set_crypt (struct ahash_request * req, struct  
scatterlist * src, u8 * result, unsigned int nbytes);
```

## Arguments

<i>req</i>	ahash_request handle to be updated
<i>src</i>	source scatter/gather list
<i>result</i>	buffer that is filled with the message digest -- the caller must ensure that the buffer has sufficient space by, for example, calling <code>crypto_ahash_digestsize</code>
<i>nbytes</i>	number of bytes to process from the source scatter/gather list

## Description

By using this call, the caller references the source scatter/gather list. The source scatter/gather list points to the data the message digest is to be calculated for.

# Synchronous Message Digest API

The synchronous message digest API is used with the ciphers of type `CRYPTO_ALG_TYPE_SHASH` (listed as type “shash” in `/proc/crypto`)

The message digest API is able to maintain state information for the caller.

The synchronous message digest API can store user-related context in its `shash_desc` request data structure.

## Name

`crypto_alloc_shash` — allocate message digest handle

## Synopsis

```
struct crypto_shash * crypto_alloc_shash (const char * alg_name, u32
type, u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the message digest cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for a message digest. The returned struct `crypto_shash` is the cipher handle that is required for any subsequent API invocation for that message digest.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.

## Name

`crypto_free_shash` — zeroize and free the message digest handle

## Synopsis

```
void crypto_free_shash (struct crypto_shash * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_shash_blocksize` — obtain block size for cipher

## Synopsis

```
unsigned int crypto_shash_blocksize (struct crypto_shash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The block size for the message digest cipher referenced with the cipher handle is returned.

## Return

block size of cipher

## Name

`crypto_shash_digestsize` — obtain message digest size

## Synopsis

```
unsigned int crypto_shash_digestsize (struct crypto_shash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size for the message digest created by the message digest cipher referenced with the cipher handle is returned.

## Return

digest size of cipher

## Name

`crypto_shash_descsize` — obtain the operational state size

## Synopsis

```
unsigned int crypto_shash_descsize (struct crypto_shash * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The size of the operational state the cipher needs during operation is returned for the hash referenced with the cipher handle. This size is required to calculate the memory requirements to allow the caller allocating sufficient memory for operational state.

The operational state is defined with struct `shash_desc` where the size of that data structure is to be calculated as `sizeof(struct shash_desc) + crypto_shash_descsize(alg)`

## Return

size of the operational state

## Name

`crypto_shash_setkey` — set key for message digest

## Synopsis

```
int crypto_shash_setkey (struct crypto_shash * tfm, const u8 * key,  
unsigned int keylen);
```

## Arguments

<i>tfm</i>	cipher handle
<i>key</i>	buffer holding the key
<i>keylen</i>	length of the key in bytes

## Description

The caller provided key is set for the keyed message digest cipher. The cipher handle must point to a keyed message digest cipher in order for this function to succeed.

## Return

0 if the setting of the key was successful; < 0 if an error occurred



## Name

`crypto_shash_digest` — calculate message digest for buffer

## Synopsis

```
int crypto_shash_digest (struct shash_desc * desc, const u8 * data,  
unsigned int len, u8 * out);
```

## Arguments

*desc*    see `crypto_shash_final`

*data*    see `crypto_shash_update`

*len*     see `crypto_shash_update`

*out*     see `crypto_shash_final`

## Description

This function is a “short-hand” for the function calls of `crypto_shash_init`, `crypto_shash_update` and `crypto_shash_final`. The parameters have the same meaning as discussed for those separate three functions.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_shash_export` — extract operational state for message digest

## Synopsis

```
int crypto_shash_export (struct shash_desc * desc, void * out);
```

## Arguments

*desc*    reference to the operational state handle whose state is exported

*out*     output buffer of sufficient size that can hold the hash state

## Description

This function exports the hash state of the operational state handle into the caller-allocated output buffer out which must have sufficient size (e.g. by calling `crypto_shash_descsize`).

## Return

0 if the export creation was successful; < 0 if an error occurred

## Name

`crypto_shash_import` — import operational state

## Synopsis

```
int crypto_shash_import (struct shash_desc * desc, const void * in);
```

## Arguments

*desc*    reference to the operational state handle the state imported into

*in*      buffer holding the state

## Description

This function imports the hash state into the operational state handle from the input buffer. That buffer should have been generated with the `crypto_ahash_export` function.

## Return

0 if the import was successful; < 0 if an error occurred

## Name

`crypto_shash_init` — (re)initialize message digest

## Synopsis

```
int crypto_shash_init (struct shash_desc * desc);
```

## Arguments

*desc* operational state handle that is already filled

## Description

The call (re-)initializes the message digest referenced by the operational state handle. Any potentially existing state created by previous operations is discarded.

## Return

0 if the message digest initialization was successful; < 0 if an error occurred

## Name

`crypto_shash_update` — add data to message digest for processing

## Synopsis

```
int crypto_shash_update (struct shash_desc * desc, const u8 * data,  
unsigned int len);
```

## Arguments

*desc* operational state handle that is already initialized

*data* input data to be added to the message digest

*len* length of the input data

## Description

Updates the message digest state of the operational state handle.

## Return

0 if the message digest update was successful; < 0 if an error occurred

## Name

`crypto_shash_final` — calculate message digest

## Synopsis

```
int crypto_shash_final (struct shash_desc * desc, u8 * out);
```

## Arguments

*desc* operational state handle that is already filled with data

*out* output buffer filled with the message digest

## Description

Finalize the message digest operation and create the message digest based on all data added to the cipher handle. The message digest is placed into the output buffer. The caller must ensure that the output buffer is large enough by using `crypto_shash_digestsize`.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

## Name

`crypto_shash_finup` — calculate message digest of buffer

## Synopsis

```
int crypto_shash_finup (struct shash_desc * desc, const u8 * data,  
unsigned int len, u8 * out);
```

## Arguments

*desc* see `crypto_shash_final`

*data* see `crypto_shash_update`

*len* see `crypto_shash_update`

*out* see `crypto_shash_final`

## Description

This function is a “short-hand” for the function calls of `crypto_shash_update` and `crypto_shash_final`. The parameters have the same meaning as discussed for those separate functions.

## Return

0 if the message digest creation was successful; < 0 if an error occurred

# Crypto API Random Number API

The random number generator API is used with the ciphers of type `CRYPTO_ALG_TYPE_RNG` (listed as type “rng” in `/proc/crypto`)

## Name

`crypto_alloc_rng` — - allocate RNG handle

## Synopsis

```
struct crypto_rng * crypto_alloc_rng (const char * alg_name, u32 type,
u32 mask);
```

## Arguments

*alg\_name* is the `cra_name` / name or `cra_driver_name` / driver name of the message digest cipher

*type* specifies the type of the cipher

*mask* specifies the mask for the cipher

## Description

Allocate a cipher handle for a random number generator. The returned struct `crypto_rng` is the cipher handle that is required for any subsequent API invocation for that random number generator.

For all random number generators, this call creates a new private copy of the random number generator that does not share a state with other instances. The only exception is the “krng” random number generator which is a kernel crypto API use case for the `get_random_bytes` function of the `/dev/random` driver.

## Return

allocated cipher handle in case of success; `IS_ERR` is true in case of an error, `PTR_ERR` returns the error code.



## Name

`crypto_rng_alg` — obtain name of RNG

## Synopsis

```
struct rng_alg * crypto_rng_alg (struct crypto_rng * tfm);
```

## Arguments

*tfm* cipher handle

## Description

Return the generic name (`cra_name`) of the initialized random number generator

## Return

generic name string

## Name

`crypto_free_rng` — zeroize and free RNG handle

## Synopsis

```
void crypto_free_rng (struct crypto_rng * tfm);
```

## Arguments

*tfm* cipher handle to be freed

## Name

`crypto_rng_get_bytes` — get random number

## Synopsis

```
int crypto_rng_get_bytes (struct crypto_rng * tfm, u8 * rdata, unsigned  
int dlen);
```

## Arguments

*tfm*      cipher handle

*rdata*    output buffer holding the random numbers

*dlen*     length of the output buffer

## Description

This function fills the caller-allocated buffer with random numbers using the random number generator referenced by the cipher handle.

## Return

> 0 function was successful and returns the number of generated bytes; < 0 if an error occurred

## Name

`crypto_rng_reset` — re-initialize the RNG

## Synopsis

```
int crypto_rng_reset (struct crypto_rng * tfm, u8 * seed, unsigned int  
slen);
```

## Arguments

*tfm*    cipher handle

*seed*   seed input data

*slen*   length of the seed input data

## Description

The reset function completely re-initializes the random number generator referenced by the cipher handle by clearing the current state. The new state is initialized with the caller provided seed or automatically, depending on the random number generator type (the ANSI X9.31 RNG requires caller-provided seed, the SP800-90A DRBGs perform an automatic seeding). The seed is provided as a parameter to this function call. The provided seed should have the length of the seed size defined for the random number generator as defined by `crypto_rng_seedsz`.

## Return

0 if the setting of the key was successful; < 0 if an error occurred

## Name

`crypto_rng_seedsizesize` — obtain seed size of RNG

## Synopsis

```
int crypto_rng_seedsizesize (struct crypto_rng * tfm);
```

## Arguments

*tfm* cipher handle

## Description

The function returns the seed size for the random number generator referenced by the cipher handle. This value may be zero if the random number generator does not implement or require a reseeding. For example, the SP800-90A DRBGs implement an automated reseeding after reaching a pre-defined threshold.

## Return

seed size for the random number generator

---

# Chapter 5. Code Examples

## Code Example For Asynchronous Block Cipher Operation

```
struct tcrypt_result {
    struct completion completion;
    int err;
};

/* tie all data structures together */
struct ablkcipher_def {
    struct scatterlist sg;
    struct crypto_ablkcipher *tfm;
    struct ablkcipher_request *req;
    struct tcrypt_result result;
};

/* Callback function */
static void test_ablkcipher_cb(struct crypto_async_request *req, int error)
{
    struct tcrypt_result *result = req->data;

    if (error == -EINPROGRESS)
        return;
    result->err = error;
    complete(&result->completion);
    pr_info("Encryption finished successfully\n");
}

/* Perform cipher operation */
static unsigned int test_ablkcipher_encdec(struct ablkcipher_def *ablk,
                                           int enc)
{
    int rc = 0;

    if (enc)
        rc = crypto_ablkcipher_encrypt(ablk->req);
    else
        rc = crypto_ablkcipher_decrypt(ablk->req);

    switch (rc) {
    case 0:
        break;
    case -EINPROGRESS:
    case -EBUSY:
        rc = wait_for_completion_interruptible(
            &ablk->result.completion);
        if (!rc && !ablk->result.err) {
```

```
        reinit_completion(&ablk->result.completion);
        break;
    }
default:
    pr_info("ablkcipher encrypt returned with %d result %d\n",
            rc, ablk->result.err);
    break;
}
init_completion(&ablk->result.completion);

return rc;
}

/* Initialize and trigger cipher operation */
static int test_ablkcipher(void)
{
    struct ablkcipher_def ablk;
    struct crypto_ablkcipher *ablkcipher = NULL;
    struct ablkcipher_request *req = NULL;
    char *scratchpad = NULL;
    char *ivdata = NULL;
    unsigned char key[32];
    int ret = -EFAULT;

    ablkcipher = crypto_alloc_ablkcipher("cbc-aes-aesni", 0, 0);
    if (IS_ERR(ablkcipher)) {
        pr_info("could not allocate ablkcipher handle\n");
        return PTR_ERR(ablkcipher);
    }

    req = ablkcipher_request_alloc(ablkcipher, GFP_KERNEL);
    if (IS_ERR(req)) {
        pr_info("could not allocate request queue\n");
        ret = PTR_ERR(req);
        goto out;
    }

    ablkcipher_request_set_callback(req, CRYPTO_TFM_REQ_MAY_BACKLOG,
        test_ablkcipher_cb,
        &ablk.result);

    /* AES 256 with random key */
    get_random_bytes(&key, 32);
    if (crypto_ablkcipher_setkey(ablkcipher, key, 32)) {
        pr_info("key could not be set\n");
        ret = -EAGAIN;
        goto out;
    }

    /* IV will be random */
    ivdata = kmalloc(16, GFP_KERNEL);
    if (!ivdata) {
        pr_info("could not allocate ivdata\n");
        goto out;
    }
}
```

```
}
get_random_bytes(ivdata, 16);

/* Input data will be random */
scratchpad = kmalloc(16, GFP_KERNEL);
if (!scratchpad) {
    pr_info("could not allocate scratchpad\n");
    goto out;
}
get_random_bytes(scratchpad, 16);

ablk.tfm = ablkcipher;
ablk.req = req;

/* We encrypt one block */
sg_init_one(&ablk.sg, scratchpad, 16);
ablkcipher_request_set_crypt(req, &ablk.sg, &ablk.sg, 16, ivdata);
init_completion(&ablk.result.completion);

/* encrypt data */
ret = test_ablkcipher_encdec(&ablk, 1);
if (ret)
    goto out;

pr_info("Encryption triggered successfully\n");

out:
if (ablkcipher)
    crypto_free_ablkcipher(ablkcipher);
if (req)
    ablkcipher_request_free(req);
if (ivdata)
    kfree(ivdata);
if (scratchpad)
    kfree(scratchpad);
return ret;
}
```

## Code Example For Synchronous Block Cipher Operation

```
static int test_blkcipher(void)
{
    struct crypto_blkcipher *blkcipher = NULL;
    char *cipher = "cbc(aes)";
    // AES 128
    charkey =
"\x12\x34\x56\x78\x90\xab\xcd\xef\x12\x34\x56\x78\x90\xab\xcd\xef";
    chariv =
```



```
"\x12\x34\x56\x78\x90\xab\xcd\xef\x12\x34\x56\x78\x90\xab\xcd\xef";
unsigned int ivsize = 0;
char *scratchpad = NULL; // holds plaintext and ciphertext
struct scatterlist sg;
struct blkcipher_desc desc;
int ret = -EFAULT;

blkcipher = crypto_alloc_blkcipher(cipher, 0, 0);
if (IS_ERR(blkcipher)) {
    printk("could not allocate blkcipher handle for %s\n", cipher);
    return -PTR_ERR(blkcipher);
}

if (crypto_blkcipher_setkey(blkcipher, key, strlen(key))) {
    printk("key could not be set\n");
    ret = -EAGAIN;
    goto out;
}

ivsize = crypto_blkcipher_ivsize(blkcipher);
if (ivsize) {
    if (ivsize != strlen(iv))
        printk("IV length differs from expected length\n");
    crypto_blkcipher_set_iv(blkcipher, iv, ivsize);
}

scratchpad = kmalloc(crypto_blkcipher_blocksize(blkcipher), GFP_KERNEL);
if (!scratchpad) {
    printk("could not allocate scratchpad for %s\n", cipher);
    goto out;
}
/* get some random data that we want to encrypt */
get_random_bytes(scratchpad, crypto_blkcipher_blocksize(blkcipher));

desc.flags = 0;
desc.tfm = blkcipher;
sg_init_one(&sg, scratchpad, crypto_blkcipher_blocksize(blkcipher));

/* encrypt data in place */
crypto_blkcipher_encrypt(&desc, &sg, &sg,
    crypto_blkcipher_blocksize(blkcipher));

/* decrypt data in place
 * crypto_blkcipher_decrypt(&desc, &sg, &sg,
 */
    crypto_blkcipher_blocksize(blkcipher));

printk("Cipher operation completed\n");
return 0;

out:
if (blkcipher)
    crypto_free_blkcipher(blkcipher);
if (scratchpad)
```

```
    kzfree(scratchpad);
    return ret;
}
```

## Code Example For Use of Operational State Memory With SHASH

```
struct sdesc {
    struct shash_desc shash;
    char ctx[];
};

static struct sdescinit_sdesc(struct crypto_shash *alg)
{
    struct sdescsdesc;
    int size;

    size = sizeof(struct shash_desc) + crypto_shash_descsize(alg);
    sdesc = kmalloc(size, GFP_KERNEL);
    if (!sdesc)
        return ERR_PTR(-ENOMEM);
    sdesc->shash.tfm = alg;
    sdesc->shash.flags = 0x0;
    return sdesc;
}

static int calc_hash(struct crypto_shashalg,
                    const unsigned chardata, unsigned int datalen,
                    unsigned chardigest) {
    struct sdescsdesc;
    int ret;

    sdesc = init_sdesc(alg);
    if (IS_ERR(sdesc)) {
        pr_info("trusted_key: can't alloc %s\n", hash_alg);
        return PTR_ERR(sdesc);
    }

    ret = crypto_shash_digest(&sdesc->shash, data, datalen, digest);
    kfree(sdesc);
    return ret;
}
```

## Code Example For Random Number Generator Usage

```
static int get_random_numbers(u8 *buf, unsigned int len)
{
    struct crypto_rngrng = NULL;
    char drbg = "drbg_nopr_sha256"; /* Hash DRBG with SHA-256, no PR */
    int ret;

    if (!buf || !len) {
        pr_debug("No output buffer provided\n");
        return -EINVAL;
    }

    rng = crypto_alloc_rng(drbg, 0, 0);
    if (IS_ERR(rng)) {
        pr_debug("could not allocate RNG handle for %s\n", drbg);
        return -PTR_ERR(rng);
    }

    ret = crypto_rng_get_bytes(rng, buf, len);
    if (ret < 0)
        pr_debug("generation of random numbers failed\n");
    else if (ret == 0)
        pr_debug("RNG returned no data");
    else
        pr_debug("RNG returned %d bytes of data\n", ret);

out:
    crypto_free_rng(rng);
    return ret;
}
```