Trusted Application Programming Reference on Portable TEE

The National Institute of Advanced Industrial Science and Technology

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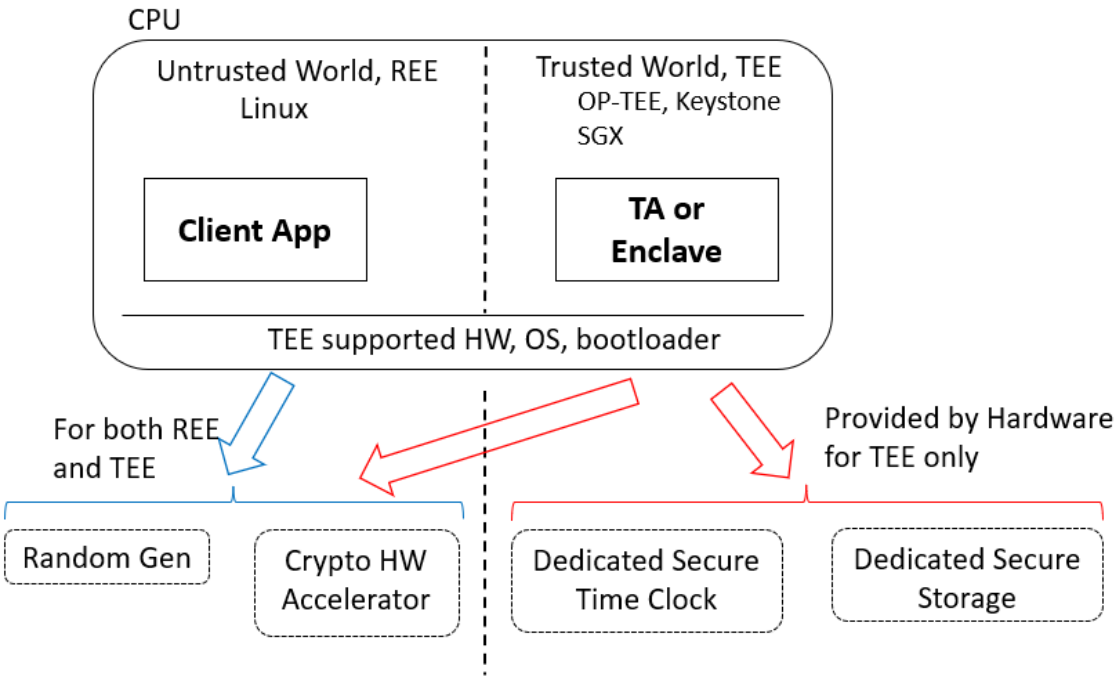
1 Overview of TA-Ref

1.1 Features of TA-Ref

- Provides Portable API and SDK among Intel SGX, ARM TrustZone-A and RISC-V Keystone
- Provides portability for source codes of Trusted Applications among SGX, TrustZone and Keystone
- Provides subset of Global Platform API

1.1.1 Hardware Features of TA-Ref on TEE



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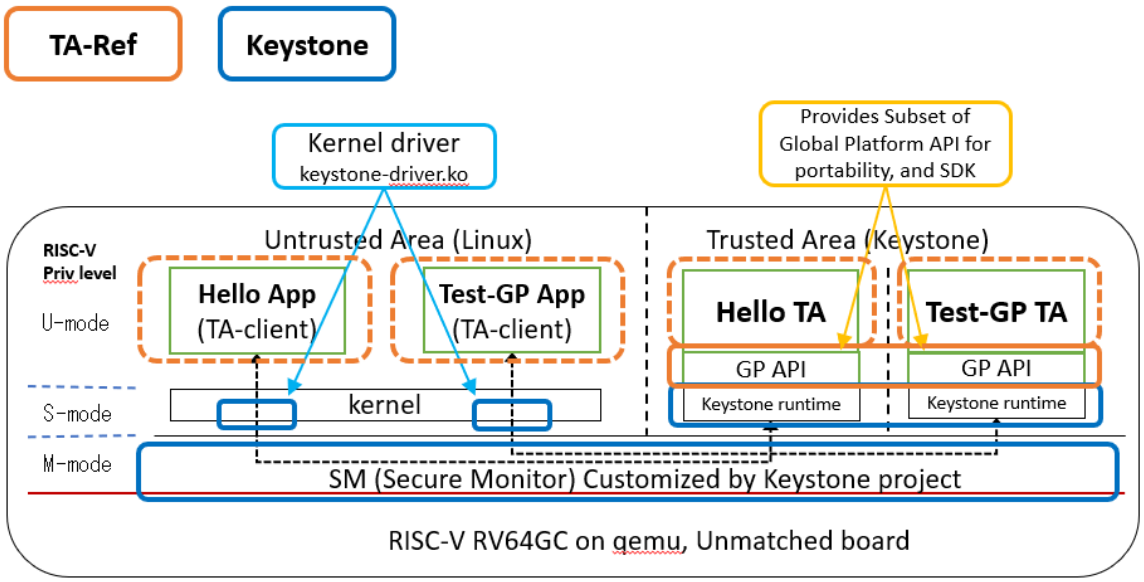
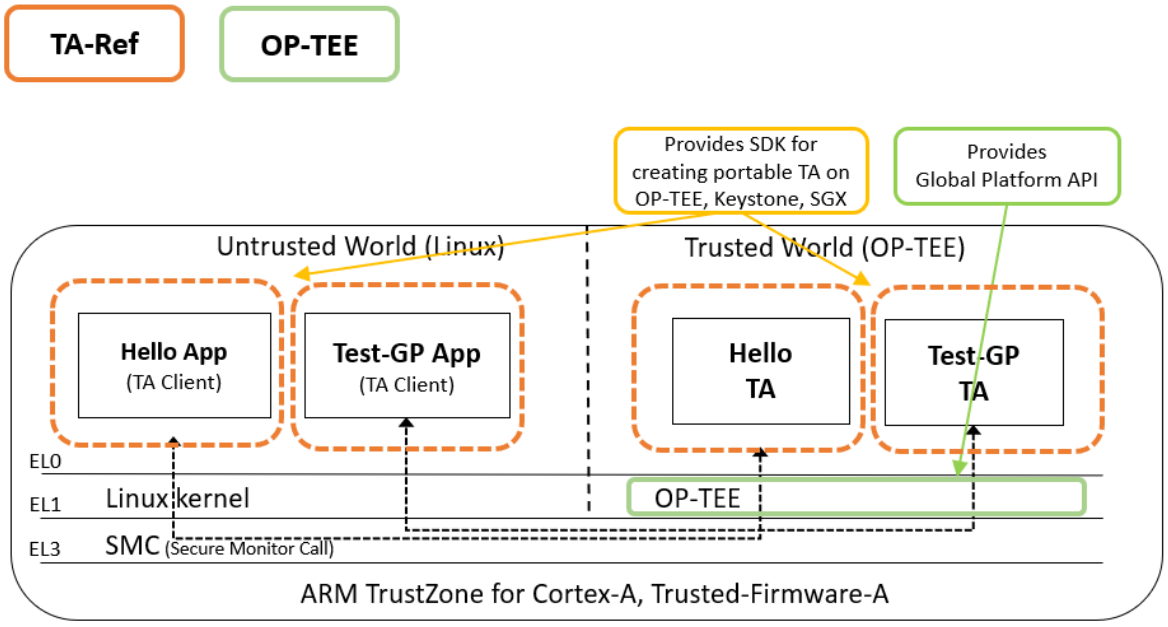
1.2 Components of TA-Ref

1.2.1 TA-Ref Components on Keystone



1.2.2 TA-Ref Components on OP-TEE



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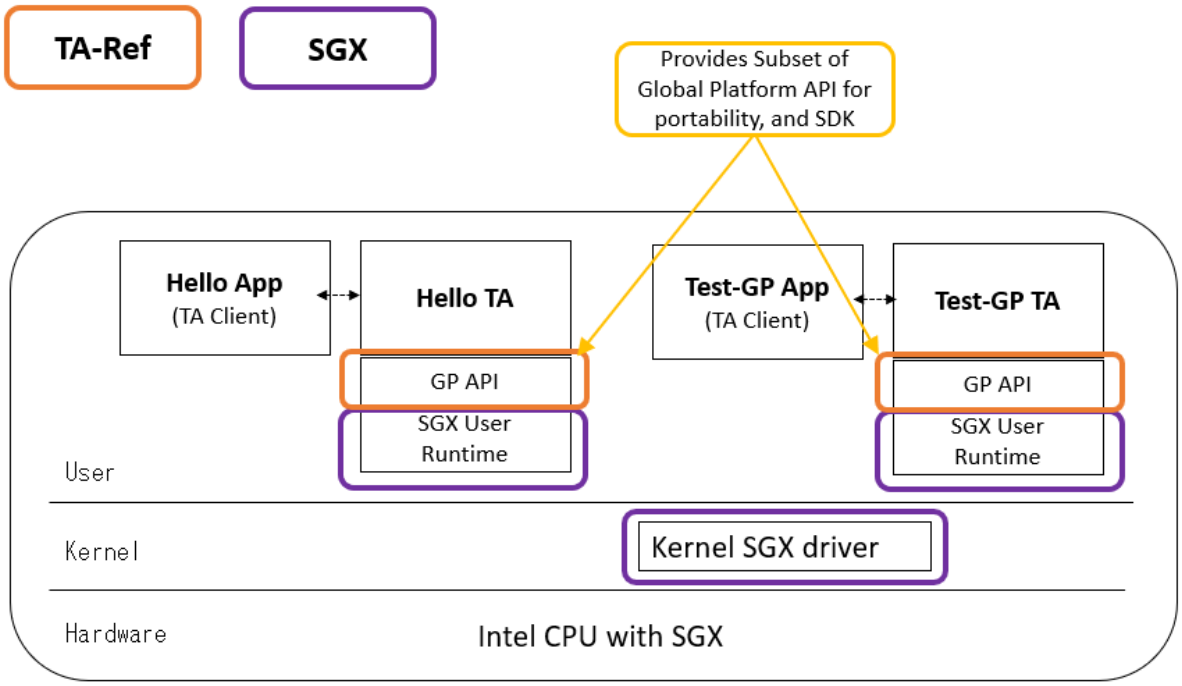
1.2.3 TA-Ref Components on SGX



1.3 What we did on RISC-V

- We designed the GP internal API library to be portable.
- Keystone SDK is utilized because of runtime "Eyrie".
- The library is ported to Intel SGX as well as RISC-V Keystone.

1.3.1 Challenges faced during Implementation

- The combination of GP internal API and cipher suite is big.
  - To reduce the size, We pick up some important GP internal APIs.
- Some APIs depend on CPU architecture.
  - We separate APIs into CPU architecture dependent / independent.
- Integrate GP TEE Internal API to Keystone SDK.
  - Keystone SDK includes EDL (Enclave Definition Language) named “keedger”.
  - Keedger creates the code for OCALL (request from TEE to REE) to check the pointer and boundary.

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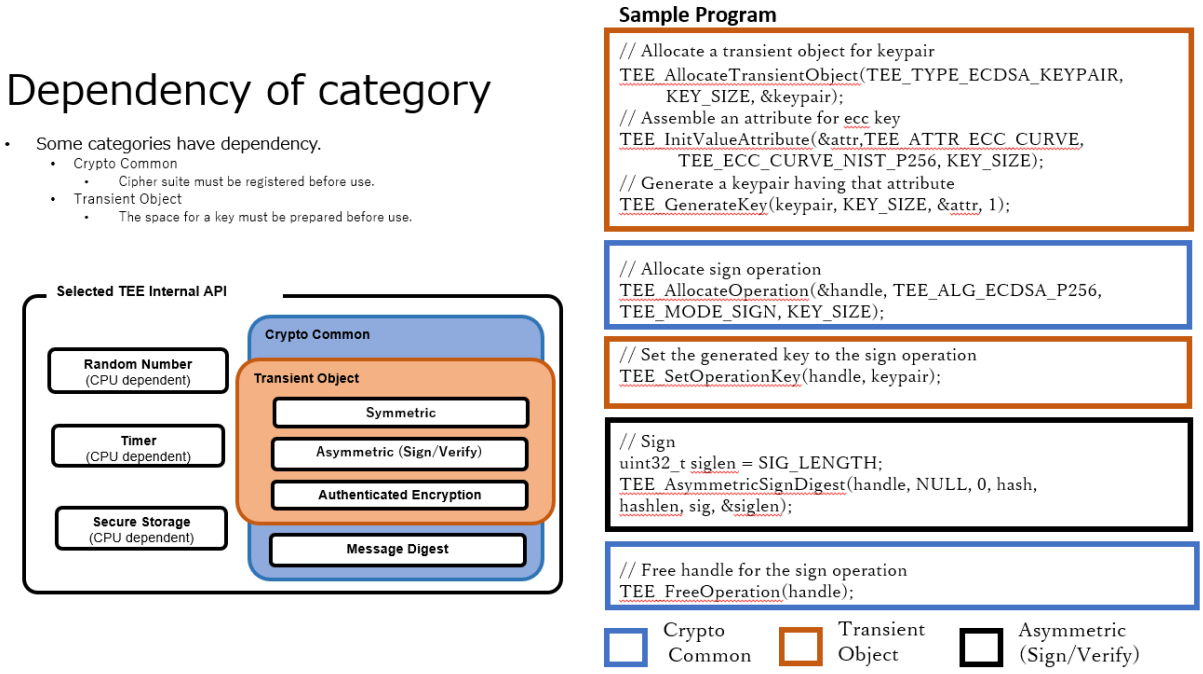
1.3.2 Selected GP TEE Internal API's for testing

- CPU architecture dependent
  - Random Generator, Time, Secure Storage, Transient Object(TEE_GenerateKey)
- CPU architecture independent(Crypto)
  - Transient Object(exclude TEE_GenerateKey), Crypto Common, Authenticated Encryption, Symmetric/Asymmetric Cipher, Message Digest

Following shows the table of CPU Dependent and Independent API's with its functions.

Category	CPU (In)Dependent	Functions
Random Number	Dependent	TEE_GenerateRandom
Time	Dependent	TEE_GetREETime, TEE_GetSystemTime
Secure Storage	Dependent	TEE_CreatePersistentObject, TEE_OpenPersistentObject, TEE_ReadObjectData, TEE_WriteObjectData, TEE_CloseObject
Transient Object	Dependent Independent	TEE_GenerateKey, TEE_AllocateTransientObject, TEE_FreeTransientObject, TEE_InitRefAttribute, TEE_InitValueAttribute, TEE_SetOperationKey
Crypto Common	Independent	TEE_AllocateOperation, TEE_FreeOperation
Authenticated Encryption	Independent	TEE_AEInit, TEE_AEUpdateAAD, TEE_AEUpdate, TEE_AEEncryptFinal, TEE_AEDecryptFinal
Symmetric Cipher	Independent	TEE_CipherInit, TEE_CipherUpdate, TEE_CipherDoFinal
Asymmetric Cipher	Independent	TEE_AsymmetricSignDigest, TEE_AsymmetricVerifyDigest
Message Digest	Independent	TEE_DigestUpdate, TEE_DigestDoFinal

1.4 Dependency of category



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2 API comparison with full set of GP API

2.1 GP API

API Functions by Category

APIs supported by both GP and AIST-GP are in Blue

API list from TEE Internal Core API Specification documentation, GlobalPlatform Technology

- Asymmetric
  - TEE_AsymmetricDecrypt
  - TEE_AsymmetricEncrypt
  - TEE_AsymmetricSignDigest
  - TEE_AsymmetricVerifyDigest
- Authenticated Encryption
  - TEE_AEDecryptFinal
  - TEE_AEEncryptFinal
  - TEE_AEInit
  - TEE_AEUpdate
  - TEE_AEUpdateAAD
- Basic Arithmetic
  - TEE_BigIntAdd
  - TEE_BigIntDiv
  - TEE_BigIntMul
  - TEE_BigIntNeg
  - TEE_BigIntSquare
  - TEE_BigIntSub
- Cancellation
  - TEE_GetCancellationFlag
  - TEE_MaskCancellation
  - TEE_UnmaskCancellation
- Converter
  - TEE_BigIntConvertFromOctetString
  - TEE_BigIntConvertFromS32
  - TEE_BigIntConvertToOctetString
  - TEE_BigIntConvertToS32
- Data Stream Access
  - TEE_ReadObjectData
  - TEE_SeekObjectData
  - TEE_TruncateObjectData
  - TEE_WriteObjectData
- Deprecated
  - TEE_CloseAndDeletePersistentObject
  - TEE_CopyObjectAttributes
  - TEE_GetObjectInfo,
  - TEE_RestrictObjectUsage
- Fast Modular Multiplication
  - TEE_BigIntComputeFMM
  - TEE_BigIntConvertFromFMM
  - TEE_BigIntConvertToFMM
- Generic Object
  - TEE_CloseObject
  - TEE_GetObjectBufferAttribute
  - TEE_GetObjectInfo (deprecated)
  - TEE_GetObjectInfo1
  - TEE_GetObjectValueAttribute
  - TEE_RestrictObjectUsage (deprecated)
  - TEE_RestrictObjectUsage1
- Generic Operation
  - TEE_AllocateOperation
  - TEE_CopyOperation
  - TEE_FreeOperation
  - TEE_GetOperationInfo
  - TEE_GetOperationInfoMultiple
  - TEE_IsAlgorithmSupported
  - TEE_ResetOperation
  - TEE_SetOperationKey
  - TEE_SetOperationKey2
- Initialization
  - TEE_BigIntInit
  - TEE_BigIntInitFMM
  - TEE_BigIntInitFMMContext
- Internal Client API
  - TEE_CloseTASession
  - TEE_InvokeTACommand
  - TEE_OpenTASession
- Key Derivation
  - TEE_DeriveKey
- Logical Operation
  - TEE_BigIntCmp
  - TEE_BigIntCmpS32
  - TEE_BigIntGetBit
  - TEE_BigIntGetBitCount
  - TEE_BigIntShiftRight
- MAC
  - TEE_MACCompareFinal
  - TEE_MACComputeFinal
  - TEE_MACInit
  - TEE_MACUpdate
- Memory Allocation and Size of Objects
  - TEE_BigIntFMMContextSizeInU32
  - TEE_BigIntFMMSizeInU32
  - TEE_BigIntSizeInU32 (macro)
- Memory Management
  - TEE_CheckMemoryAccessRights
  - TEE_Free
  - TEE_GetInstanceData
  - TEE_Malloc
  - TEE_MemCompare
  - TEE_MemFill
  - TEE_MemMove
  - TEE_Realloc
  - TEE_SetInstanceData
- Message Digest
  - TEE_DigestDoFinal
  - TEE_DigestUpdate
- Modular Arithmetic
  - TEE_BigIntAddMod
  - TEE_BigIntInvMod
  - TEE_BigIntMod
  - TEE_BigIntMulMod
  - TEE_BigIntSquareMod
  - TEE_BigIntSubMod

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- Other Arithmetic
  - TEE_BigIntComputeExtendedGcd
  - TEE_BigIntIsProbablePrime
  - TEE_BigIntRelativePrime
- Panic Function
  - TEE_Panic
- Persistent Object
  - TEE_CloseAndDeletePersistentObject (deprecated)
  - TEE_CloseAndDeletePersistentObject1
  - TEE_CreatePersistentObject
  - TEE_OpenPersistentObject
  - TEE_RenamePersistentObject
- Persistent Object Enumeration *
  - TEE_AllocatePersistentObjectEnumerator
  - TEE_FreePersistentObjectEnumerator
  - TEE_GetNextPersistentObject
  - TEE_ResetPersistentObjectEnumerator
  - TEE_StartPersistentObjectEnumerator
- Property Access
  - TEE_AllocatePropertyEnumerator
  - TEE_FreePropertyEnumerator
  - TEE_GetNextProperty
  - TEE_GetPropertyAsBinaryBlock
  - TEE_GetPropertyAsBool
  - TEE_GetPropertyAsIdentity
  - TEE_GetPropertyAsString
  - TEE_GetPropertyAsU32
  - TEE_GetPropertyAsU64
  - TEE_GetPropertyAsUUID
  - TEE_GetPropertyName
  - TEE_ResetPropertyEnumerator
  - TEE_StartPropertyEnumerator
- Random Data Generation
  - TEE_GenerateRandom
- Symmetric Cipher
  - TEE_CipherDoFinal
  - TEE_CipherInit
  - TEE_CipherUpdate
- TA Interface
  - TA_CloseSessionEntryPoint
  - TA_CreateEntryPoint
  - TA_DestroyEntryPoint
  - TA_InvokeCommandEntryPoint
  - TA_OpenSessionEntryPoint
- Time
  - TEE_GetREETime
  - TEE_GetSystemTime
  - TEE_GetTAPersistentTime
  - TEE_SetTAPersistentTime
  - TEE_Wait
- Transient Object
  - TEE_AllocateTransientObject
  - TEE_CopyObjectAttributes (deprecated)
  - TEE_CopyObjectAttributes1
  - TEE_FreeTransientObject
  - TEE_GenerateKey
  - TEE_InitRefAttribute
  - TEE_InitValueAttribute
  - TEE_PopulateTransientObject
  - TEE_ResetTransientObject

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3 How to run sample TA programs on ta-ref

Currently ta-ref supports writing TA's for three targets namely

- Keystone
- OP-TEE
- Intel SGX

The pre-built ta-ref docker images for all three targets are already available. The details are mentioned below

Target	docker image
Keystone	trasioteam/taref-dev:keystone
OP-TEE	trasioteam/taref-dev:optee
Intel SGX	trasioteam/taref-dev:sgx

3.1 Run samples for Keystone

Sample to be executed : **message_digest**

Docker Image : **trasioteam/taref-dev:keystone**

Following are the steps to be executed to run samples for Keystone.

```
# Pull the docker image
$ docker pull trasioteam/taref-dev:keystone

#Run the docker image
$ docker run -it trasioteam/taref-dev:keystone

# [Inside docker image]
# Initally you would be logged-in as build-user.
# If you are root user, change to build-user using # su build-user command.

# Changes to ta-ref folder
$ cd ${TAREF_DIR}

# Move to keystone build directory
$ cd samples/message_digest/build-keystone/

# Make the message-digest sample
$ make

# Run the qemu console
$ make run-qemu

# This opens us qemu console and login using
# buildroot login: root
# Password: sifive

# [Inside Qemu Console]
# Execute the sample and see the output
# Load the keystone driver
$ insmod keystone-driver.ko

# Run the message-digest program
$./App-keystone

# Exit the qemu console by clicking Ctrl-A X or $ poweroff command
### Ctrl-a x
```

Following is the output inside qemu when you execute the sample program.

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```
# insmod keystone-driver.ko
[   90.867089] keystone_driver: loading out-of-tree module taints kernel.
[   90.877175] keystone_enclave: keystone enclave v1.0.0
#
# ./App-keystone
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799de000-0x179c00000 (2184 KB), va 0xffffffff001de000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
main start
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 39 46 2d 2a 23 20 f8 da 57 2a 97 b0 b3 94 73 d4 31 2e 02 28 b2 3e 2c 2f e0 ae 9b 6c 67 f2 34
       3c
TEE_CreatePersistentObject(): start
TEE_WriteObjectData(): start
TEE_CloseObject(): start
main end
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799de000-0x179c00000 (2184 KB), va 0xffffffff001de000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
main start
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 39 46 2d 2a 23 20 f8 da 57 2a 97 b0 b3 94 73 d4 31 2e 02 28 b2 3e 2c 2f e0 ae 9b 6c 67 f2 34
       3c
TEE_OpenPersistentObject(): start
TEE_ReadObjectData(): start
TEE_CloseObject(): start
hash: matched!
main end
#
```

3.2 Run samples for OP-TEE

Sample to be executed : **message_digest**

Docker Image : **trasioteam/taref-dev:optee**

Following are the steps to be executed to run samples for OP-TEE.

```
# Pull the docker image
$ docker pull trasioteam/taref-dev:optee

# Run the docker image
$ docker run -it trasioteam/taref-dev:optee

# [Inside docker image]
# Initally you would be logged-in as build-user.
# If you are root user, change to build-user using # su build-user command.
$ cd ${TAREF_DIR}

# Move to Optee build directory
$ cd samples/message_digest/build-optee/

# Make the message-digest sample
$ make

# Make the qemu
make install_qemu

# Run the qemu console
$ make run-qemu

# This opens us qemu console and login using
# buildroot login: root

# [Inside Qemu Console]
# Execute the sample and see the output
# Run the message-digest program
./App-optee
```

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```
# The output of the program is not displayed inside qemu.
# Inside the docker, it cannot open two console, one for Linux and one for optee,
# so saving the console output to file for optee. It is saved inside the serial.log

# Exit the qemu console by clicking Ctrl-A X or $ poweroff command
### Ctrl-a x
```

To view the output, open the serial log file by executing the following command outside qemu.

```
$ cat /home/user/optee/out/bin/serial1.log

hash: be 45 cb 26 05 bf 36 be bd e6 84 84 1a 28 f0 fd 43 c6 98 50 a3 dc e5 fe db a6 99 28 ee 3a 89
      91
hash: be 45 cb 26 05 bf 36 be bd e6 84 84 1a 28 f0 fd 43 c6 98 50 a3 dc e5 fe db a6 99 28 ee 3a 89
      91
hash: matched!
D/TC:? 0 tee_ta_close_session:499 csess 0x6377e860 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
#
```

3.3 Run samples for Intel SGX

Sample to be executed : **message_digest**

Docker Image : **trasioteam/taref-dev:sgx**

Following are the steps to be executed to run samples for SGX.

```
# Pull the docker image
$ docker pull trasioteam/taref-dev:sgx

# Run the docker image
$ docker run -it trasioteam/taref-dev:sgx

# [Inside docker image]
# Initally you would be logged-in as build-user.
# If you are root user, change to build-user using # su build-user command.
$ cd ${TAREF_DIR}

# Move to SGX build directory
$ cd samples/message_digest/build-sgx/

# Make the message-digest sample for Simulation mode
$ make
# This creates the App_sgx and enclave.signed.so
# You can copy this two files alone to any places and run the App_sgx
$ ./App_sgx
```

Trimmed the output in the App_sgx shown below

```
.
.
[read_cpusvn_file ../cpusvn_util.cpp:96] Couldn't find/open the configuration file
       /home/user/.cpusvn.conf.
main start
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 39 46 2d 2a 23 20 f8 da 57 2a 97 b0 b3 94 73 d4 31 2e 02 28 b2 3e 2c 2f e0 ae 9b 6c 67 f2 34
       3c
TEE_CreatePersistentObject(): start
TEE_WriteObjectData(): start
TEE_CloseObject(): start
main end
main start
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 39 46 2d 2a 23 20 f8 da 57 2a 97 b0 b3 94 73 d4 31 2e 02 28 b2 3e 2c 2f e0 ae 9b 6c 67 f2 34
       3c
```

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```
TEE_OpenPersistentObject(): start
TEE_ReadObjectData(): start
TEE_CloseObject(): start
hash: matched!
main end
Info: Enclave successfully returned.
build-user@b9755ab0abea:~/ta-ref/samples/message_digest/build-sgx$ ^C
build-user@b9755ab0abea:~/ta-ref/samples/message_digest/build-sgx$ exit
exit
```

4 How to write your first 'Hello World' TA Program

To understand how to write TA,We are going to write a simple 'Hello World' TA program. The objective of the program is to print the text 'Hello World'.

To do that, first we will copy the existing sample program from ta-ref `samples` directory

Have a look on the directory structure of sample program inside ta-ref directory.

```
build-user@39ddcd17144c:~/ta-ref$ tree hello_world_ta/
hello_world_ta/
├── App-keystone.cpp
├── App-optee.c
├── App-sgx.cpp
├── build-keystone
│   └── Makefile
├── build-optee
│   ├── app.mk
│   ├── enclave.mk
│   ├── Makefile
│   ├── sub.mk
│   └── user_ta_header_defines.h
├── build-sgx
│   ├── app.mk
│   ├── config
│   │   └── Enclave.config.xml
│   ├── Enclave.lds
│   ├── enclave.mk
│   ├── Enclave_private.pem
│   └── Makefile
└── Enclave.c
```

Basically we need to modify two files

1) Enclave.c (Common to all three targets)

2) App-<target>.c

- App-keystone.cpp (incase of Keystone)
- App-optee.c (Incase of OP-TEE)
- App-sgx.cpp (Incase of SGX)

4.1 Writing 'Hello World' TA for Keystone

Step 1: Run the docker image

Run the ta-ref pre-built docker for keystone.

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```
# Download / Refresh the docker image
$ docker pull trasioteam/taref-dev:keystone

# Run the docker image
$ docker run -it trasioteam/taref-dev:keystone
```

Step 2: Copy sample directory and modify

Copy the sample 'message_digest' and rename to the name you need. Here, we are naming it to `hello_world_ta`

```
$ cd ${USER_DIR}
$ cp -r ${TAREF_DIR}/samples/message_digest/ hello_world_ta
$ cd hello_world_ta
```

Step 3 : Modifications to Enclave.c (Common to all three targets)

`Enclave.c` is the place where we write the business logic. In our case, our business logic is to print the text 'Hello World'.

Look for the #define statement `TA_InvokeCommandEntryPoint()` function. This is the place we are going to modify

Before modification

```
#define TA_REF_HASH_GEN    0x11111111
#define TA_REF_HASH_CHECK  0x22222222
TEE_Result TA_InvokeCommandEntryPoint(void *sess_ctx,
                                      uint32_t cmd_id,
                                      uint32_t param_types, TEE_Param params[4])
{
    int ret = TEE_SUCCESS;
    switch (cmd_id) {
    case TA_REF_HASH_GEN:
        message_digest_gen();
        return TEE_SUCCESS;
    case TA_REF_HASH_CHECK:
        ret = message_digest_check();
        if (ret != TEE_SUCCESS)
            ret = TEE_ERROR_SIGNATURE_INVALID;
        return ret;
    default:
        return TEE_ERROR_BAD_PARAMETERS;
    }
}
```

After Modification

```
#define TA_REF_PRINT_HELLO    0x11111111
TEE_Result TA_InvokeCommandEntryPoint(void *sess_ctx,
                                      uint32_t cmd_id,
                                      uint32_t param_types, TEE_Param params[4])
{
    int ret = TEE_SUCCESS;
    switch (cmd_id) {
    case TA_REF_PRINT_HELLO:
        tee_printf("Hello World \n");
        return TEE_SUCCESS;
    default:
        return TEE_ERROR_BAD_PARAMETERS;
    }
}
```

In the modification, we have removed the existing switch cases and added a new case to print 'Hello World' text. Various functions available to be used here are shown in Chapter 2 and few important functions are explained in detail below.

Please save your changes and exit Enclave.c

Step 4 : Modifications to App-keystone.c

App-keystone.cpp is the main function which invokes Enclave.c. The objective is to call the TA_InvokeCommandEntryPoint() which we modified in the previous step.

Before Modification

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```
  #define TA_REF_HASH_GEN    0x11111111
  #define TA_REF_HASH_CHECK  0x22222222
  // Inside main() function
run_enclave(TA_REF_HASH_GEN);
run_enclave(TA_REF_HASH_CHECK);
```

After modification

```
#define TA_REF_PRINT_HELLO    0x11111111
// Inside main() function
run_enclave(TA_REF_PRINT_HELLO);
```

Step 5: Execute the 'Hello World' TA for Keystone

Change directory to the `build-keystone` directory.

```
# Change to build-<target> directory
$ cd build-keystone

# Make the TA
$ make

# Run the qemu console
$ make run-qemu

# This opens us qemu console and login using
# buildroot login: root
# Password: sifive
#

# [Inside Qemu Console]
# Execute the sample and see the output
# Load the keystone driver
$ insmod keystone-driver.ko

# Run the message-digest program
$./App-keystone
# [Ouput log printing Hello world]
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799dd000-0x179c00000 (2188 KB), va 0xffffffff001dd000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
main start
Hello World
main end
# Exit the qemu console by clicking Ctrl-A X or $ poweroff command
### Ctrl-a x
```

Here you can see the text 'Hello World' printed in the log.

4.2 Writing 'Hello World' TA for OP-TEE

Step 1: Run the docker image

Run the ta-ref pre-built docker for optee.

```
# Download / Refresh the docker image
$ docker pull trasioteam/taref-dev:optee

# Run the docker image
$ docker run -it trasioteam/taref-dev:optee
```

Step 2: Copy sample directory and modify

Copy the sample 'message_digest' and rename to the name you need. Here, we are naming it to `hello_world_ta`

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```
$ cd ${USER_DIR}
$ cp -r ${TAREF_DIR}/samples/message_digest/ hello_world_ta
$ cd hello_world_ta
```

Step 3 : Modifications to Enclave.c

The modification is same as Keystone. So please refer the Step 3 of Writing 'Hello World' TA for keystone.

Step 4 : Modification to App-optee.cpp

App-optee.c is the main function which invokes Enclave.c. The objective is to call the TA_InvokeCommandEntryPoint() which we modified in the previous step.

Look for the #define statement and `main(void)` function in the program

Before modification

```
#define TA_REF_HASH_GEN    0x11111111
#define TA_REF_HASH_CHECK  0x22222222
// Inside main(void) function
res = TEEC_InvokeCommand(&sess, TA_REF_HASH_GEN, &op,
                         &err_origin);
res = TEEC_InvokeCommand(&sess, TA_REF_HASH_CHECK, &op,
                         &err_origin);
```

After modification

```
#define TA_REF_PRINT_HELLO    0x11111111
// Inside main(void) function
res = TEEC_InvokeCommand(&sess, TA_REF_PRINT_HELLO, &op,
                         &err_origin);
```

Step 5: Execute the 'Hello World' TA for OP-TEE

Change directory to the `build-optee` directory.

```
# Change to build-<target> directory
$ cd build-optee

# Make the TA
$ make

# After successful make of TA, Make the qemu
$ make install_qemu

# Run the qemu console
$ make run-qemu
# This opens us qemu console and login using
# buildroot login: root

# [Inside Qemu Console]
# Execute the create TA program
# No ouput is shown inside qemu, its stored in serial.log
# ./App-optee

# Exit the qemu console by clicking Ctrl-A X or $ poweroff command
### Ctrl-a x
```

To view the output, open the serial log file by executing the following command outside qemu.

```
$ cat /home/user/optee/out/bin/serial1.log

[Trimmed output]
D/TC:? 0 tee_ta_close_session:518 Destroy session
**Hello World**
D/TC:? 0 tee_ta_close_session:499 csess 0x3293e860 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
```

Here you can see the text 'Hello World' printed in the log.

4.3 Writing 'Hello World' TA for Intel SGX

Step 1: Run the docker image

Run the ta-ref pre-built docker for sgx.

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```
# Download / Refresh the docker image
$ docker pull trasioteam/taref-dev:sgx

# Run the docker image
$ docker run -it trasioteam/taref-dev:sgx
```

Step 2: Copy sample directory and modify

Copy the sample 'message_digest' and rename to the name you need. Here, we are naming it to `hello_world_ta`

```
$ cd ${USER_DIR}
$ cp -r ${TAREF_DIR}/samples/message_digest/ hello_world_ta
$ cd hello_world_ta
```

Step 3 : Modifications to Enclave.c

The modification is same as Keystone. So please refer the Step 3 of Writing 'Hello World' TA for keystone.

Step 4 : Modification to App-sgx.cpp

App-sgx.c is the main function which invokes Enclave.c. The objective is to call the TA_InvokeCommandEntryPoint() which we modified in the previous step.

Look for the #define statement and `main(void)` function in the program

Before modification

```
#define TA_REF_HASH_GEN    0x11111111
#define TA_REF_HASH_CHECK  0x22222222
// Inside main(void) function
/* Calling Trusted Application */
ret = ecall_ta_main(global_eid, TA_REF_HASH_GEN);
if (ret != SGX_SUCCESS)
    goto main_out;
ret = ecall_ta_main(global_eid, TA_REF_HASH_CHECK);
if (ret != SGX_SUCCESS)
    goto main_out;
```

After modification

```
#define TA_REF_PRINT_HELLO    0x11111111
// Inside main(void) function
/* Calling Trusted Application */
ret = ecall_ta_main(global_eid, TA_REF_PRINT_HELLO);
if (ret != SGX_SUCCESS)
    goto main_out;
```

Step 5: Execute the 'Hello World' TA for Intel SGX

Change directory to the `build-sgx` directory.

```
# Change to build-<target> directory
$ cd build-sgx

# Make the message-digest sample for Simulation mode
$ make

# This creates the App_sgx and enclave.signed.so
# You can copy this two files alone to any places and run the App_sgx
$ ./App_sgx

# [Trimmed Output]
main start
Hello World
main end
Info: Enclave successfully returned.
```

Here you can see the text 'Hello World' printed in the log.

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5 AIST supported GP API's in TA's

Following are the set of AIST supported GP API's that can be used when writing your own TA is shown below.

5.1 Time Functions

/**

- ree_time_get() - Retrieves the current REE system time.
-
- Retrieves the current time as seen from the point of view of the REE which
- typically runs on Linux/Android or Windows with gettimeofday().
- It is not safe to use the value of TEE_GetREETime() in TEE for security
- sensitive purposes but it is a good way to check what the apps on REE
- see the current time is.
-

  Returns

- returns time value from OS running on REE */

```
struct timeval ree_time_get(void)
{
    TEE_Time time;
    struct timeval tv;
    /* REE time */
    TEE_GetREETime(&time);
    tee_printf ("@GP REE time %u sec %u millis\n", time.seconds, time.millis);
    tv.tv_sec = time.seconds, tv.tv_usec = time.millis * 1000;
    return tv;
}
```

/**

- tee_time_get() - Retrieves the current secure system time for the usage in TEE.
-
- The TEE_GetSystemTime() returns the time value which is not able to be
- changed by User Applications on the REE side, but returns a tamper safe
- time value which normally requires hardware implementation with a separate
- RTC chip in the area where OS on REE can not access it and backed up with
- shield battery. The secure system is for security sensitive operations,
- such as checking expiration date of certificates and keys.
-

  Returns

- returns time value for the usage in TEE */

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```
struct timeval tee_time_get(void)
{
    TEE_Time time;
    struct timeval tv;
    /* System time */
    TEE_GetSystemTime(&time);
    tee_printf ("@GP Secure time %u sec %u millis\n", time.seconds, time.millis);
    tv.tv_sec = time.seconds, tv.tv_usec = time.millis * 1000;
    return tv;
}
```

5.2 Random Functions

/**

- tee_random_get() - Generates the random value for secure operation in TEE.
-
- It returns the closest value to the true random generator but the quality
- of the randomness depends on the hardware implementation.
- Quality of the random value is very important for having a good security
- level on many cryptographic algorithms used inside TEE. It is recommended
- to have equivalent level of SP 800-90B and FIPS 140-3.
-

  Returns

- returns random value */

```
void tee_random_get(void)
{
    unsigned char rbuf[16];
    TEE_GenerateRandom(rbuf, sizeof(rbuf));
    tee_printf("random: ");
    for (int i = 0; i < sizeof(rbuf); i++) {
        tee_printf ("%02x", rbuf[i]);
    }
    tee_printf("\n");
}
```

5.3 Hash Functions

/**

- message_digest_gen() - Example program to show how to use hash functions
- with ta-ref API.
-
- Calculate hash value of a data in SHA256 and store it.
- Check the return value of each API call on real product development. */

```
void message_digest_gen(void)
{
```

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```
    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f
    };
    size_t hashlen = SHA_LENGTH;
    uint8_t hash[SHA_LENGTH];
    uint8_t *pdata = data;
    TEE_OperationHandle handle;
    TEE_Result rv;
    TEE_AllocateOperation(&handle, TEE_ALG_SHA256, TEE_MODE_DIGEST, SHA_LENGTH);
    TEE_DigestUpdate(handle, pdata, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    TEE_DigestDoFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, hash, &hashlen);
    TEE_FreeOperation(handle);
    tee_printf("hash: ");
    for (int i = 0; i < hashlen; i++) {
        tee_printf ("%02x ", hash[i]);
    }
    tee_printf("\n");
    secure_storage_write(hash, hashlen, "hash_value");
}
```

/**

- message_digest_check() - Example program to show how to use hash
- functions with ta-ref API.
-
- Checking the hash value is the easiest way to confirm the integrity of
- the data. Calculate hash value of a data and compare it with the saved
- hash value to verify whether the data is the same as the previous data.
- Check the return value of each API call on real product development.
-

  Returns

- 0 on data match, others if not */

```
int message_digest_check(void)
{
    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f
    };
    size_t hashlen = SHA_LENGTH;
    uint8_t hash[SHA_LENGTH];
    uint8_t saved_hash[SHA_LENGTH];
    uint8_t *pdata = data;
    TEE_OperationHandle handle;
    TEE_Result rv;
    int ret;
    TEE_AllocateOperation(&handle, TEE_ALG_SHA256, TEE_MODE_DIGEST, SHA_LENGTH);
    TEE_DigestUpdate(handle, data, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    TEE_DigestDoFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, hash, &hashlen);
    TEE_FreeOperation(handle);
    tee_printf("hash: ");
    for (int i = 0; i < hashlen; i++) {
        tee_printf ("%02x ", hash[i]);
    }
    tee_printf("\n");
    secure_storage_read(saved_hash, &hashlen, "hash_value");
    ret = memcmp(saved_hash, hash, hashlen);
    if (ret == 0) {
        tee_printf("hash: matched!\n");
    }
    return ret;
}
```

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5.4 Symmetric Crypto AES-GCM Functions

/**

- Example program to show how to use AES 256 GCM functions with ta-ref API.
-
- Generate a key and encypt a data and stores it.
- Check the return value of each API call on real product development. ∗/

```
void symmetric_key_enc(void)
{
    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
        0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
        0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d, 0x1e, 0x1f
    };
    uint8_t out[ENCDATA_MAX];
    size_t  outlen = ENCDATA_MAX;
    uint8_t iv[TAG_LEN];
    uint8_t tag[TAG_LEN];
    size_t  taglen = TAG_LEN_BITS;
    uint8_t *pdata = data;
    size_t  keylen = 256;
    TEE_OperationHandle handle;
    TEE_Result rv;
    TEE_AllocateTransientObject(TEE_TYPE_AES, 256, &key);
    TEE_GenerateKey(key, 256, NULL, 0);
    TEE_AllocateOperation(&handle, TEE_ALG_AES_GCM, TEE_MODE_ENCRYPT, 256);
    TEE_SetOperationKey(handle, key);
    // tee_printf("key: ");
    // for (int i = 0; i < 256 / 8; i++) {
    //   tee_printf ("%02x", key[i]);
    // }
    // tee_printf("\n");
    TEE_GenerateRandom(iv, sizeof(iv));
    TEE_AEInit(handle, iv, sizeof(iv), TAG_LEN_BITS, 0, 0);
    TEE_AEUpdateAAD(handle, pdata, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    /* Equivalent in openssl is EVP_EncryptFinal() */
    TEE_AEEncryptFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, out, &outlen, tag, &taglen);
    TEE_FreeOperation(handle);
    tee_printf("Encrypted Data: size:%d ", outlen);
    for (int i = 0; i < outlen; i++) {
      tee_printf ("%02x", out[i]);
    }
    tee_printf("\n");
    tee_printf("tag: size: %d ", taglen);
    for (int i = 0; i < taglen; i++) {
      tee_printf ("%02x", tag[i]);
    }
    tee_printf("\n");
    // secure_storage_write(key, keylen, "sym_key");
    secure_storage_write(out, outlen, "enc_data");
}
```

/**

- Example program to show how to use AES 256 GCM functions with ta-ref API.
-
- Retrive the key from secure store and decrypt the data.
-

  Returns

- 0 on data match, others if not ∗/

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```
int symmetric_key_dec(void)
{
    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
        0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
        0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d, 0x1e, 0x1f
    };
    size_t  keylen = 256;
    uint8_t out[ENCDATA_MAX];
    size_t  outlen = ENCDATA_MAX;
    uint8_t iv[TAG_LEN];
    uint8_t tag[TAG_LEN];
    size_t  taglen = TAG_LEN_BITS;
    uint8_t *pdata = data;
    int ret;
    TEE_OperationHandle handle;
    TEE_Result rv;
    // secure_storage_read(key, &keylen, "sym_key");
    secure_storage_read(out, &outlen, "enc_data");
    tee_printf("Reading Stored Data: size:%d ", outlen);
    for (int i = 0; i < outlen; i++) {
      tee_printf ("%02x", out[i]);
    }
    tee_printf("\n");
    TEE_AllocateOperation(&handle, TEE_ALG_AES_GCM, TEE_MODE_DECRYPT, 256);
    TEE_SetOperationKey(handle, key);
    /* Equivalant of EVP_DecryptInit_ex() in openssl  */
    TEE_AEInit(handle, iv, sizeof(iv), TAG_LEN_BITS, 0, 0);
    TEE_AEUpdateAAD(handle, pdata, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    /* Equivalent in openssl is EVP_EncryptFinal() */
    TEE_AEDecryptFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, out, &outlen, tag, &taglen);
    TEE_FreeOperation(handle);
    TEE_FreeTransientObject(key);
    tee_printf("Decrypted Data: ");
    for (int i = 0; i < outlen; i++) {
      tee_printf ("%02x", out[i]);
    }
    tee_printf("\n");
    tee_printf("Actual Data: ");
    for (int i = 0; i < outlen; i++) {
      tee_printf ("%02x", data[i]);
    }
    tee_printf("\n");
    ret = memcmp(data, out, outlen);
    if (ret == 0) {
        tee_printf("decrypt: Data matched!\n");
    } else {
        tee_printf("decrypt: Data does not match!\n");
    }
    return ret;
}
```

5.5 Asymmetric Crypto Functions

/**

- Example program to show how to use asymmetric key encryption functions with ECDSA_P256
- on ta-ref API.
-
- Generate a keypair and creating signature of a data and stores them.
- Check the return value of each API call on real product development. */

```
void asymmetric_key_enc(void)
{
    tee_printf("Start of Aysmmetric Encryption\n");
    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
```

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```
        0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
        0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d, 0x1e, 0x1f
    };
    uint8_t sig[SIG_LENGTH];
    size_t  siglen = SIG_LENGTH;
    uint8_t *pdata = data;
    unsigned char hash[DATA_SIZE];
    uint32_t hashlen = DATA_SIZE;
    TEE_ObjectHandle keypair;
    TEE_OperationHandle handle;
    TEE_Attribute attr;
    TEE_Result rv;
    TEE_AllocateOperation(&handle, TEE_ALG_SHA256, TEE_MODE_DIGEST, SHA_LENGTH);
    TEE_DigestUpdate(handle, pdata, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    TEE_DigestDoFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, hash, &hashlen);
    TEE_FreeOperation(handle);
    tee_printf("hash: size %d", hashlen);
    for (int i = 0; i < hashlen; i++) {
      tee_printf ("%02x", hash[i]);
    }
    tee_printf("\n");
    TEE_AllocateTransientObject(TEE_TYPE_ECDSA_KEYPAIR, 256, &keypair);
    TEE_InitValueAttribute(&attr, TEE_ATTR_ECC_CURVE, TEE_ECC_CURVE_NIST_P256,
                           256);
    TEE_GenerateKey(keypair, 256, &attr, 1);
    TEE_AllocateOperation(&handle, TEE_ALG_ECDSA_P256, TEE_MODE_SIGN, 256);
    TEE_SetOperationKey(handle, keypair);
    TEE_AsymmetricSignDigest(handle, NULL, 0, hash, hashlen, sig, &siglen);
    TEE_FreeOperation(handle);
    tee_printf("Signature: size:%d ", siglen);
    for (int i = 0; i < siglen; i++) {
      tee_printf ("%02x", sig[i]);
    }
    secure_storage_write(keypair, 256 / 8, "keypair");
    secure_storage_write(sig, siglen, "sig_data");
    tee_printf("End of Aysmmetric Encryption\n");
}
```

/**

- Example program to show how to use asymmetric key Decryption functions with ECDSA_P256
- on ta-ref API.
-

Returns

- 0 on successful decryption, others if not */

```
int asymmetric_key_dec(void)
{
    tee_printf("Start of Aysmmetric Decryption\n");

    uint8_t data[DATA_SIZE] = {
        0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f,
        0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
        0x18, 0x19, 0x1a, 0x1b, 0x1c, 0x1d, 0x1e, 0x1f
    };
    uint8_t sig[TAG_LEN];
    size_t  siglen = TAG_LEN_BITS;
    uint8_t *pdata = data;
    unsigned char hash[DATA_SIZE];
    uint32_t hashlen = DATA_SIZE;
    int ret;
    TEE_OperationHandle handle;
    TEE_ObjectHandle key;
    TEE_Result verify_ok;
    TEE_ObjectHandle keypair;
    // secure_storage_read(keypair, 256 / 8, "keypair");
    //secure_storage_read(sig, siglen, "sig_data");
    TEE_AllocateOperation(&handle, TEE_ALG_SHA256, TEE_MODE_DIGEST, SHA_LENGTH);
    TEE_DigestUpdate(handle, pdata, CHUNK_SIZE);
    pdata += CHUNK_SIZE;
    TEE_DigestDoFinal(handle, pdata, DATA_SIZE - CHUNK_SIZE, hash, &hashlen);
    TEE_FreeOperation(handle);
    tee_printf("hash: size %d", hashlen);
    for (int i = 0; i < hashlen; i++) {
```

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```
      tee_printf ("%02x", hash[i]);
    }
    tee_printf("\n");
    TEE_AllocateOperation(&handle, TEE_ALG_ECDSA_P256, TEE_MODE_VERIFY, 256);
    TEE_SetOperationKey(handle, keypair);
    verify_ok = TEE_AsymmetricVerifyDigest(handle, NULL, 0, hash, hashlen, sig, siglen);
    TEE_FreeOperation(handle);
//    TEE_FreeTransientObject(keypair);
    if (verify_ok == TEE_SUCCESS) {
      tee_printf("verify ok\n");
      ret = 0;
    } else {
      tee_printf("verify fails\n");
      ret = -1;
    }
    tee_printf("End of Aysmmetric Decryption\n");
    return ret;
}
```

5.6 Open, Read, Write, Close On Secure Storage

/**

- secure_storage_write() - Example program to show how to use secure
- storage with ta-ref API. Write the data to secure storage.
-
- The secure storage is for storing cryptographic keys, certificates,
- security sensitive data such as personalization data. How the secure
- storage is secure is implementation dependent. Ideally the secure storage
- is provided separately from REE accessible areas and can not be tampered
- from User Application on REE, read, write, delete nore retrievable the
- file name. Typically requires hardware support, and if not then some easy
- implementation might be just saving the data on a filesystem on Linux
- residing in REE which does not provide the secure level as mentioned here.
- The data are saved with different encryption keys from other TAs, and
- not able to read the same data by other TAs. */

```
void secure_storage_write(void)
{
    uint8_t data[DATA_SIZE] = {
        0xff, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f
    };
    TEE_ObjectHandle object;
    TEE_CreatePersistentObject(TEE_STORAGE_PRIVATE,
                               "filename", strlen("filename"),
                               (TEE_DATA_FLAG_ACCESS_WRITE
                                | TEE_DATA_FLAG_OVERWRITE),
                               TEE_HANDLE_NULL,
                               NULL, 0,
                               &object);
    TEE_WriteObjectData(object, (const char *)data, DATA_SIZE);
    TEE_CloseObject(object);

}
```

/**

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- secure_storage_read() - Example program to show how to use secure
- storage with ta-ref API. Read the data from secure storage.
-
- Read the data from the secure storage and compare with expected data.
-

Returns

- TEE_SUCCESS if the data mached, others if not. ∗/

```
int secure_storage_read(void)
{
    uint8_t cmp_data[DATA_SIZE] = {
        0xff, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
        0x08, 0x09, 0x0a, 0x0b, 0x0c, 0x0d, 0x0e, 0x0f
    };
    uint8_t buf[DATA_SIZE * 2];
    TEE_ObjectHandle object;
    TEE_OpenPersistentObject(TEE_STORAGE_PRIVATE,
                             "filename", strlen("filename"),
                             TEE_DATA_FLAG_ACCESS_READ,
                             &object);
    uint32_t count;
    TEE_ReadObjectData(object, (char *)buf, DATA_SIZE, &count);
    TEE_CloseObject(object);
    tee_printf("%d bytes read: ", count);
    for (uint32_t i = 0; i < count; i++) {
      tee_printf ("%02x", buf[i]);
    }
    tee_printf("\n");
    int verify_ok;
    verify_ok = !memcmp(buf, cmp_data, count);
    if (verify_ok) {
        tee_printf("verify ok\n");
    return TEE_SUCCESS;
    } else {
        tee_printf("verify fails\n");
    return -1;
    }
    return TEE_SUCCESS;
}
```

5.7 API Error Codes and its values

API ERROR CODE	VALUE
TEE_SUCCESS	0x00000000
TEE_ERROR_CORRUPT_OBJECT	0xF0100001
TEE_ERROR_CORRUPT_OBJECT_2	0xF0100002
TEE_ERROR_STORAGE_NOT_AVAILABLE	0xF0100003
TEE_ERROR_STORAGE_NOT_AVAILABLE↩ _2	0xF0100004
TEE_ERROR_GENERIC	0xFFFF0000
TEE_ERROR_ACCESS_DENIED	0xFFFF0001
TEE_ERROR_CANCEL	0xFFFF0002
TEE_ERROR_ACCESS_CONFLICT	0xFFFF0003
TEE_ERROR_EXCESS_DATA	0xFFFF0004
TEE_ERROR_BAD_FORMAT	0xFFFF0005
TEE_ERROR_BAD_PARAMETERS	0xFFFF0006
TEE_ERROR_BAD_STATE	0xFFFF0007
TEE_ERROR_ITEM_NOT_FOUND	0xFFFF0008
TEE_ERROR_NOT_IMPLEMENTED	0xFFFF0009
TEE_ERROR_NOT_SUPPORTED	0xFFFF000A
TEE_ERROR_NO_DATA	0xFFFF000B

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API ERROR CODE	VALUE
TEE_ERROR_OUT_OF_MEMORY	0xFFFF000C
TEE_ERROR_BUSY	0xFFFF000D
TEE_ERROR_COMMUNICATION	0xFFFF000E
TEE_ERROR_SECURITY	0xFFFF000F
TEE_ERROR_SHORT_BUFFER	0xFFFF0010
TEE_ERROR_EXTERNAL_CANCEL	0xFFFF0011
TEE_ERROR_OVERFLOW	0xFFFF300F
TEE_ERROR_TARGET_DEAD	0xFFFF3024
TEE_ERROR_STORAGE_NO_SPACE	0xFFFF3041
TEE_ERROR_MAC_INVALID	0xFFFF3071
TEE_ERROR_SIGNATURE_INVALID	0xFFFF3072
TEE_ERROR_TIME_NOT_SET	0xFFFF5000

6 Preparation and building ta-ref with docker

6.1 Preparation

For building ta-ref with docker, it is required to install docker on Ubuntu.

For the first time users of docker, please have a look on https://docs.docker.com/engine/

The following installation steps is for Ubuntu 20.04

6.1.1 Installing Docker

```
$ sudo apt update

# Next, install a few prerequisite packages which let apt use packages over HTTPS:
$ sudo apt install apt-transport-https ca-certificates curl software-properties-common

# Then add the GPG key for the official Docker repository to your system:
$ curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -

# Add the Docker repository to APT sources:
$ sudo add-apt-repository "deb [arch=amd64] https://download.docker.com/linux/ubuntu focal stable"

# This will also update our package database with the Docker packages from the newly added repo.
# Make sure you are about to install from the Docker repo instead of the default Ubuntu repo:
$ apt-cache policy docker-ce

#Finally, install Docker
$ sudo apt install docker-ce
```

6.1.2 Executing Docker without sudo

By default, the docker command can only be run the root user or by a user in the docker group, which is automatically created during Docker's installation process. If you attempt to run the docker command without prefixing it with sudo or without being in the docker group, you'll get an output like this:

```
docker: Cannot connect to the Docker daemon. Is the docker daemon running on this host?.
```

To avoid typing sudo whenever we run the docker command, add your username to the docker group.

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```
$ sudo groupadd docker
$ sudo gpasswd -a $USER docker
# Logout and then log-in again to apply the changes to the group
```

After you logout and login, you can probably run the docker command without `sudo`

```
$ docker run hello-world
```

6.1.3 Create a docker network tamproto

A docker network named tamproto is required when we run ta-ref for Keystone. The local network is required to connect with tamproto service running locally.

```
$ docker network create tamproto_default
```

6.2 Docker images details

The docker images with all necessary packages for building ta-ref for all three targets are already available. Make sure you have account on docker-hub. If not please create one on `dockerhub.com` The details are mentioned below

Target	docker image
Keystone	aistcpsec/tee-dev:keystone-1.↩ 0.0
OP-TEE	aistcpsec/tee-dev:optee-3.10.0
Intel SGX	aistcpsec/tee-dev:sgx-2.10

6.3 Building ta-ref with Docker

6.3.1 Building ta-ref for Keystone with docker

Following commands are to be executed on Ubuntu 20.04.

```
# Clone the ta-ref repo and checkout teep-master branch
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref/
$ git checkout teep-master

# Sync and update the submodules
$ git submodule sync --recursive
$ git submodule update --init --recursive

# Start the docker
$ docker run --network tamproto_default -it --rm -v $(pwd):/home/user/ta-ref
 aistcpsec/tee-dev:keystone-1.0.0
```

After you start the docker command, you will be logged-in inside the docker container. Following are the commands to be executed inside the docker

```
# [Inside docker image]

$ cd ta-ref/
$ source env/keystone.sh
```

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```
# Build test_hello directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_hello

# Build test_gp directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_gp
```

By the above steps, we have successfully built the ta-ref. Below we are going to push it into qemu and test its working

Test the built test_hello, test_gp binaries in Qemu

```
# Copy the test_hello inside qemu root
$ mkdir $KEYSTONE_DIR/build/overlay/root/test_hello
$ cp test_hello/keystone/App/App.client $KEYSTONE_DIR/build/overlay/root/test_hello/
$ cp test_hello/keystone/Enclave/Enclave.eapp_riscv $KEYSTONE_DIR/build/overlay/root/test_hello/
$ cp $KEYSTONE_SDK_DIR/runtime/eyrie-rt $KEYSTONE_DIR/build/overlay/root/test_hello/


# Copy the test_gp inside qemu root
$ mkdir $KEYSTONE_DIR/build/overlay/root/test_gp
$ cp test_gp/keystone/App/App.client $KEYSTONE_DIR/build/overlay/root/test_gp/
$ cp test_gp/keystone/Enclave/Enclave.eapp_riscv $KEYSTONE_DIR/build/overlay/root/test_gp/
$ cp $KEYSTONE_SDK_DIR/runtime/eyrie-rt $KEYSTONE_DIR/build/overlay/root/test_gp/

# Re-build the keystone again to copy test_hello and test_gp inside qemu
$ cd $KEYSTONE_DIR/build
$ make


# Start the Qemu console from $KEYSTONE_DIR/build dir
$ ./scripts/run-qemu.sh

# When asked for username and password use
# username : root
# password : sifive

# Inside Qemu run the steps to test test_hello and test_gp
# Load keystone driver
$ insmod keystone-driver.ko

# Test test_hello
# cd test_hello/
# ./App.client Enclave.eapp_riscv eyrie-rt

[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0xb7c00000-0xb8000000 (4096 KB) (boot.c:128)
[debug] FREE: 0xb7dbb000-0xb8000000 (2324 KB), va 0xffffffff001bb000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
hello world!

# Test Test_gp
# cd test_gp   (From base dir)
# ./App.client Enclave.eapp_riscv eyrie-rt

[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0xb8000000-0xb8400000 (4096 KB) (boot.c:128)
[debug] FREE: 0xb81dd000-0xb8400000 (2188 KB), va 0xffffffff001dd000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
main start
TEE_GenerateRandom(0x000000003FFFFEE0, 16): start
@random: 5c066e270ed690d9f1f0a3ba094def05
TEE_GetREETime(): start
@GP REE time 241 sec 936 millis
TEE_GetSystemTime(): start
@GP System time 1312074212 sec 5 millis
TEE_CreatePersistentObject(): start
TEE_WriteObjectData(): start
TEE_CloseObject(): start
TEE_OpenPersistentObject(): start
TEE_ReadObjectData(): start
TEE_CloseObject(): start
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232
425262728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f50
515253545556575859 5a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7
d7e7f808182838485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9
aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d
6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
```

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```
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFD88, 32): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFED0, 16): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: 50b5316159d5e023fec5006a079f11117cc82d59e3888ee815cae300b9d7def43fb05ec75912e6e0068
a5fad284797bc61412db0b6395eb1403fd8dd5d81241654811d0e0ed6a52471dcd4958395b669f72b2ee2ab55585
4cd4772c4e4c5b1224c345e1a2b161e048c82e28950220c757ce05cb5339b92d88dc3a8d8318ce0b0280c94c15b7
779bcc456515176a11df946a91c40c124035a475074108f8c819d571384cff43a70fcae958ab6438fbec47bf1585
7b6b1b1ca98edcd8bc88140a6956a62a164e4da1b76f1e36e62402ec6cb6214f1a9b1ed9fbf0505454de33efdde3
71952be81fee1ac47e07203d41ea10024aca056d3010c01d0b1c792851cd7
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526
2728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f5051525354
55565758595a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182
838485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0
b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcddde
dfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFC68, 32): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFEC8, 16): start
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: 5fbd1a14a83504ef595f73c6af425023ec6e6aca5ffb47b2b88666ddb7f8cf17ce32486e1efa7d09a53
369024e936eb9312431ed341feaed8cead7e985fea9baa72092cfd8e1955cd9428dd13fb48431aeae6fef34d200b
7b3e7bd25352e9c2a705a9d1570caf6019ca157f05ce9adec42c313a54162194a691d015564d7199b2f7e3ebf9d5
98ce408a930cf83d50924dcde08a57e110820bbad531612d3730138ca025c209f5ac285625001faffd4344ea3a72
a85d46295de4ca573d1ff8f21754d1faa550ad12f32aa4885f5acaeed96cc795d99768c884402e3462041bd596dd
d676dc154a7ca0c7d654a8670aec8e23486ec9e1897543d754476472fd04e
@tag: 9b8bd6ab05b44879079b894835aaedf1
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262
728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455
565758595a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838
485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2
b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e
1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFE28, 32): start
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: 3b018bbf24235c4c367c276beafbf4dcec071ab885b37f3096081e98e8cb03fb97bb637d21c98fc0d60
06fb082d2a8690d6fa8c0fb2ae666670883b83bd27107
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
TEE_FreeOperation(): start
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
```

6.3.2 Building ta-ref for OP-TEE with docker

Following commands are to be executed on Ubuntu 20.04.

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```
# Clone the ta-ref repo and checkout teep-master branch
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref/
$ git checkout teep-master

# Sync and update the submodules
$ git submodule sync --recursive
$ git submodule update --init --recursive

# Start the docker
$ docker run -it --rm -v $(pwd):/home/user/ta-ref aistcpsec/tee-dev:optee-3.10.0
```

After you start the docker command, you will be logged-in inside the docker container. Following are the commands to be executed inside the docker

```
# [Inside docker image]

$ cd ta-ref/
$ source env/optee_qemu.sh

# Build test_hello directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_hello

# Build test_gp directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_gp
```

By the above steps, we have successfully built the ta-ref. Below we are going to push it into qemu and test its working

Test the built test_hello, test_gp binaries in Qemu

```
# Extract the rootfs.cpio.gz into a directory
$ cd ${OPTEE_OUTBR_DIR}/images
$ rm -rf rootfs && mkdir rootfs && cd rootfs
$ gzip -dc ../rootfs.cpio.gz | sudo cpio -i

# Copy the test binaries into the extracted directory
# Create test directories inside root folder and copy the binaries - TEST_HELLO
$ export OPTEE_TEST_HELLO_DIR=${OPTEE_OUTBR_DIR}/images/rootfs/root/test_hello
$ sudo mkdir ${OPTEE_TEST_HELLO_DIR}
$ sudo cp ~/ta-ref/test_hello/optee/App/optee_ref_ta ${OPTEE_TEST_HELLO_DIR}
$ sudo cp ~/ta-ref/test_hello/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
      ${OPTEE_TEST_HELLO_DIR}

# Create test directories inside root folder and copy the binaries - TEST_GP
$ export OPTEE_TEST_GP_DIR=${OPTEE_OUTBR_DIR}/images/rootfs/root/test_gp
$ sudo mkdir ${OPTEE_TEST_GP_DIR}
$ sudo cp ~/ta-ref/test_gp/optee/App/optee_ref_ta ${OPTEE_TEST_GP_DIR}
$ sudo cp ~/ta-ref/test_gp/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
      ${OPTEE_TEST_GP_DIR}
$ sudo cp ~/ta-ref/test_gp/optee/Enclave/Enclave.nm ${OPTEE_TEST_GP_DIR}

# Re-pack the rootfs folder into a cpio archive
$ cd ${OPTEE_OUTBR_DIR}/images/rootfs
$ sudo find . | sudo cpio -o -H newc 2> /dev/null | gzip -c9 > ../rootfs.cpio.gz

# Start the Qemu console from $OPTEE_DIR/build directory
$ ln -sf /home/user/optee/out-br/images/rootfs.cpio.gz /home/user/optee/out/bin
$ cd /home/user/optee/out/bin && \
    /home/user/optee/qemu/aarch64-softmmu/qemu-system-aarch64 \
        -nographic \
        -serial mon:stdio -serial file:serial1.log \
        -smp 2 \
        -machine virt,secure=on -cpu cortex-a57 \
        -d unimp -semihosting-config enable,target=native \
        -m 1057 \
        -bios bl1.bin \
        -initrd rootfs.cpio.gz \
        -kernel Image -no-acpi \
        -append "console=ttyAMA0,38400 keep_bootcon root=/dev/vda2"
# If you face any error like
# qemu-system-aarch64: keep_bootcon: Could not open 'keep_bootcon': No such file or directory
# Just replace the double quotes in the last line with single quotes.
# When asked for builroot login, please enter root
# buildroot login: root

# Inside Qemu run the steps to test test_hello and test_gp
# Test test_hello
$ cd test_hello/
```

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```
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /lib/optee_armtz/
$ ./optee_ref_ta

--- enclave log start---
ecall_ta_main() start
hello world!
ecall_ta_main() end
--- enclave log end---
#

# Test test_gp
$ cd ../test_gp/
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /lib/optee_armtz/
$ ./optee_ref_ta

start TEEC_InvokeCommand
--- enclave log start---
ecall_ta_main() start
@random: 3efa2690dc1857e1a45ee256fac75917
@GP REE time 1643004179 sec 669 millis
@GP System time 71 sec 804 millis
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f2021222
32425262728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e
4f505152535455565758595a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797
a7b7c7d7e7f808182838485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5
a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d
1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfc
fdfeff
verify ok
hash: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@cipher: 1a5004415312bf2ae919686a94aeaed65bc44a84724c12871945636443f03236104e406a12d5dc1
78b20a797b00fc38e42338e748ea60add29bbfc9c4253db4768114e019ed632408009a05cf21191e74faba54
4510290fca5cccc16e1befdf456c73c4e564adbde6704b4a8d8ef9d910bb0cd38653ab04eba9aa332abd2274
b6e5ea01563ff604f2ce4e7b11495b264bf9b6fd2692c609186f3413f8b893ea0b1c826f6d74da8dcb92d6d2
367ec0dfd1874c5e9f226e6f08a3a81431d944a35c46023f72dc2538f71dcd831282111b716723b4a178fa92
5bd901474b7392c5f7a06c0ecb7ce975677369eebeffbcfed4aa8b08d4974241ba9df0008f061395d
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f2021222324
25262728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f50
515253545556575859 5a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c
7d7e7f808182838485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8
a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4
d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@cipher: 0d3296d0049822159014b5cf781415ac6c43a57cf7d1e61abbc54eca7a802cd47c4b9f470017eff
d2511b310b3e1bf5093a52a0a2370ac354cd97cd984bb5cf7fdeba3009b69fbded49ac8789a4ada774436807
fe8452888fbf26eee36332894be13e7ff1ea60e02dfcc9b43a39c0088be43a871a342c1199638599 36c8bbce
4ffc215c1d7115d28fa2fef08cdca0e38131e967824ffa30a072ba8f7d66d2795e19beb08e32ffaf2b2a92d8
2a0b3ef796cbb1c290512963617abb5ecc31f14747e204057e3a90ad3e561efba681d58e0b7bb69c5a6a5250
c892bceb3dfc9d8c79e644a7aa234c4f5e7d94fb4867bd97d6dc8f26443345995802a9a320a64c22b
@tag: a38fd49dc4c3f453f35db8af29d8e371
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f2021222324
25262728292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f50
515253545556575859 5a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c
7d7e7f808182838485868788898a8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8
a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4
d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@digest: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@signature: a43c693ccede4504bc921c41ad9c937cd5ed3bab2494a72079f51deffb4d32d3840f55e699aa3
ec092e033efd4662bb702c6de4cb338f65bd015647d5a10bc62
@@TEE_FreeOperation:
verify ok
ecall_ta_main() end

--- enclave log end---
res = TEEC_SUCCESS; TEEC_InvokeCommand succeeded!
#
```

6.3.3 Building ta-ref for Intel SGX with docker

Following commands are to be executed on Ubuntu 20.04.

```
# Clone the ta-ref repo and checkout teep-master branch
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref/
$ git checkout teep-master

# Sync and update the submodules
$ git submodule sync --recursive
$ git submodule update --init --recursive
```

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```
# Start the docker
$ docker run -it --rm -v $(pwd):/home/user/ta-ref aistcpsec/tee-dev:sgx-2.10
```

Commands to be executed inside docker:

```
$ cd ta-ref/

# Source SGX environment variables
$ source /opt/intel/sgxsdk/environment
$ source env/sgx_x64.sh

# Build test_hello directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_hello

# Build test_gp directory
$ make build test-bin MACHINE=SIM TEST_DIR=test_gp
```

By the above steps, we have successfully built the ta-ref. Since we are building in SIM mode, We can execute in docker itself.

There are two files required to test_hello 1) ./sgx_app 2)enclave.signed.so copy the files into a directory and then execute the ./sgx_app command

Test the built test_hello, test_gp binaries in Docker SIM mode

Make sure test_hello is already built in SIM mode. [Inside /home/user directory]

Test_hello:

```
$ cd
$ mkdir test_hello

# Copy the sgx_app for test_hello
$ cp ta-ref/test_hello/sgx/App/sgx_app test_hello/
# Copy the enclave
$ cp ta-ref/test_hello/sgx/Enclave/enclave.signed.so test_hello/

# Change to test_hello
$ cd test_hello/

# Run the program
$ ./sgx_app
# [trimmed output]
hello world!
Info: Enclave successfully returned.
```

Test_gp:

Make sure test_hello is already built in SIM mode. [Inside /home/user directory]

```
$ cd
$ mkdir test_gp

# Copy the sgx_app for test_gp
$ cp ta-ref/test_gp/sgx/App/sgx_app test_gp/
# Copy the enclave
$ cp ta-ref/test_gp/sgx/Enclave/enclave.signed.so test_gp/

# Change to test_gp
$ cd test_gp/

# Run the program
$ ./sgx_app
# [trimmed output]
main start
TEE_GenerateRandom(): start
@random: 59af0039e8013fd0cc698c4115b682a3
TEE_GetREETime(): start
request to get unix time 1642994685, 852
@GP REE time 1642994685 sec 852 millis
TEE_GetSystemTime(): start
```

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```
@GP System time 2624667013 sec 537 millis
TEE_CreatePersistentObject(): start
request to open FileOne flags 241 -> 3
TEE_WriteObjectData(): start
request to write 256 bytes to descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
TEE_OpenPersistentObject(): start
request to open FileOne flags 0 -> 3
TEE_ReadObjectData(): start
request to read 256 bytes from descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728
292a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f5051525354555657585 9
5a5b5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a
8b8c8d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babb
bcbdbebfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebec
edeeeff0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: 8fc07ed506c8616090c591ada2836179ba21c2b2d79f87600f57d64b489846808f0d0609a808c1184f37c5766
a0d92bc3d0db2d2644b788ae4ba4d2b7073757f6c948611a1163b166a6491aceefbab9f1655a754a610e3ffea5d7e8eac1
936399eaa91e0b2a804788996ebbda7d98988dec8458038c23ab4b2ec7c51eff0f04da2b5c5023b63093aa6b4181b5d2b3
fe724aa3ac9eaeb557bfeef4bec0dbba9f000e877641b60cf450a15b9fda70526f1023e7889607d5d8b4a9e559f6e2779c
925fd997d9431820c3d30593eabd3fd1b80d6ece5cb54edacac0560363546e9d330add6cb2c0daeb843eddfb299eeca505
298ae1a5100e58a46bce4502745a5ed
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f10111213141516171819 1a1b1c1d1e1f2021222324252627282 92
a2b2c2d2e2f303132333435363738393a3b3c3d3e3f40414243444546474849 4a4b4c4d4e4f505152535455565758595a5b
5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8
d8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbe
bfc0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff
0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: db9dbbc85217721dc3b7901f18bb90dff2f23044f34b932805ef4f36be6602122b61281074fb483f4710d7e1576
a67a2377c5ea13fb976ae041b0cec9d49e60cd6cfa869c0700ffff54a02c8b22f11add2824d5f7fb4898cb28a269db083cd8
d49c6183691202eafa5b81d0167b7f46df3c51a28ed4dc146321a909d624d34fe64ee38189617f9f2df636f7e77a79cc105b
ad81a64b3a756c092d4f8d4f78c302d8411952bdb3fee378f4c12c51b6158b6b633c9cffc3c0dab4cad0aa3a63036e420437
45bf04eb9c2e852bfcc3dc0ff1dfb516c62aa12f0bc2e01073ff1198f0d9d85c7e2d1c52f321cca5536fef8f7be661fd3ce2
466ba20c17214bba2eb62
@tag: b462f462e0b7eb0382cd2eba81d976d5
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a2
b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c5d
5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e8f9
091929394959697989 99a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0c1c2
c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2f3f4f
5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
```

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```
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: 62077f18091b203c70318ad9830e41a947aa644208cfedd3dc3889b6321738dafd15f1f3dc531128672da50a5d
88f5dd82d09f026be004c8d6f41a8dbc80da04
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
TEE_FreeOperation(): start
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
Info: Enclave successfully returned.
```

7 Preparation before building ta-ref without Docker

All the preparation steps below are based on Ubuntu 20.04

7.1 Keystone(RISC-V Unleased)

Keystone is an open-source TEE framework for RISC-V processors. For more details check,

- http://docs.keystone-enclave.org/en/latest

7.1.1 Required Packages

Install the following packages for building ta-ref on Keystone

```
$ sudo apt-get update
# Following packages are required for Keystone
$ sudo apt-get install -y autoconf automake autotools-dev bc bison \
  build-essential curl expat libexpat1-dev flex gawk gcc git gperf libgmp-dev \
  libmpc-dev libmpfr-dev libtool texinfo tmux patchutils zlib1g-dev wget \
  bzip2 patch vim-common lbzip2 python pkg-config libglib2.0-dev libpixman-1-dev \
  libssl-dev screen device-tree-compiler expect makeself unzip cpio rsync cmake \
  p7zip-full
# Following packages are required for clang, keyedge and make run commands in ta-ref.
$ sudo apt-get install -y clang-tools-6.0 libclang-6.0-dev cmake \
    ocaml expect screen sshpass
```

7.1.2 Download RISC-V toolchain and Keystone SDK

Download the keystone sources

```
$ git clone https://github.com/keystone-enclave/keystone.git -b v1.0.0
$ cd keystone
$ ./fast-setup.sh
$ source ./source.sh
```

After executing the `./fast-setup.sh`, the toolchain for RISC-V has been installed at `keystone/riscv/bin` and it adds to your PATH.

Make the following changes to increase the max edge calls

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```
sed -i 's/MAX_EDGE_CALL 10$/MAX_EDGE_CALL 1000/' <keystone_dir>/sdk/include/edge/edge_common.h
```

Build the Keystone SDK

Make sure you are in keystone directory.

```
$ cd sdk/
$ mkdir -p build
$ cd build
$ cmake .. $SDK_FLAGS
$ make
$ make install
```

Build the Qemu Image

Make sure you are in `keystone` directory.

```
$ mkdir -p build
$ cd build
$ cmake ..
$ make
$ make image
```

Launch the QEMU image

Make sure you are in `keystone\build` directory.

```
$ ./scripts/run-qemu.sh
Welcome to Buildroot
```

Login to console with the following credentials

buildroot login = root, Password = sifive

```
buildroot login: root
Password:
$
```

Poweroff the console incase, if you want to exit.

```
$ poweroff
```

You can also use `CTRL^A + X` to exit Qemu Console.

7.1.3 Run Keystone examples

Run the following commands to generate hello world example programs to be executed on qemu.

Make sure you are in `keystone\build` directory.

```
$ make hello-package
$ cp -r examples/hello ./overlay/root/
# Update the image
$ make image
```

Launch QEMU console

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```
$ ./scripts/run-qemu.sh
Welcome to Buildroot
```

Login to console with user=root, passwd=sifive

```
buildroot login: root
Password:
$
```

Run hello example

```
$ insmod keystone-driver.ko
[  365.354299] keystone_driver: loading out-of-tree module taints kernel.
[  365.364279] keystone_enclave: keystone enclave v0.2
$ ./hello/hello.ke
Verifying archive integrity...  100%   All good.
Uncompressing Keystone vault archive  100%
hello, world!
```

You can also run the tests by executing `./tests.ke`

Poweroff the console incase, if you want to exit.

```
$ poweroff
```

7.2 OP-TEE (ARM64 Raspberry Pi 3 Model B)

OP-TEE is a Trusted Execution Environment (TEE) designed as companion to a non-secure Linux kernel running on Arm. Lets build OP-TEE for QEMU and Raspberry Pi3 Model B development board. For more details check,

- https://optee.readthedocs.io/en/latest/

7.2.1 Required Packages

Install the following packages

```
$ sudo dpkg --add-architecture i386
$ sudo apt-get update -y
$ sudo apt-get install -y android-tools-adb android-tools-fastboot autoconf \
  automake bc bison build-essential ccache cscope curl device-tree-compiler \
  expect flex ftp-upload gdisk iasl libattr1-dev libc6:i386 libcap-dev \
  libfdt-dev libftdi-dev libglib2.0-dev libhidapi-dev libncurses5-dev \
  libpixman-1-dev libssl-dev libstdc++6:i386 libtool libz1:i386 make \
  mtools netcat python python-crypto python3-crypto python-pyelftools \
  python3-pycryptodome python3-pyelftools python3-serial vim-common \
  rsync unzip uuid-dev xdg-utils xterm xz-utils zlib1g-dev \
  git python3-pip wget cpio texlive texinfo locales
```

Set the locale to English, to cope with the problem, https://github.com/OP-TEE/build/issues/424#issuecomment-631302208.

```
$ locale-gen en_US.UTF-8
$ export LANG=en_US.UTF-8
$ export LANGUAGE=en_US:en
$ export LC_ALL=en_US.UTF-8
```

7.2.2 Download and build OP-TEE Toolchains 3.10.0

Create the directory to build the OP-TEE toolchains and export the toolchain directory

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```
$ mkdir -p /opt/arm-tc
$ export TOOLCHAIN_DIR=/opt/arm-tc
```

Clone and build the OP-TEE toolchain

```
$ git clone https://github.com/OP-TEE/build.git -b 3.10.0
$ cd build
$ sudo make TOOLCHAIN_ROOT=${TOOLCHAIN_DIR} -f toolchain.mk -j2
$ export PATH=${TOOLCHAIN_DIR}/aarch64/bin;${TOOLCHAIN_DIR}/aarch32/bin;${PATH}
```

7.2.3 Download OP-TEE 3.10.0

Install Androi repo to sync the OP-TEE repo

```
$ sudo git config --global user.name "dummy" && \
  sudo git config --global user.email "dummy@gmail.com" && \
  sudo git config --global color.ui false && \
  mkdir ~/bin && \
  curl https://storage.googleapis.com/git-repo-downloads/repo > ~/bin/repo && \
  chmod a+x ~/bin/repo
$ export PATH=$~/bin:${PATH}
```

Get the source code for optee

```
$ mkdir optee && cd optee
$ export OPTEE_DIR=$(pwd)
$ repo init -u https://github.com/OP-TEE/manifest.git -m qemu_v8.xml -b 3.10.0
$ repo sync -j4 --no-clone-bundle
```

7.2.4 Build OP-TEE 3.10.0

```
$ cd ${OPTEE_DIR}/build
$ ln -s ${TOOLCHAIN_DIR} ${OPTEE_DIR}/toolchains
$ make TOOLCHAIN_ROOT=${TOOLCHAIN_DIR} -j`nproc`
```

If build is successfull, the rootfs can be found as follows

```
$ ls -l ${OPTEE_DIR}/out-br/images/rootfs.cpio.gz
```

7.2.4.1 Clone and Build OP-TEE v3.9.0 for RPI3

Copy the following lines into "optee-rpi3.sh" script

```
#!/bin/bash -u
export OPTEE_VER=$1
export OPTEE_DIR=${PWD}/optee_${OPTEE_VER}_rpi3
mkdir ${OPTEE_DIR} || true
cd ${OPTEE_DIR}
~/bin/repo init -u https://github.com/knknkn1162/manifest.git -m rpi3.xml -b ${OPTEE_VER}
~/bin/repo sync -j4 --no-clone-bundle
ln -s ~/toolchains ${OPTEE_DIR}/. || true
echo 'CONFIG_CMDLINE="console=ttyAMA0,115200 kgdboc=ttyAMA0,115200 root=/dev/mmcblk0p2
      rootfstype=ext4 noinitrd rw rootwait init=/lib/systemd/systemd"' > build/defconfig-cmdline.txt
cd build
make OPTEE_CLIENT_BIN_ARCH_EXCLUDE=/boot
    LINUX_DEFCONFIG_COMMON_FILES="${OPTEE_DIR}/linux/arch/arm64/configs/bcmrpi3_defconfig
    ${OPTEE_DIR}/build/kconfigs/rpi3.conf ${OPTEE_DIR}/build/defconfig-cmdline.txt"
       BR2_PACKAGE_OPTEE_OS_EXT=n BR2_PACKAGE_OPTEE_TEST_EXT=n
    BR2_PACKAGE_OPTEE_EXAMPLES_EXT=n BR2_TOOLCHAIN_EXTERNAL_GCC_8=y BR2_TOOLCHAIN_EXTERNAL_HEADERS_4_19=y
       BR2_HOST_GCC_AT_LEAST_8=y
    BR2_TOOLCHAIN_HEADERS_AT_LEAST="4.19" -j'nproc'
```

Run the script as follows

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```
$ chmod +x optee-rpi3.sh
$ ./optee-rpi3.sh 3.9.0
```

If build is successfull, the rootfs can be found as follows

```
$ ls -l ../out-br/images/rootfs.cpio.gz
```

7.2.5 Run OP-TEE Examples

7.2.5.1 Launching QEMU Console

Run following commands from OP-TEE build directory

```
$ cd $OPTEE_DIR/build
$ make run
```

Once above command is success, QEMU is ready

```
* QEMU is now waiting to start the execution
* Start execution with either a 'c' followed by <enter> in the QEMU console or
* attach a debugger and continue from there.
*
* To run OP-TEE tests, use the xtest command in the 'Normal World' terminal
* Enter 'xtest -h' for help.
cd /TEE/demo/rpi3/optee_3.9.0_qemu/build/../out/bin
     && /TEE/demo/rpi3/optee_3.9.0_qemu/build/../qemu/aarch64-softmmu/qemu-system-aarch64 \
    -nographic \
    -serial tcp:localhost:54320 -serial tcp:localhost:54321 \
    -smp 2 \
    -s -S -machine virt,secure=on -cpu cortex-a57 \
    -d unimp -semihosting-config enable,target=native \
    -m 1057 \
    -bios bl1.bin \
    -initrd rootfs.cpio.gz \
    -kernel Image -no-acpi \
    -append 'console=ttyAMA0,38400 keep_bootcon root=/dev/vda2' \
    -object rng-random,filename=/dev/urandom,id=rng0 -device virtio-rng-pci,rng=rng0,max-bytes=1024,
        period=1000 -netdev user,id=vmnic -device virtio-net-device,netdev=vmnic
QEMU 3.0.93 monitor - type 'help' for more information
(qemu) c
Now Optee started to boot from another tab on the Terminal
```

7.2.5.2 Run hello world example

Once boot completed it displays following message, then enter "root" to login to the shell

```
Welcome to Buildroot, type root or test to login
buildroot login: root
$
$ optee_example_hello_world
Invoking TA to increment 42
TA incremented value to 43
```

Poweroff the console in case, if you want to exit.

```
$ poweroff
```

7.3 SGX (Intel NUC)

Intel(R) Software Guard Extensions (Intel(R) SGX) is an Intel technology for application developers who is seeking to protect selected code and data from disclosure or modification. For more details check,

- https://github.com/intel/linux-sgx/blob/master/README.md

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7.3.1 List of machines which are confirmed to work

1. Intel NUC7PJYH - Intel(R) Celeron(R) J4005 CPU @ 2.00GHz
2. Intel NUC7PJYH - Intel(R) Pentium(R) Silver J5005 CPU @ 1.50GHz
3. Intel NUC9VXQNX - Intel(R) Xeon(R) E-2286M CPU @ 2.40GHz (Partially working)

7.3.2 BIOS Versions which are failed or scucceeded in IAS Test

1. BIOS Version JYGLKCPX.86A.0050.2019.0418.1441 - IAS Test was Failed
2. BIOS Version JYGLKCPX.86A.0053.2019.1015.1510 - IAS Test was Failed
3. BIOS Version JYGLKCPX.86A.0057.2020.1020.1637 - IAS Test was Success
4. BIOS Version QNCFLX70.0034.2019.1125.1424 - IAS Test was Failed
5. BIOS Version QNCFLX70.0059.2020.1130.2122 - IAS Test was Success

Update BIOS from:

- https://downloadcenter.intel.com/download/29987/BIOS-Update-JYGLKCPX-
- https://downloadcenter.intel.com/download/30069/BIOS-Update-QNCFLX70-

7.3.3 BIOS Settings

1. Make sure you are running with latest version BIOS
2. Make sure you enabled SGX support in BIOS
3. Make sure `Secure Boot` disabled in BIOS

Refer: https://github.com/intel/sgx-software-enable/blob/master/README.md

7.3.4 Required Packages

Intall following packages on Ubuntu 18.04

```
$ sudo apt-get install build-essential ocaml ocamlbuild automake autoconf libtool wget python
       libssl-dev git cmake perl libssl-dev libcurl4-openssl-dev protobuf-compiler libprotobuf-dev
       debhelper cmake reprepro expect unzip sshpass
```

7.3.5 Build SGX

There are 3 components which need to be build for SGX

1. linux-sgx
2. linux-sgx-driver
3. sgx-ra-sample

7.3.5.1 SGX SDK

Clone and build

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```
$ git clone https://github.com/intel/linux-sgx.git -b sgx_2.10
$ cd linux-sgx
$ git checkout sgx_2.10
$ ./download_prebuilt.sh
$ sudo cp external/toolset/ubuntu18.04/{as,ld,ld.gold,objdump} /usr/local/bin/
$ make -j`nproc` sdk_install_pkg DEBUG=1
```

Install SGX SDK

```
$ sudo ./linux/installer/bin//sgx_linux_x64_sdk_${version}.bin
```

where ${version} is a string something similar to 2.10.100.2.
Answer the question with `no` and input the install dir as `/opt/intel`

Build and Install SGX PSW packages
See here: https://github.com/intel/linux-sgx#install-the-intelr-sgx-psw

```
$ source /opt/intel/sgxsdk/environment
$ make deb_psw_pkg DEBUG=1
$ rm ./linux/installer/deb/*/*sgx-dcap-pccs*.deb
$ sudo dpkg -i ./linux/installer/deb/*/*.deb
```

Install SGX PSW packages from Intel Repository

See here: https://github.com/intel/linux-sgx#install-the-intelr-sgx-psw-1
Using the local repo is recommended, since the system will resolve the dependencies automatically.
Check at page no.7, https://download.01.org/intel-sgx/sgx-linux/2.9/docs/Intel_↩SGX_Installation_Guide_Linux_2.9_Open_Source.pdf

```
$ sudo apt install libsgx-enclave-common libsgx-epid libsgx-launch libsgx-urts libsgx-uae-service
       libsgx-quote-ex
```

If you see below error,

```
Errors were encountered while processing:
 /tmp/apt-dpkg-install-pCB0cR/04-libsgx-headers_2.12.100.3-bionic1_amd64.deb
```

Here is the fix

```
$ sudo apt -o Dpkg::Options::="--force-overwrite" --fix-broken install
```

7.3.5.2 Build and Install SGX Driver

See `linux-sgx-driver`.

Caveat: Whenever updating kernel, don't forget rebuilding this driver with new version of the kernel header. (There are a few linux-sgx-driver-dkms repo, though I've experianced troubles with them.)

Clone and build

```
$ git clone https://github.com/intel/linux-sgx-driver.git
$ cd linux-sgx-driver
$ make
```

Install SGX driver

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```
$ sudo mkdir -p "/lib/modules/"`uname -r`"/kernel/drivers/intel/sgx"
$ sudo cp isgx.ko "/lib/modules/"`uname -r`"/kernel/drivers/intel/sgx"
$ sudo sh -c "cat /etc/modules | grep -Fxq isgx || echo isgx » /etc/modules"
$ sudo /sbin/depmod
$ sudo /sbin/modprobe isgx
```

When modprove fails with "Operation is not permitted", disable `secure boot` in BIOS. So that the unsigned kernel driver can be installed. If it is success, reboot your machine and verify `sudo lsmod | grep isgx` if it shows `isgx.ko`

7.3.6 Run sgx-ra-sample

7.3.6.1 Build sgx-ra-sample Clone and build OpenSSL 1.1.c

```
$ wget https://www.openssl.org/source/openssl-1.1.1c.tar.gz
$ tar xf openssl-1.1.1c.tar.gz
$ cd openssl-1.1.1c/
$ ./config --prefix=/opt/openssl/1.1.1c --openssldir=/opt/openssl/1.1.1c
$ make
$ sudo make install
$ cd ..
```

Clone and build sgx-ra-sample

```
$ git clone https://github.com/intel/sgx-ra-sample.git
$ cd sgx-ra-sample/
$ ./bootstrap
$ ./configure --with-openssldir=/opt/openssl/1.1.1c
$ make
```

7.3.6.2 Prepare for IAS Test

1. Obtain a subscription key for the Intel SGX Attestation Service Utilizing Enhanced Privacy ID (EPID). See here: https://api.portal.trustedservices.intel.com/EPID-attestation
2. Download Intel_SGX_Attestation_RootCA.pem form above portal.
3. Edit `settings` file and update the file with your own values obtained from portal.

```
@@ -15,14 +15,14 @@ QUERY_IAS_PRODUCTION=0
 # Your Service Provider ID. This should be a 32-character hex string.
 # [REQUIRED]

-SPID=0123456789ABCDEF0123456789ABCDEF
+SPID=EF9AE4A8635825B88751C8698CB370B4


 # Set to a non-zero value if this SPID is associated with linkable
 # quotes. If you change this, you'll need to change SPID,
 # IAS_PRIMARY_SUBSCRIPTION_KEY and IAS_SECONDARY_SUBSCRIPTION_KEY too.

-LINKABLE=0
+LINKABLE=1

 #===========================================================================
@@ -50,18 +50,18 @@ USE_PLATFORM_SERVICES=0
 # More Info: https://api.portal.trustedservices.intel.com/EPID-attestation
 # Associated SPID above is required

-IAS_PRIMARY_SUBSCRIPTION_KEY=
+IAS_PRIMARY_SUBSCRIPTION_KEY=b6da4c9c41464924a14954ad8c03e8cf

 # Intel Attestation Service  Secondary Subscription Key
```

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```
 # This will be used in case the primary subscription key does not work

-IAS_SECONDARY_SUBSCRIPTION_KEY=
+IAS_SECONDARY_SUBSCRIPTION_KEY=188d91f86c064deb97e7472175ae1e79

 # The Intel IAS SGX Report Signing CA file. You are sent this certificate
 # when you apply for access to SGX Developer Services at
 # http://software.intel.com/sgx [REQUIRED]

-IAS_REPORT_SIGNING_CA_FILE=
+IAS_REPORT_SIGNING_CA_FILE=./Intel_SGX_Attestation_RootCA.pem

 # Debugging options
@@ -82,7 +82,7 @@ IAS_REPORT_SIGNING_CA_FILE=

 # Set to non-zero for verbose output

-VERBOSE=0
+VERBOSE=1
```

7.3.6.3 Run IAS Test

Run "run-server"

```
$ ./run-server
Listening for connections on port 7777
Waiting for a client to connect...
Connection from 127.0.0.1
Waiting for msg0||msg1
---- Copy/Paste Msg2 Below to Client -----------------------------------------
44f2e22125f052e0118018febceefd469f1f4b73de22b34ebdf27003605963946bb862980be691a2f532d8e66abb2ce4eaad
f778593b1ce7a14b2759f133beceef9ae4a8635825b88751c8698cb370b401000100fbb75d7ce414edc45510aa87a7547ffb
a65415fca10e83c0936729c2abfb6c2687ee6dde5c6540a835fae6032bbfaf9f8eaefbcfafcf606e94ece103d82ecc82a457
a16692d4023dad4e4fee38fb20d00000000
--------------------------------------------------------------------------------
Waiting for msg3
+++ POST data written to /tmp/wgetpostwnMRxU
---- Copy/Paste Msg4 Below to Client -----------------------------------------
030000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000
--------------------------------------------------------------------------------
Waiting for a client to connect...
```

Open another terminal and run "run-client"

```
$ ./run-client
---- Copy/Paste Msg0||Msg1 Below to SP ----------------------------------------
00000000a7fa6ed63bec97891885abc2e2e80bd4bb2bd5bb32a7e142337f486bb9f6e76a9db59aa9
aaac50cd24c3625451a79bce7c51e24447981444cf51666f3b61cd0cfb0b0000
--------------------------------------------------------------------------------
Waiting for msg2
---- Copy/Paste Msg3 Below to SP ----------------------------------------------
787d992031b5ed7d57f149aec7f04912a7fa6ed63bec97891885abc2e2e80bd4bb2bd5bb32a7e142337f486bb9f6e76a9db5
9aa9aaac50cd24c3625451a79bce7c51e24447981444cf51666f3b61cd0c000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000002000100fb0b00000b000a000000
0000ef9ae4a8635825b88751c8698cb370b400000000000000000000000000000000303000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000700000000000000300000000000000188d
d04a51cc90bf27ca2e733a3a97557dcaabff3e2d037d11a1d0680c8f22c1000000000000000000000000000000000000000
000000000000000000000000bd71c6380ef77c5417e8b2d1ce2d4b6504b9f418e5049342440cfff2443d95bd0000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000100000000000000
000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000ab2e17de92aadea169f418e9266ea4e79b393f0028754ed46c6e538d3aed1e5a000000000000000000000000000000
000000000000000000000000000000000a80200007657efd8ff80410670f40aba48cc5a0c61aa70a3c656f021c28104503
9ea3c16f5831825fd3405eb6090d70a6e87853374eefb690285367ac35f471df09571fda8f96de9e2067f6f7c12fa97a4f06
5311e71d01cd97a89c93c9ba9b0d02d56723f67a51ee742974c46d05e313db18826f6b4183a83a421b0df4b6c3a059b814a3
7d6b905f28422076e41d23016b22d1ec2ea5712c6bc470070313d8d50f6968b97e1ca65524ec677191b5ccb5c14e9629efc1
e1e1cc6e87388143712c1f15593ec5fdea02ce426139c461cfd6cc63025124ed5ea5c0160fdb59ea65e97449d44d78355018
c54f11290930d8464096723fc0e25421fb0849a156ce0af973af0324a86bdb583501f0779e86d108afef02faa6c73c6d6035
e8d4c8ba3478ca58779dd26f015d31dff046e8d74fe680100004af4eed5e48babde1db56dc88ab96a689de24c33ad955ca33
86d9bf9fb842d2ef2f09883e9dead7e5c58c841181e987599532e769b3e1445a570c7b7fc5d866906d5064770919001a47b3
f4dde0635451047a0d1fc8a3971525866fa07da59e3cce44e71eba19a8a00e265ecc04dc5529a942afe6dd222045e746411c
```

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```
d4c89541a432de0c7464ba8d54e775f1530098a3fc4876c140028e12edcd0e3df1b176271f74207b54b0bd76a9d4b3549f8b
b950a492a64a4949eeaa8192432d99eabebd46eb56507a675c184de8ee6c53461753cf123bb9e26ddfb8422e4c130efe7c5d
f3f328cb02945bfa575f79e376d9aac40da397e9cdcb449f223842bec9e07e4b2c736409ed964799ac9cf51a71f0cbdf91f9
4bd362e761ae35ed27d2872112caf2476846e397141106d9898b96295fa969dbd9b48c7dd8f27c5ba1bb1d6bb202aad86346
695c8f18efe073e9424382f3f73757ee99e95c30da5dd47d94185eda2b97613b0872a622c58f4f2dd91d1e4d876ac8e40a18
60a
------------------------------------------------------------------------------
---- Enclave Trust Status from Service Provider ----------------------------
Enclave TRUSTED
```

7.3.6.4 Possible wget Error

Server may invoke wget command to get some files from intel servers. If the server side fails with following error

```
Connecting to api.trustedservices.intel.com (api.trustedservices.intel.com)|40.87.90.88|:443...
       connected.
ERROR: cannot verify api.trustedservices.intel.com's certificate, issued by 'CN=COMODO RSA
       Organization Validation Secure Server CA,O=COMODO CA Limited,L=Salford,ST=Greater
       Manchester,C=GB':
  Unable to locally verify the issuer's authority.
To connect to api.trustedservices.intel.com insecurely, use '--no-check-certificate'.
```

then add a line `ca-certificate = /etc/ssl/certs/ca-certificates.crt` to /etc/wgetrc file as super user, then test again.

7.3.6.5 BIOS Updating

If BIOS version is outdated, IAS may not succeed. So when you are done with BIOS update, the sgx driver would be reqired to make and install again.

Update BIOS from:

- https://downloadcenter.intel.com/download/29987/BIOS-Update-JYGLKCPX-
- https://downloadcenter.intel.com/download/30069/BIOS-Update-QNCFLX70-

7.3.6.6 Run LocalAttestation

Running SDK code samples in simulation mode

```
$ source /opt/intel/sgxsdk/environment
$ cd linux-sgx/SampleCode/LocalAttestation
$ make SGX_MODE=SIM
$ cd bin
$ ./app
succeed to load enclaves.
succeed to establish secure channel.
Succeed to exchange secure message...
Succeed to close Session...
```

Running in hardware mode (It works when you have latest BIOS and SGX support is enabled in BIOS)

```
$ source /opt/intel/sgxsdk/environment
$ cd linux-sgx/SampleCode/LocalAttestation
$ make SGX_MODE=HW
$ cd bin
$ ./app
succeed to load enclaves.
succeed to establish secure channel.
Succeed to exchange secure message...
Succeed to close Session...
```

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7.4 Doxygen

This PDF (ta-ref.pdf) was generated using Doxygen version 1.9.2. To install `doxygen-1.9.2` following procedure is necessary.

7.4.1 Required Packages

Install following packages on Ubuntu. Its better to install from package rather than using apt-install.

```
$ sudo apt install doxygen-latex graphviz texlive-full texlive-latex-base latex-cjk-all
```

Above packages required to generate PDF using doxygen.

7.4.2 Build and Install Doxygen

```
$ git clone https://github.com/doxygen/doxygen.git
$ cd doxygen
$ mkdir build
$ cd build
$ cmake -G "Unix Makefiles" ..
$ make
$ sudo make install
```

7.5 Customizing MbedTLS Configuration file

MbedTLS is a C library that implements cryptographic primitives, X.509 certificate manipulation and the SSL/TLS and DTLS protocols. MbedTLS has a configuration file `config.h` where we can select platform-specific settings, customize the features that will be build, select the modules and its configurations.

In our case, we customize mbedtls config file to add/remove crypto algorithms when building the mbedtls. The mbedtls default config supports many cryto algorithms which might be unneccessary and also increases the built binary size.

It is advisable to reduce the size of the binaries, by selecting only the required crypto algorithms for the embedded systems.

7.5.1 What can be customized?

1. how many hash algorithms to be supported
   For ex: md5, sha1, sha256, sha3 or etc
2. how many symmetric algorithms to be supported
   For ex: des, aes-cbc, aes-gcm or etc
3. how many asymmetric algorithms to be supported
   For ex: dsa, rsa, ecdsa, eddsa or etc and their key length

7.5.2 mbedtls configuration file (config.h)

The mbedtls official way is customizing config file is by editing the `include/mbedtls/config.h` file. But in optee's build system, it require modifying
`optee_os/lib/libmbedtls/include/mbedtls_config_kernel.h`

Below are the different environments mbedtls config file locations, reference file and sample config.h configurations.

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7.5.2.1 Optee mbetls config file

Location of the config file in optee environment
`optee/mbedtls/include/mbedtls/config.h`

Have a look at the source which uses config.h file for reference.
Example source:
`optee/mbedtls/include/mbedtls/library/ssl_ciphersuites.c`

Some sample configurations can be found in `configs/` directory. In Optee, the contents of configs directory is listed below.

```
$ ls -l optee/mbedtls/configs
total 24
-rw-r--r-- 1 akirat akirat 2852 Feb 17  2021 config-ccm-psk-tls1_2.h
-rw-r--r-- 1 akirat akirat 2102 Feb 17  2021 config-mini-tls1_1.h
-rw-r--r-- 1 akirat akirat 2628 Feb 17  2021 config-no-entropy.h
-rw-r--r-- 1 akirat akirat 3573 Feb 17  2021 config-suite-b.h
-rw-r--r-- 1 akirat akirat 2680 Feb 17  2021 config-thread.h
-rw-r--r-- 1 akirat akirat 1050 Feb 17  2021 README.txt
```

7.5.2.2 ta-ref mbetls config file

Location of the config file in ta-ref environment
`ta-ref/teep-device/libteep/mbedtls/include/mbedtls/config.h`

Have a look at the source which uses config.h file for reference.
Example source:
`ta-ref/teep-device/libteep/mbedtls/include/mbedtls/library/ssl_↩ ciphersuites.c`

Some sample configurations can be found in `configs/` directory. In ta-ref, the contents of configs directory is listed below.

```
$ ls -l ta-ref/teep-device/libteep/mbedtls/configs
total 24
-rw-r--r-- 1 akirat akirat 2852 Feb 18  2021 config-ccm-psk-tls1_2.h
-rw-r--r-- 1 akirat akirat 2102 Feb 18  2021 config-mini-tls1_1.h
-rw-r--r-- 1 akirat akirat 2628 Feb 18  2021 config-no-entropy.h
-rw-r--r-- 1 akirat akirat 3573 Feb 18  2021 config-suite-b.h
-rw-r--r-- 1 akirat akirat 2680 Feb 18  2021 config-thread.h
-rw-r--r-- 1 akirat akirat 1050 Feb 18  2021 README.txt
```

7.5.2.3 teep-device mbetls config file

Location of the config file in teep-device environment
`teep-device/libteep/mbedtls/include/mbedtls/config.h`

Have a look at the source which uses config.h file for reference.
Example source:
`teep-device/libteep/mbedtls/include/mbedtls/library/ssl_ciphersuites.c`

Some sample configurations can be found in `configs/` directory. In teep-device, the contents of configs directory is listed below.

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```
$ ls -l teep-device/libteep/mbedtls/configs
total 24
-rw-r--r-- 1 akirat akirat 2852 Feb 18  2021 config-ccm-psk-tls1_2.h
-rw-r--r-- 1 akirat akirat 2102 Feb 18  2021 config-mini-tls1_1.h
-rw-r--r-- 1 akirat akirat 2628 Feb 18  2021 config-no-entropy.h
-rw-r--r-- 1 akirat akirat 3573 Feb 18  2021 config-suite-b.h
-rw-r--r-- 1 akirat akirat 2680 Feb 18  2021 config-thread.h
-rw-r--r-- 1 akirat akirat 1050 Feb 18  2021 README.txt
```

7.5.3 Supplement Investigation information

It is necessary to edit the following file to select the cryptographic algorithm when using mbedtls in optee.

In optee, AES-GCM is not included by default. So we need to modify the mbedtls config file to enable AES-GCM algorithm. Below is the path of the file in optee kernal where we will select the crypto algorithms.
`optee/optee_os/lib/libmbedtls/include/mbedtls_config_kernel.h`

Below is the path of file in TA SDK where we will select the crypto algorithms. In TA sdk, the AES-GCM is enabled by default. So any TA which uses AES-GCM should build successfully without any modification to the mbedtls config file.
`optee/optee_os/lib/libmbedtls/include/mbedtls_config_uta.h`

8 Building ta-ref without Docker

8.1 ta-ref with Keystone

Make sure Keystone and other dependant sources have been built

8.1.1 Cloning source and building

Install required packages

```
$ sudo apt-get update
$ sudo apt-get install -y clang-tools-6.0 libclang-6.0-dev cmake ocaml expect screen sshpass
```

Setup Env

```
$ export KEYSTONE_DIR=<path to your keystone directory>
$ export PATH=$PATH:$KEYSTONE_DIR/riscv/bin
```

Clone and Build KEYEDGE

```
$ GIT_SSL_NO_VERIFY=1 git clone --recursive https://192.168.100.100/rinkai/keyedge.git
$ cd keyedge
$ git checkout f9406aba2117147cc54462ede4766e26f028ced9
$ make
```

Clone and Build KEEDGER8R

```
$ GIT_SSL_NO_VERIFY=1 git clone --recursive https://192.168.100.100/rinkai/keedger8r.git
$ cd keedger8r
$ make
```

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```
$ sed -i 's/MAX_EDGE_CALL 10$/MAX_EDGE_CALL 1000/' ${KEYSTONE_DIR}/sdk/lib/edge/include/edge_common.h
$ make -C ${KEYSTONE_DIR}/sdk/lib clean all
```

Clone the source

```
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref
$ git checkout teep-device-tb-slim
$ git submodule sync --recursive
git submodule update --init --recursive
```

Build

```
$ export KEYSTONE_DIR=<path to keystone directory>
$ export KEYSTONE_SDK_DIR=$KEYSTONE_DIR/sdk
$ export KEYEDGE_DIR=<path to keyedge directory>
$ export KEEDGER8R_DIR=<path to keedger8r directory>
$ source env/keystone.sh
$ make build test-bin MACHINE=HIFIVE TEST_DIR=test_hello
$ make build test-bin MACHINE=HIFIVE TEST_DIR=test_gp
```

8.1.2 Check ta-ref by running test_gp, test_hello, on QEMU

Copy the test_hello and test_gp programs to QEMU.

8.1.2.1 Launch QEMU Console

```
$ cd $KEYSTONE_DIR
$ ./scripts/run-qemu.sh
Welcome to Buildroot
```

8.1.2.2 test_hello

Run test_hello

```
$ cp test_hello/keystone/Enclave/Enclave.eapp_riscv $KEYSTONE_DIR/buildroot_overlay/root/test_hello/
$ cp test_hello/keystone/Enclave/App.client $KEYSTONE_DIR/buildroot_overlay/root/test_hello/
$ cp $KEYSTONE_SDK_DIR/rts/eyrie/eyrie-rt $KEYSTONE_DIR/buildroot_overlay/root/test_hello/

$ insmod keystone-driver.ko
./App.client Enclave.eapp_riscv eyrie-rt
hello world!
```

8.1.2.3 test_gp

Run test_gp

```
$ cp test_gp/keystone/Enclave/Enclave.eapp_riscv $KEYSTONE_DIR/buildroot_overlay/root/test_gp/
$ cp test_gp/keystone/Enclave/App.client $KEYSTONE_DIR/buildroot_overlay/root/test_gp/
$ cp $KEYSTONE_SDK_DIR/rts/eyrie/eyrie-rt $KEYSTONE_DIR/buildroot_overlay/root/test_gp/
$ insmod keystone-driver.ko
$ ./App.client Enclave.eapp_riscv eyrie-rt
main start
TEE_GenerateRandom(0x000000003FFFFEE0, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@random: 5ea8741bd8a3b298cf53d214eca693fb
TEE_GetREETime(): start
```

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```
@[SE] gettimeofday 77 sec 865873 usec -> 0
@GP REE time 77 sec 865 millis
TEE_GetSystemTime(): start
@GP System time 100063195 sec 609 millis
TEE_CreatePersistentObject(): start
@[SE] open file FileOne flags 241 -> 3 (0)
TEE_WriteObjectData(): start
@[SE] write desc 3 buf 480d0 len 256-> 256
TEE_CloseObject(): start
@[SE] close desc 3 -> 0
TEE_OpenPersistentObject(): start
@[SE] open file FileOne flags 0 -> 3 (0)
TEE_ReadObjectData(): start
@[SE] read desc 3 buf fff41664 len 256-> 256
TEE_CloseObject(): start
@[SE] close desc 3 -> 0
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829
2a2b2c2d2e2f303132333435363738393a3b3c3d3f
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFD88, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFED0, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: e94431cd22a6029185d0dbb1a17b5d62843bfeef25591583d2d668ec6fed1c692f88ce4754d690c346c8d9f2726
630e0386abf4e45699a2ca2b34b344eaa454bc489c
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFC68, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFEC8, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: c23e9ce04589e80a66debe23a788ae5393bdcd8e875e87e1bcf2b2d998f6418ccc6ee4ab112fdbfc5175868691e
fb40781a318ff439d30b49cc9f726886ad42d5be15
@tag: a551f999317b3fbd1eea7b622ce2caee
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFE28, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: d6e6b6e54db8b6a62fc1927886938bead27f4813f19ce77182e3016b5426bcad067ca98cd75f9dfddafe9eb0
655c48df992d3ad674db69d831f26ae63caf1405
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
```

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```
TEE_FreeOperation(): start
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
```

8.2 ta-ref with OP-TEE

Make sure optee_3.9.0_rpi3 has been built already.

8.2.1 Cloning source and building

Clone the source

```
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref
$ git checkout teep-device-tb-slim
$ git submodule sync --recursive
$ git submodule update --init --recursive
```

Build

```
$ export OPTEE_DIR=<path to optee_3.9.0_rpi3>
$ source env/optee_rpi3.sh
$ make build test-bin MACHINE=RPI3 TEST_DIR=test_hello
$ make build test-bin MACHINE=RPI3 TEST_DIR=test_gp
```

8.2.2 Check ta-ref by running test_gp, test_hello, on QEMU

Copy the test_hello and test_gp programs to QEMU buildroot directory

```
$ mkdir -p optee_3.9.0_qemu/out-br/target/home/gitlab/out/{test_hello,test_gp}
$ cp ta-ref/test_hello/optee/App/optee_ref_ta optee_3.9.0_qemu/out-br/target/home/gitlab/out/test_hello/
$ cp ta-ref/test_hello/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
     optee_3.9.0_qemu/out-br/target/home/gitlab/out/test_hello/
$ cp ta-ref/test_gp/optee/App/optee_ref_ta
     optee_3.9.0_qemu/out-br/target/home/gitlab/out/test_gp/
$ cp ta-ref/test_gp/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
     optee_3.9.0_qemu/out-br/target/home/gitlab/out/test_gp/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ cp ./test_gp/optee/Enclave/Enclave.nm
    /TEE/demo/rpi3/optee_3.9.0_qemu/out-br/target/home/gitlab/out/test_gp/
```

8.2.2.1 test_hello

Run test_hello

```
$ cd /home/gitlab/out/test_hello/
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /home/gitlab/out/
$ ln -s /home/gitlab/out/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
     /lib64/optee_armtz/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ ./optee_ref_ta
--- enclave log start---
ecall_ta_main() start
hello world!
ecall_ta_main() end
--- enclave log end---
```

If executed successfully, you see above messages

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8.2.2.2 test_gp

Run test_gp

```
$ cd /home/gitlab/out/test_gp/
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /home/gitlab/out/
$ ln -s /home/gitlab/out/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
     /lib64/optee_armtz/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ ./optee_ref_ta
start TEEC_InvokeCommand
--- enclave log start---
ecall_ta_main() start
@random: fe0c7d3eefb9bd5e63b8a0cce29af7eb
@GP REE time 1612156259 sec 390 millis
@GP System time 249187 sec 954 millis
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829
2a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b
5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d
8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1
f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
hash: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@cipher: 30a558176172c53be4a2ac320776de105da79c29726879fe67d06b629f065731285f8a90f8a521ce34eceea51e1
5e928d157ea10d149bb687dd78be79469c28696506283edcda527fcd86f6a47e852bbc3488df3fc651b46b034faf4ab5f12f
51a285478ea01e58d40e8177d415be243df93b23cdf889feb91fa3be8906fe190d836fe61168aed0473406be1054dd88a381
ef25381d920ea3780ba74fb1cfe1434cbd168de8386dcc2e2b92eee0fc432f3c0514f462cbeaf96753b174a4a673f323e671
61272fe932ead4bc95770fcc130dd5877b521d6a79f961eeadd1680042f69257ccf9368927aa170176af8ac211dd22161997
7224837232dad970220f4
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@cipher: ff409d8fe203bf0d81de36832b86c702f07edd343f408d3a2fb5ab347b4f72b10031efff0c17b7e0bc56c3f2f95
f53c0d731ed87eb3e1187b6714a25cfc65082284682b44450941654e7edc99af0f7b037c3ba9ea731036070aa9496e34cfeb
db6845e8aa9955416ba227970d3dd1f8207b5743e1490a7f5fd78d81fce0a24576de06a2f528d49c5b11e79a5cab015806ba
d73f118e205a3645a95b2b330ffd9da12e00c693e7ee8cfd04eb0f08c3c657c4fa0ae384ed2d5ab1e15ffc835c3e4cc116cd
1049611f896cf445ab36dc8b393a6fe75d20d45b2273a5d8c2d3b935e3f22bc82b24c952812d66a902155d288d5f26ac6722
fe72498bd72ea523c914c
@tag: 9b357baf76d2632fa7d16231640d6324
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@digest: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@signature: 719fa9898f3423b754675b835268f9b2368b77a429eeabf7369d60d135dee08158c3902fd2ed3c1bf17cb34e
76f2ba25da915fa3970c757962f7533c8d8bad7d
@@TEE_FreeOperation:
verify ok
ecall_ta_main() end
--- enclave log end---
res = TEEC_SUCCESS; TEEC_InvokeCommand succeeded!
```

If executed successfully, you see above messages

8.3 ta-ref with SGX

Build ta-ref for Intel SGX platforms

8.3.1 Cloning source and building

Clone the source

```
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref
$ git checkout teep-device-tb-slim
```

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```
$ git submodule sync --recursive
$ git submodule update --init --recursive
```

Build

```
$ source /opt/intel/sgxsdk/environment
$ source env/sgx_x64.sh
$ make build test-bin MACHINE=NUC TEST_DIR=test_hello
$ make build test-bin MACHINE=NUC TEST_DIR=test_gp
```

8.3.2 Check ta-ref by running test_gp, test_hello, simulation mode on any pc

Copy the ta-ref's test_hello & test_gp executables to test directory

8.3.2.1 test_hello

Run test_hello

```
$ cp test_hello/sgx/Enclave/enclave.signed.so <test directory>
$ cp test_hello/sgx/App/sgx_app <test directory>
$ <test directory>/sgx_app
hello world!
Info: Enclave successfully returned.
```

8.3.2.2 test_gp

Run test_gp

```
$ cp test_gp/sgx/Enclave/enclave.signed.so <test directory>
$ cp test_gp/sgx/App/sgx_app <test directory>
$ <test directory>/sgx_app
main start
TEE_GenerateRandom(): start
@random: f35c1d1e4bbf6641c5511c9dc5aaf638
TEE_GetREETime(): start
request to get unix time 1612257364, 199
@GP REE time 1612257364 sec 199 millis
TEE_GetSystemTime(): start
@GP System time 727941859 sec 984 millis
TEE_CreatePersistentObject(): start
request to open FileOne flags 241 -> 3
TEE_WriteObjectData(): start
request to write 256 bytes to descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
TEE_OpenPersistentObject(): start
request to open FileOne flags 0 -> 3
TEE_ReadObjectData(): start
request to read 256 bytes from descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f2021222324252627282
2a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b
5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d
8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1
f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
```

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```
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: 7427bff21e729a824a239e25332ebd455d18fa6aec1ec6618b77c252f768e0a9345608b0135727568867ce5b0fa
c872f6647787861b88220840281f3944eea456a2769081e6598079b52edc541e2201ffd2e96a6c3e485be25a0ce4f5c07544
aa0c67b3e34bd069b293843daf66db51b751b3c09f2a9c6912c22a6062c8ecbd0effd4698081660e218f6f0c1249e3691a33
e91836953953513040eb29ce709efe50f96e67f07d6a1b00f08beacebc5950f9744b0049cb76ec5ba17a49d7270b60034c47
23bb79dc61d465062b0394e8d93f98c2391ee2b02b7b537b375e0e1cc5eeb8eb2e62df839048db0f1fdbdd1b7f5c6ef2faa1
a5b305ef045936c9146f8
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: e33f34122c80b9a10002725e4e21542256da7c7cd3f6dd1b62b71cf8308f9e4a0daa50b29880a8f76707c4ed432
549c4da9e68e7930189d2127fdd7aa2379106090814b5deed9a9e161ef0886da03a2a94c3fb9e0faadfd1ce8bb09fb5388bb
23a042944fbe269d486aa4f21a91a41968184122520dfc308850059efce660a52adb17361bd52f570bfba05cccad32ffa9ea
c94914725ded073355f28eb3dc30d60f00cfd2de76c3a05df8bef32f302bb4d14b493a3a90b1dee4eba64e625695c4d58ec4
febf8436d62e4cac82fcbd00e60c8138af7176995a742b08a572f64e539e9f9850a9f6f33907a829108ca6540332aab53f3f
6a4fd2c3de35c5556a427
@tag: 4c920ce2aef079e468ab24e25730d9d2
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: 100b392ce043e9b8dc703088f505dd3083ec47bfcb8d59d968a66b54e80464d684d56dc9c44336f08fd96309
79863a2d8fb7cd672a819ef609357e9ac6a3d80e
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
TEE_FreeOperation(): start
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
Info: Enclave successfully returned.
```

8.4 Generating ta-ref.pdf with Doxygen

As a pre-requisite, make sure `doxygen-1.9.2` was installed and built already.

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8.4.1 Cloning source and building docs

Clone the ta-ref source

```
$ git clone https://192.168.100.100/rinkai/ta-ref.git
$ cd ta-ref
$ git checkout teep-master
```

Build the documentation

```
# Export TEE Variable, TEE can be set to anything
$ export TEE=keystone
# Build the docs
$ make docs
```

After running the `make docs`, the doxygen build will be started and generates the ta-ref.pdf inside `docs` folder.

9 Running on Development Boards

9.1 Keystone, Unleased

Make sure Keystone and other dependant sources have been built

9.1.1 Preparation of rootfs on SD Card

Build a modified gdisk which can handle the sifive specific partition types.

Prerequisites: libncursesw5-dev, libpopt-dev

```
$ cd ..
$ sudo apt install libncursesw5-dev lib64ncurses5-dev uuid-dev libpopt-dev build-essential
$ git clone https://192.168.100.100/rinkai/gptfdisk.git
$ cd gptfdisk
$ git checkout -b risc-v-sd 3d6a15873f582803aa8ad3288b3e32d3daff9fde
$ make
```

9.1.1.1 Create SD-card partition manually

```
$ sudo ./gdisk /dev/mmcblk0
GPT fdisk (gdisk) version 1.0.4
Partition table scan:
  MBR: protective
  BSD: not present
  APM: not present
  GPT: present
Found valid GPT with protective MBR; using GPT.
Command (? for help): n
Partition number (1-128, default 1): 1
First sector (34-15523806, default = 2048) or {+-}size{KMGTP}:
Last sector (2048-15523806, default = 15523806) or {+-}size{KMGTP}: 67583
Current type is 'Linux filesystem'
Hex code or GUID (L to show codes, Enter = 8300): 5202
Changed type of partition to 'SiFive bare-metal (or stage 2 loader)'
Command (? for help): n
Partition number (2-128, default 2): 4
First sector (34-15523806, default = 67584) or {+-}size{KMGTP}:
Last sector (67584-15523806, default = 15523806) or {+-}size{KMGTP}: 67839
Current type is 'Linux filesystem'
```

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```
Hex code or GUID (L to show codes, Enter = 8300): 5201
Changed type of partition to 'SiFive FSBL (first-stage bootloader)'
Command (? for help): n
Partition number (2-128, default 2):
First sector (34-15523806, default = 69632) or {+-}size{KMGTP}: 264192
Last sector (264192-15523806, default = 15523806) or {+-}size{KMGTP}:
Current type is 'Linux filesystem'
Hex code or GUID (L to show codes, Enter = 8300): 8300
Changed type of partition to 'Linux filesystem'
Command (? for help): p
Disk /dev/mmcblk0: 15523840 sectors, 7.4 GiB
Sector size (logical/physical): 512/512 bytes
Disk identifier (GUID): 11A0F8F6-D5DE-4993-8C0D-D543DFBA17AD
Partition table holds up to 128 entries
Main partition table begins at sector 2 and ends at sector 33
First usable sector is 34, last usable sector is 15523806
Partitions will be aligned on 2048-sector boundaries
Total free space is 198366 sectors (96.9 MiB)
Number  Start (sector)    End (sector)  Size       Code  Name
   1            2048           67583   32.0 MiB    5202  SiFive bare-metal (...
   2          264192        15523806   7.3 GiB     8300  Linux filesystem
   4           67584           67839   128.0 KiB   5201  SiFive FSBL (first-...
Command (? for help): i
Partition number (1-4): 4
Partition GUID code: 5B193300-FC78-40CD-8002-E86C45580B47 (SiFive FSBL (first-stage bootloader))
Partition unique GUID: FC1FBC7C-EC94-4B0A-9DAF-0ED85452B885
First sector: 67584 (at 33.0 MiB)
Last sector: 67839 (at 33.1 MiB)
Partition size: 256 sectors (128.0 KiB)
Attribute flags: 0000000000000000
Partition name: 'SiFive FSBL (first-stage bootloader)'
Command (? for help): i
Partition number (1-4): 1
Partition GUID code: 2E54B353-1271-4842-806F-E436D6AF6985 (SiFive bare-metal (or stage 2 loader))
Partition unique GUID: 2FFF07EF-E44A-4278-A16D-C29697C6653D
First sector: 2048 (at 1024.0 KiB)
Last sector: 67583 (at 33.0 MiB)
Partition size: 65536 sectors (32.0 MiB)
Attribute flags: 0000000000000000
Partition name: 'SiFive bare-metal (or stage 2 loader'
Command (? for help): wq
Final checks complete. About to write GPT data. THIS WILL OVERWRITE EXISTING
PARTITIONS!!
Do you want to proceed? (Y/N): y
OK; writing new GUID partition table (GPT) to /dev/mmcblk1.
Warning: The kernel is still using the old partition table.
The new table will be used at the next reboot or after you
run partprobe(8) or kpartx(8)
The operation has completed successfully.
```

9.1.1.2 Write boot and rootfs files into SD-card

Build FSBL for hifive-Unleased board

```
$ git clone https://github.com/keystone-enclave/freedom-u540-c000-bootloader.git
$ cd freedom-u540-c000-bootloader
$ git checkout -b dev-unleashed bbfcc288fb438312af51adef420aa444a0833452
$ # Make sure riscv64 compiler set to PATH (export PATH=$KEYSTONE_DIR/riscv/bin:$PATH)
$ make
```

Writing fsbl.bin and bbl.bin

```
$ sudo dd if=freedom-u540-c000-bootloader/fsbl.bin of=/dev/mmcblk0p4 bs=4096 conv=fsync
$ sudo dd if=$KEYSTONE_DIR/hifive-work/bbl.bin of=/dev/mmcblk0p1 bs=4096 conv=fsync
```

Once files written, insert the SD-card into unleased

9.1.2 Copying binaries of test_hello and test_gp

```
$ sudo mount /dev/mmcblk0p1 /media/rootfs/
$ sudo mkdir /media/rootfs/root/{test_hello,test_gp}
```

Copy test_hello

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```
$ sudo cp ta-ref/test_hello/keystone/Enclave/Enclave.eapp_riscv /media/rootfs/root/test_hello/
$ sudo cp ta-ref/test_hello/keystone/Enclave/App.client /media/rootfs/root/test_hello/
$ sudo cp $KEYSTONE_SDK_DIR/rts/eyrie/eyrie-rt /media/rootfs/root/test_hello/
```

Copy test_gp

```
$ sudo cp ta-ref/test_gp/keystone/Enclave/Enclave.eapp_riscv /media/rootfs/root/test_gp/
$ sudo cp ta-ref/test_gp/keystone/Enclave/App.client /media/rootfs/root/test_gp/
$ sudo cp $KEYSTONE_SDK_DIR/rts/eyrie/eyrie-rt /media/rootfs/root/test_gp/
```

Now, we are ready to test on unleased board.

9.1.3 Check test_hello and test_gp on Unleased

1. Insert SD-card into unleased board
2. Boot Hifive-Unleased board
3. Connect Unleased board with your development machine over USB-Serial cable (/dev/ttyUSB1)
4. Checking on Unleased
   Login to serial console with user=root, passwd=sifive

```
buildroot login: root
Password:
$
```

test_hello:

```
$ insmod keystone-driver.ko
./App.client Enclave.eapp_riscv eyrie-rt
hello world!
```

test_gp:

```
$ insmod keystone-driver.ko
./App.client Enclave.eapp_riscv eyrie-rt
main start
TEE_GenerateRandom(0x000000003FFFFEE0, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@random: 5ea8741bd8a3b298cf53d214eca693fb
TEE_GetREETime(): start
@[SE] gettimeofday 77 sec 865873 usec -> 0
@GP REE time 77 sec 865 millis
TEE_GetSystemTime(): start
@GP System time 100063195 sec 609 millis
TEE_CreatePersistentObject(): start
@[SE] open file FileOne flags 241 -> 3 (0)
TEE_WriteObjectData(): start
@[SE] write desc 3 buf 480d0 len 256-> 256
TEE_CloseObject(): start
@[SE] close desc 3 -> 0
TEE_OpenPersistentObject(): start
@[SE] open file FileOne flags 0 -> 3 (0)
TEE_ReadObjectData(): start
@[SE] read desc 3 buf fff41664 len 256-> 256
TEE_CloseObject(): start
@[SE] close desc 3 -> 0
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f2021222324252627282
2a2b2c2d2e2f303132333435363738393a3b3c3d3f
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
```

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```
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFD88, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFED0, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: e94431cd22a6029185d0dbb1a17b5d62843bfeef25591583d2d668ec6fed1c692f88ce4754d690c346c8d9f2726
630e0386abf4e45699a2ca2b34b344eaa454bc489c
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFC68, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AllocateOperation(): start
TEE_GenerateRandom(0x000000003FFFFEC8, 16): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: c23e9ce04589e80a66debe23a788ae5393bdcd8e875e87e1bcf2b2d998f6418ccc6ee4ab112fdbfc5175868691e
fb40781a318ff439d30b49cc9f726886ad42d5be15
@tag: a551f999317b3fbd1eea7b622ce2caee
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(0x000000003FFFFE28, 32): start
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
@[SE] getrandom buf fff41844 len 16 flags 0 -> 16
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: d6e6b6e54db8b6a62fc1927886938bead27f4813f19ce77182e3016b5426bcad067ca98cd75f9dfddafe9eb0
655c48df992d3ad674db69d831f26ae63caf1405
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
TEE_FreeOperation(): start
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
```

Test is successful.

9.2 OP-TEE, RPI3

Make sure OP-TEE v3.9.0 and other dependant sources have been built

9.2.1 Preparation of rootfs on SD Card

Use following examples to create partitions of boot and roots on SD-card

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```
$ make img-help
$ fdisk /dev/sdx   # where sdx is the name of your sd-card
   > p             # prints partition table
   > d             # repeat until all partitions are deleted
   > n             # create a new partition
   > p             # create primary
   > 1             # make it the first partition
   > <enter>       # use the default sector
   > +32M          # create a boot partition with 32MB of space
   > n             # create rootfs partition
   > p
   > 2
   > <enter>
   > <enter>       # fill the remaining disk, adjust size to fit your needs
   > t             # change partition type
   > 1             # select first partition
   > e             # use type 'e' (FAT16)
   > a             # make partition bootable
   > 1             # select first partition
   > p             # double check everything looks right
   > w             # write partition table to disk.
```

Usually your SD-card detected as `/dev/mmcblk0`. After partition it looks like below BOOT partition = /dev/mmcblk0p1 rootfs partition = /dev/mmcblk0p2

Write boot file

```
$ mkfs.vfat -F16 -n BOOT /dev/mmcblk0p1
$ mkdir -p /media/boot
$ sudo mount /dev/mmcblk0p1 /media/boot
$ cd /media
$ gunzip -cd optee_3.9.0_rpi3/out-br/images/rootfs.cpio.gz | sudo cpio -idmv "boot/*"
$ umount boot
```

Write rootfs

```
$ mkfs.ext4 -L rootfs /dev/mmcblk0p2
$ mkdir -p /media/rootfs
$ sudo mount /dev/mmcblk0p2 /media/rootfs
$ cd rootfs
$ gunzip -cd <your-base-dir>/optee_3.9.0_rpi3/build/../out-br/images/rootfs.cpio.gz | sudo cpio
      -idmv
$ rm -rf /media/rootfs/boot/*
$ cd .. && sudo umount rootfs
```

If you use CI from AIST, download rpi3_sdimage as follows

```
$ wget http://192.168.100.100:2000/optee_rpi3_sdimage.tar.xz
$ tar xf optee_rpi3_sdimage.tar.xz
$ dd if=rpi3_sdimage.bin of=/dev/mmcblk0p2 conv=fsync bs=4096
```

Now SD-card is ready to boot RPI3.

9.2.2 Copying binaries of test_hello and test_gp to rootfs partition

Copying test_hello & test_gp

```
$ sudo mount /dev/mmcblk0p2 /media/rootfs
$ sudo mkdir -p /media/rootfs/home/gitlab/out/{test_hello,test_gp}
$ sudo cp ta-ref/test_hello/optee/App/optee_ref_ta /media/rootfs/home/gitlab/out/test_hello/
$ sudo cp ta-ref/test_hello/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
   /media/rootfs/home/gitlab/out/test_hello/
$ sudo cp ta-ref/test_gp/optee/App/optee_ref_ta /media/rootfs/home/gitlab/out/test_gp/
$ sudo cp ta-ref/test_gp/optee/Enclave/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
   /media/rootfs/home/gitlab/out/test_gp/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ sudo cp ta-ref/test_gp/optee/Enclave/Enclave.nm /media/rootfs/home/gitlab/out/test_gp/
```

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9.2.3 Check test_hello and test_gp

1. Insert SD-card into RPI3 board, then power-on
2. Connect RPI3 board Serial console to your laptop (/dev/ttyUSB0 over minicom)
3. Checking on RPI3

Login to Serial console and enter "root" as username

```
buildroot login: root
Password:
$
```

test_hello:

```
$ cp /home/gitlab/out/test_hello/
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /home/gitlab/out/
$ ln -s /home/gitlab/out/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
    /lib64/optee_armtz/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ ./optee_ref_ta
--- enclave log start---
ecall_ta_main() start
hello world!
ecall_ta_main() end
--- enclave log end---
```

If executed successfully, you see above messages

test_gp:

```
$ cd /home/gitlab/out/test_gp/
$ cp a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta /home/gitlab/out/
$ ln -s /home/gitlab/out/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
  /lib64/optee_armtz/a6f77c1e-96fe-4a0e-9e74-262582a4c8f1.ta
$ ./optee_ref_ta
start TEEC_InvokeCommand
--- enclave log start---
ecall_ta_main() start
@random: fe0c7d3eefb9bd5e63b8a0cce29af7eb
@GP REE time 1612156259 sec 390 millis
@GP System time 249187 sec 954 millis
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829
2a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b
5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d
8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1
f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
hash: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@cipher: 30a558176172c53be4a2ac320776de105da79c29726879fe67d06b629f065731285f8a90f8a521ce34eceea51e1
5e928d157ea10d149bb687dd78be79469c28696506283edcda527fcd86f6a47e852bbc3488df3fc651b46b034faf4ab5f12f
51a285478ea01e58d40e8177d415be243df93b23cdf889feb91fa3be8906fe190d836fe61168aed0473406be1054dd88a381
ef25381d920ea3780ba74fb1cfe1434cbd168de8386dcc2e2b92eee0fc432f3c0514f462cbeaf96753b174a4a673f323e671
61272fe932ead4bc95770fcc130dd5877b521d6a79f961eeadd1680042f69257ccf9368927aa170176af8ac211dd22161997
7224837232dad970220f4
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@cipher: ff409d8fe203bf0d81de36832b86c702f07edd343f408d3a2fb5ab347b4f72b10031efff0c17b7e0bc56c3f2f95
f53c0d731ed87eb3e1187b6714a25cfc65082284682b44450941654e7edc99af0f7b037c3ba9ea731036070aa9496e34cfeb
db6845e8aa9955416ba227970d3dd1f8207b5743e1490a7f5fd78d81fce0a24576de06a2f528d49c5b11e79a5cab015806ba
d73f118e205a3645a95b2b330ffd9da12e00c693e7ee8cfd04eb0f08c3c657c4fa0ae384ed2d5ab1e15ffc835c3e4cc116cd
1049611f896cf445ab36dc8b393a6fe75d20d45b2273a5d8c2d3b935e3f22bc82b24c952812d66a902155d288d5f26ac6722
fe72498bd72ea523c914c
@tag: 9b357baf76d2632fa7d16231640d6324
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f202122232425262728292a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
```

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```
8f90919293949596979899a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
@digest: 40aff2e9d2d8922e47afd4648e6967497158785fbd1da870e7110266bf944880
@signature: 719fa9898f3423b754675b835268f9b2368b77a429eeabf7369d60d135dee08158c3902fd2ed3c1bf17cb34e
76f2ba25da915fa3970c757962f7533c8d8bad7d
@@TEE_FreeOperation:
verify ok
ecall_ta_main() end
--- enclave log end---
res = TEEC_SUCCESS; TEEC_InvokeCommand succeeded!
```

If executed successfully, you see above messages

9.3 SGX, NUC

Make sure SGX SDK, sgx driver and other dependant sources have been built and installed on NUC machine

9.3.1 Copying binaries of test_hello and test_gp to NUC machine

Login to NUC machine over SSH (Assuming that SSH enabled on NIC machine). Assuming that `ta-ref` was natively built on NUC machine at `~/ta-ref`

```
$ ssh <ssh-user>@<IP-Address> 'mkdir -p ~/{test_hello,test_gp}'
$ scp ta-ref/test_hello/sgx/Enclave/enclave.signed.so <ssh-user>@<IP-Address>:~/test_hello
$ scp ta-ref/test_hello/sgx/App/sgx_app <ssh-user>@<IP-Address>:~/test_hello
$ scp ta-ref/test_gp/sgx/Enclave/enclave.signed.so <ssh-user>@<IP-Address>:~/test_gp
$ scp ta-ref/test_gp/sgx/App/sgx_app <ssh-user>@<IP-Address>:~/test_gp
```

Now can login to NUC machine for further testing.

9.3.2 Check test_hello and test_gp

Checking test_hello

```
$ cd ~/test_hello
$ ./sgx_app
hello world!
Info: Enclave successfully returned.
```

Checking test_gp

```
$ cd ~/test_gp
$ ./sgx_app
main start
TEE_GenerateRandom(): start
@random: f35c1d1e4bbf6641c5511c9dc5aaf638
TEE_GetREETime(): start
request to get unix time 1612257364, 199
@GP REE time 1612257364 sec 199 millis
TEE_GetSystemTime(): start
@GP System time 727941859 sec 984 millis
TEE_CreatePersistentObject(): start
request to open FileOne flags 241 -> 3
TEE_WriteObjectData(): start
request to write 256 bytes to descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
TEE_OpenPersistentObject(): start
request to open FileOne flags 0 -> 3
TEE_ReadObjectData(): start
```

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```
request to read 256 bytes from descriptor 3
TEE_CloseObject(): start
request to close descriptor 3
256 bytes read: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829
2a2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b
5c5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d
8e8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1
f2f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
hash: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
@cipher: 7427bff21e729a824a239e25332ebd455d18fa6aec1ec6618b77c252f768e0a9345608b0135727568867ce5b0fa
c872f6647787861b88220840281f3944eea456a2769081e6598079b52edc541e2201ffd2e96a6c3e485be25a0ce4f5c07544
aa0c67b3e34bd069b293843daf66db51b751b3c09f2a9c6912c22a6062c8ecbd0effd4698081660e218f6f0c1249e3691a33
e91836953953513040eb29ce709efe50f96e67f07d6a1b00f08beacebc5950f9744b0049cb76ec5ba17a49d7270b60034c47
23bb79dc61d465062b0394e8d93f98c2391ee2b02b7b537b375e0e1cc5eeb8eb2e62df839048db0f1fdbdd1b7f5c6ef2faa1
a5b305ef045936c9146f8
TEE_AllocateOperation(): start
TEE_CipherInit(): start
TEE_CipherUpdate(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829 2a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateTransientObject(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AllocateOperation(): start
TEE_GenerateRandom(): start
TEE_AEInit(): start
TEE_AEEncryptFinal(): start
TEE_FreeOperation(): start
@cipher: e33f34122c80b9a10002725e4e21542256da7c7cd3f6dd1b62b71cf8308f9e4a0daa50b29880a8f76707c4ed432
549c4da9e68e7930189d2127fdd7aa2379106090814b5deed9a9e161ef0886da03a2a94c3fb9e0faadfd1ce8bb09fb5388bb
23a042944fbe269d486aa4f21a91a41968184122520dfc308850059efce660a52adb17361bd52f570bfba05cccad32ffa9ea
c94914725ded073355f28eb3dc30d60f00cfd2de76c3a05df8bef32f302bb4d14b493a3a90b1dee4eba64e625695c4d58ec4
febf8436d62e4cac82fcbd00e60c8138af7176995a742b08a572f64e539e9f9850a9f6f33907a829108ca6540332aab53f3f
6a4fd2c3de35c5556a427
@tag: 4c920ce2aef079e468ab24e25730d9d2
TEE_AllocateOperation(): start
TEE_AEInit(): start
TEE_AEDecryptFinal(): start
TEE_FreeOperation(): start
TEE_FreeTransientObject(): start
decrypted to: 000102030405060708090a0b0c0d0e0f101112131415161718191a1b1c1d1e1f20212223242526272829a
2b2c2d2e2f303132333435363738393a3b3c3d3e3f404142434445464748494a4b4c4d4e4f505152535455565758595a5b5c
5d5e5f606162636465666768696a6b6c6d6e6f707172737475767778797a7b7c7d7e7f808182838485868788898a8b8c8d8e
8f909192939495969798999a9b9c9d9e9fa0a1a2a3a4a5a6a7a8a9aaabacadaeafb0b1b2b3b4b5b6b7b8b9babbbcbdbebfc0
c1c2c3c4c5c6c7c8c9cacbcccdcecfd0d1d2d3d4d5d6d7d8d9dadbdcdddedfe0e1e2e3e4e5e6e7e8e9eaebecedeeeff0f1f2
f3f4f5f6f7f8f9fafbfcfdfeff
verify ok
TEE_AllocateOperation(): start
TEE_FreeOperation(): start
TEE_DigestDoFinal(): start
TEE_FreeOperation(): start
@digest: 9b04c091da96b997afb8f2585d608aebe9c4a904f7d52c8f28c7e4d2dd9fba5f
TEE_AllocateOperation(): start
TEE_AllocateTransientObject(): start
TEE_InitValueAttribute(): start
TEE_GenerateKey(): start
TEE_GenerateRandom(): start
TEE_AsymmetricSignDigest(): start
TEE_FreeOperation(): start
@signature: 100b392ce043e9b8dc703088f505dd3083ec47bfcb8d59d968a66b54e80464d684d56dc9c44336f08fd96309
79863a2d8fb7cd672a819ef609357e9ac6a3d80e
TEE_AllocateOperation(): start
TEE_AsymmetricVerifyDigest(): start
TEE_FreeOperation(): start
```

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```
@@TEE_FreeOperation:
TEE_FreeTransientObject(): start
verify ok
main end
Info: Enclave successfully returned.
```

10 Class Index

10.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

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11 File Index

11.1 File List

Here is a list of all files with brief descriptions:

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12 Class Documentation

12.1 __TEE_ObjectHandle Struct Reference

```
#include <tee_api_tee_types.h>
```

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Public Attributes

- unsigned int type
- int flags
- int desc
- mbedtls_aes_context persist_ctx
- unsigned char persist_iv [TEE_OBJECT_NONCE_SIZE]
- unsigned char public_key [TEE_OBJECT_KEY_SIZE]
- unsigned char private_key [TEE_OBJECT_SKEY_SIZE]

12.1.1 Member Data Documentation

12.1.1.1 desc `int __TEE_ObjectHandle::desc`

12.1.1.2 flags `int __TEE_ObjectHandle::flags`

12.1.1.3 persist_ctx `mbedtls_aes_context __TEE_ObjectHandle::persist_ctx`

12.1.1.4 persist_iv `unsigned char __TEE_ObjectHandle::persist_iv`

12.1.1.5 private_key `unsigned char __TEE_ObjectHandle::private_key`

12.1.1.6 public_key `unsigned char __TEE_ObjectHandle::public_key`

12.1.1.7 type `unsigned int __TEE_ObjectHandle::type`

The documentation for this struct was generated from the following files:

- ta-ref/api/keystone/tee_api_tee_types.h
- ta-ref/api/sgx/tee_api_tee_types.h

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12.2 __TEE_OperationHandle Struct Reference

`#include <tee_api_tee_types.h>`

Public Attributes

- int mode
- int flags
- int alg
- sha3_ctx_t ctx
- mbedtls_aes_context aectx
- mbedtls_gcm_context aegcmctx
- int aegcm_state
- unsigned char aeiv [TEE_OBJECT_NONCE_SIZE]
- unsigned char aekey [32]
- unsigned char pubkey [TEE_OBJECT_KEY_SIZE]
- unsigned char prikey [TEE_OBJECT_SKEY_SIZE]

12.2.1 Member Data Documentation

12.2.1.1 aectx `mbedtls_aes_context __TEE_OperationHandle::aectx`

12.2.1.2 aegcm_state `int __TEE_OperationHandle::aegcm_state`

12.2.1.3 aegcmctx `mbedtls_gcm_context __TEE_OperationHandle::aegcmctx`

12.2.1.4 aeiv `unsigned char __TEE_OperationHandle::aeiv`

12.2.1.5 aekey `unsigned char __TEE_OperationHandle::aekey`

12.2.1.6 alg `int __TEE_OperationHandle::alg`

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12.2.1.7 ctx `sha3_ctx_t __TEE_OperationHandle::ctx`

12.2.1.8 flags `int __TEE_OperationHandle::flags`

12.2.1.9 mode `int __TEE_OperationHandle::mode`

12.2.1.10 prikey `unsigned char __TEE_OperationHandle::prikey`

12.2.1.11 pubkey `unsigned char __TEE_OperationHandle::pubkey`

The documentation for this struct was generated from the following files:

- ta-ref/api/keystone/tee_api_tee_types.h
- ta-ref/api/sgx/tee_api_tee_types.h

12.3 _sgx_errlist_t Struct Reference

`#include <types.h>`

Public Attributes

- sgx_status_t err
- const char * msg
- const char * sug

12.3.1 Member Data Documentation

12.3.1.1 err `sgx_status_t _sgx_errlist_t::err`

12.3.1.2 msg `const char* _sgx_errlist_t::msg`

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12.3.1.3 sug `const char* _sgx_errlist_t::sug`

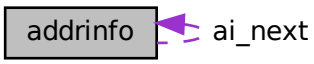
The documentation for this struct was generated from the following file:

- ta-ref/api/include/types.h

12.4 addrinfo Struct Reference

`#include <tee_api_types.h>`

Collaboration diagram for addrinfo:



Public Attributes

- int ai_flags
- int ai_family
- int ai_socktype
- int ai_protocol
- socklen_t ai_addrlen
- struct sockaddr * ai_addr
- char * ai_canonname
- struct addrinfo * ai_next

12.4.1 Member Data Documentation

12.4.1.1 ai_addr `struct sockaddr* addrinfo::ai_addr`

12.4.1.2 ai_addrlen `socklen_t addrinfo::ai_addrlen`

12.4.1.3 ai_canonname `char* addrinfo::ai_canonname`

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12.4.1.4 ai_family `int addrinfo::ai_family`

12.4.1.5 ai_flags `int addrinfo::ai_flags`

12.4.1.6 ai_next `struct addrinfo* addrinfo::ai_next`

12.4.1.7 ai_protocol `int addrinfo::ai_protocol`

12.4.1.8 ai_socktype `int addrinfo::ai_socktype`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.5 enclave_report Struct Reference

`#include <report.h>`

Public Attributes

- uint8_t hash [MDSIZE]
- uint64_t data_len
- uint8_t data [ATTEST_DATA_MAXLEN]
- uint8_t signature [SIGNATURE_SIZE]

12.5.1 Member Data Documentation

12.5.1.1 data `uint8_t enclave_report::data[ATTEST_DATA_MAXLEN]`

12.5.1.2 data_len `uint64_t enclave_report::data_len`

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12.5.1.3 hash `uint8_t enclave_report::hash[MDSIZE]`

12.5.1.4 signature `uint8_t enclave_report::signature[SIGNATURE_SIZE]`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/report.h

12.6 out_fct_wrap_type Struct Reference

Public Attributes

- void(* fct)(char character, void *arg)
- void * arg

12.6.1 Member Data Documentation

12.6.1.1 arg `void * out_fct_wrap_type::arg`

12.6.1.2 fct `void(* out_fct_wrap_type::fct)(char character, void *arg)`

The documentation for this struct was generated from the following files:

- ta-ref/api/keystone/vsnprintf.c
- ta-ref/api/sgx/vsnprintf.c

12.7 pollfd Struct Reference

```
#include <tee_api_types.h>
```

Public Attributes

- int fd
- short int events
- short int revents

12.7.1 Member Data Documentation

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12.7.1.1 events short int pollfd::events

12.7.1.2 fd int pollfd::fd

12.7.1.3 revents short int pollfd::revents

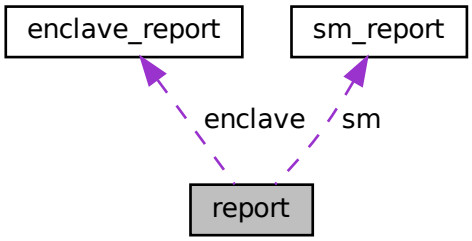
The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.8 report Struct Reference

`#include <report.h>`

Collaboration diagram for report:



Public Attributes

- struct enclave_report enclave
- struct sm_report sm
- uint8_t dev_public_key [PUBLIC_KEY_SIZE]

12.8.1 Member Data Documentation

12.8.1.1 dev_public_key uint8_t report::dev_public_key[PUBLIC_KEY_SIZE]

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12.8.1.2 enclave `struct enclave_report report::enclave`

12.8.1.3 sm `struct sm_report report::sm`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/report.h

12.9 sm_report Struct Reference

`#include <report.h>`

Public Attributes

- uint8_t hash [MDSIZE]
- uint8_t public_key [PUBLIC_KEY_SIZE]
- uint8_t signature [SIGNATURE_SIZE]

12.9.1 Member Data Documentation

12.9.1.1 hash `uint8_t sm_report::hash[MDSIZE]`

12.9.1.2 public_key `uint8_t sm_report::public_key[PUBLIC_KEY_SIZE]`

12.9.1.3 signature `uint8_t sm_report::signature[SIGNATURE_SIZE]`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/report.h

12.10 TEE_Attribute Struct Reference

`#include <tee_api_types.h>`

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Public Attributes

- uint32_t attributeID
- union {
  struct {
  void * buffer
  uint32_t length
  } ref
  struct {
  uint32_t a
  uint32_t b
  } value
  } content

12.10.1 Member Data Documentation

12.10.1.1 a `uint32_t TEE_Attribute::a`

12.10.1.2 attributeID `uint32_t TEE_Attribute::attributeID`

12.10.1.3 b `uint32_t TEE_Attribute::b`

12.10.1.4 buffer `void* TEE_Attribute::buffer`

12.10.1.5 `union { ... } TEE_Attribute::content`

12.10.1.6 length `uint32_t TEE_Attribute::length`

12.10.1.7 `struct { ... } TEE_Attribute::ref`

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12.10.1.8 struct { ... } TEE_Attribute::value

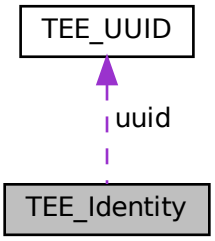
The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.11 TEE_Identity Struct Reference

`#include <tee_api_types.h>`

Collaboration diagram for TEE_Identity:



Public Attributes

- uint32_t login
- TEE_UUID uuid

12.11.1 Member Data Documentation

12.11.1.1 login uint32_t TEE_Identity::login

12.11.1.2 uuid TEE_UUID TEE_Identity::uuid

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

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12.12 TEE_ObjectInfo Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- uint32_t objectType
- union {
  uint32_t keySize
  uint32_t objectSize
  };
- union {
  uint32_t maxKeySize
  uint32_t maxObjectSize
  };
- uint32_t objectUsage
- uint32_t dataSize
- uint32_t dataPosition
- uint32_t handleFlags

12.12.1 Member Data Documentation

12.12.1.1 `__extension__ union { ... } TEE_ObjectInfo::@3`

12.12.1.2 `__extension__ union { ... } TEE_ObjectInfo::@5`

12.12.1.3 dataPosition `uint32_t TEE_ObjectInfo::dataPosition`

12.12.1.4 dataSize `uint32_t TEE_ObjectInfo::dataSize`

12.12.1.5 handleFlags `uint32_t TEE_ObjectInfo::handleFlags`

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12.12.1.6 keySize `uint32_t TEE_ObjectInfo::keySize`

12.12.1.7 maxKeySize `uint32_t TEE_ObjectInfo::maxKeySize`

12.12.1.8 maxObjectSize `uint32_t TEE_ObjectInfo::maxObjectSize`

12.12.1.9 objectSize `uint32_t TEE_ObjectInfo::objectSize`

12.12.1.10 objectType `uint32_t TEE_ObjectInfo::objectType`

12.12.1.11 objectUsage `uint32_t TEE_ObjectInfo::objectUsage`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.13 TEE_OperationInfo Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- uint32_t algorithm
- uint32_t operationClass
- uint32_t mode
- uint32_t digestLength
- uint32_t maxKeySize
- uint32_t keySize
- uint32_t requiredKeyUsage
- uint32_t handleState

12.13.1 Member Data Documentation

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12.13.1.1 algorithm `uint32_t TEE_OperationInfo::algorithm`

12.13.1.2 digestLength `uint32_t TEE_OperationInfo::digestLength`

12.13.1.3 handleState `uint32_t TEE_OperationInfo::handleState`

12.13.1.4 keySize `uint32_t TEE_OperationInfo::keySize`

12.13.1.5 maxKeySize `uint32_t TEE_OperationInfo::maxKeySize`

12.13.1.6 mode `uint32_t TEE_OperationInfo::mode`

12.13.1.7 operationClass `uint32_t TEE_OperationInfo::operationClass`

12.13.1.8 requiredKeyUsage `uint32_t TEE_OperationInfo::requiredKeyUsage`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.14 TEE_OperationInfoKey Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- uint32_t keySize
- uint32_t requiredKeyUsage

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12.14.1 Member Data Documentation

12.14.1.1 keySize `uint32_t TEE_OperationInfoKey::keySize`

12.14.1.2 requiredKeyUsage `uint32_t TEE_OperationInfoKey::requiredKeyUsage`

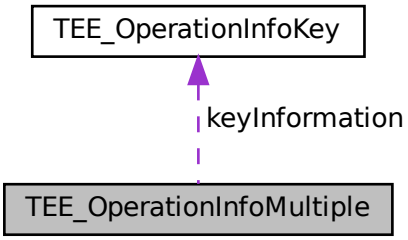
The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.15 TEE_OperationInfoMultiple Struct Reference

`#include <tee_api_types.h>`

Collaboration diagram for TEE_OperationInfoMultiple:



Public Attributes

- uint32_t algorithm
- uint32_t operationClass
- uint32_t mode
- uint32_t digestLength
- uint32_t maxKeySize
- uint32_t handleState
- uint32_t operationState
- uint32_t numberOfKeys
- TEE_OperationInfoKey keyInformation [ ]

12.15.1 Member Data Documentation

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12.15.1.1 algorithm `uint32_t TEE_OperationInfoMultiple::algorithm`

12.15.1.2 digestLength `uint32_t TEE_OperationInfoMultiple::digestLength`

12.15.1.3 handleState `uint32_t TEE_OperationInfoMultiple::handleState`

12.15.1.4 keyInformation `TEE_OperationInfoKey TEE_OperationInfoMultiple::keyInformation[]`

12.15.1.5 maxKeySize `uint32_t TEE_OperationInfoMultiple::maxKeySize`

12.15.1.6 mode `uint32_t TEE_OperationInfoMultiple::mode`

12.15.1.7 numberOfKeys `uint32_t TEE_OperationInfoMultiple::numberOfKeys`

12.15.1.8 operationClass `uint32_t TEE_OperationInfoMultiple::operationClass`

12.15.1.9 operationState `uint32_t TEE_OperationInfoMultiple::operationState`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.16 TEE_Param Union Reference

`#include <tee_api_types.h>`

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Public Attributes

- struct {
  void * buffer
  uint32_t size
  } memref

- struct {
  uint32_t a
  uint32_t b
  } value

12.16.1 Member Data Documentation

12.16.1.1 a `uint32_t TEE_Param::a`

12.16.1.2 b `uint32_t TEE_Param::b`

12.16.1.3 buffer `void* TEE_Param::buffer`

12.16.1.4 `struct { ... } TEE_Param::memref`

12.16.1.5 size `uint32_t TEE_Param::size`

12.16.1.6 `struct { ... } TEE_Param::value`

The documentation for this union was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.17 TEE_SEAID Struct Reference

`#include <tee_api_types.h>`

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Public Attributes

- uint8_t * buffer
- size_t bufferLen

12.17.1 Member Data Documentation

12.17.1.1 buffer `uint8_t* TEE_SEAID::buffer`

12.17.1.2 bufferLen `size_t TEE_SEAID::bufferLen`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.18 TEE_SEReaderProperties Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- bool sePresent
- bool teeOnly
- bool selectResponseEnable

12.18.1 Member Data Documentation

12.18.1.1 selectResponseEnable `bool TEE_SEReaderProperties::selectResponseEnable`

12.18.1.2 sePresent `bool TEE_SEReaderProperties::sePresent`

12.18.1.3 teeOnly `bool TEE_SEReaderProperties::teeOnly`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

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12.19 TEE_Time Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- uint32_t seconds
- uint32_t millis

12.19.1 Member Data Documentation

12.19.1.1 millis `uint32_t TEE_Time::millis`

12.19.1.2 seconds `uint32_t TEE_Time::seconds`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.20 TEE_UUID Struct Reference

`#include <tee_api_types.h>`

Public Attributes

- uint32_t timeLow
- uint16_t timeMid
- uint16_t timeHiAndVersion
- uint8_t clockSeqAndNode [8]

12.20.1 Member Data Documentation

12.20.1.1 clockSeqAndNode `uint8_t TEE_UUID::clockSeqAndNode[8]`

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12.20.1.2 timeHiAndVersion `uint16_t TEE_UUID::timeHiAndVersion`

12.20.1.3 timeLow `uint32_t TEE_UUID::timeLow`

12.20.1.4 timeMid `uint16_t TEE_UUID::timeMid`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_api_types.h

12.21 TEEC_Context Struct Reference

`#include <tee_client_api.h>`

Public Attributes

- int fd
- bool reg_mem

12.21.1 Detailed Description

struct TEEC_Context - Represents a connection between a client application and a TEE.

12.21.2 Member Data Documentation

12.21.2.1 fd `int TEEC_Context::fd`

12.21.2.2 reg_mem `bool TEEC_Context::reg_mem`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

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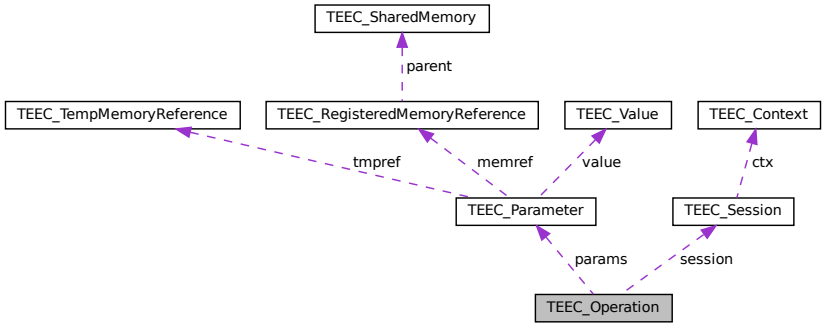
12.22 TEEC_Operation Struct Reference

`#include <tee_client_api.h>`

Collaboration diagram for TEEC_Operation:



Public Attributes

- uint32_t started
- uint32_t paramTypes
- TEEC_Parameter params [TEEC_CONFIG_PAYLOAD_REF_COUNT]
- TEEC_Session * session

12.22.1 Detailed Description

struct TEEC_Operation - Holds information and memory references used in TEEC_InvokeCommand().

Parameters

started	Client must initialize to zero if it needs to cancel an operation about to be performed.
paramTypes	Type of data passed. Use TEEC_PARAMS_TYPE macro to create the correct flags. 0 means TEEC_NONE is passed for all params.
params	Array of parameters of type TEEC_Parameter.
session	Internal pointer to the last session used by TEEC_InvokeCommand with this operation.

12.22.2 Member Data Documentation

12.22.2.1 params `TEEC_Parameter TEEC_Operation::params[TEEC_CONFIG_PAYLOAD_REF_COUNT]`

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12.22.2.2 paramTypes `uint32_t TEEC_Operation::paramTypes`

12.22.2.3 session `TEEC_Session* TEEC_Operation::session`

12.22.2.4 started `uint32_t TEEC_Operation::started`

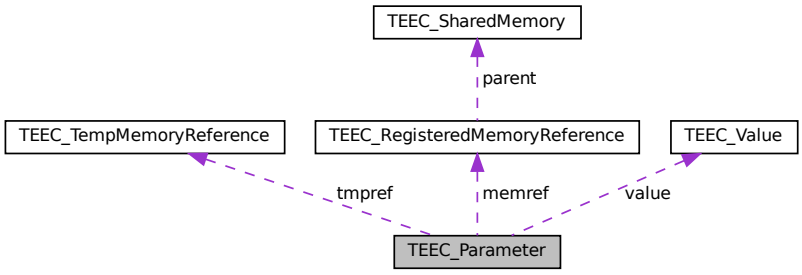
The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.23 TEEC_Parameter Union Reference

`#include <tee_client_api.h>`

Collaboration diagram for TEEC_Parameter:



Public Attributes

- TEEC_TempMemoryReference tmpref
- TEEC_RegisteredMemoryReference memref
- TEEC_Value value

12.23.1 Detailed Description

union TEEC_Parameter - Memory container to be used when passing data between client application and trusted code.

Either the client uses a shared memory reference, parts of it or a small raw data container.

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Parameters

tmpref	A temporary memory reference only valid for the duration of the operation.
memref	The entire shared memory or parts of it.
value	The small raw data container to use

12.23.2 Member Data Documentation

12.23.2.1 memref `TEEC_RegisteredMemoryReference TEEC_Parameter::memref`

12.23.2.2 tmpref `TEEC_TempMemoryReference TEEC_Parameter::tmpref`

12.23.2.3 value `TEEC_Value TEEC_Parameter::value`

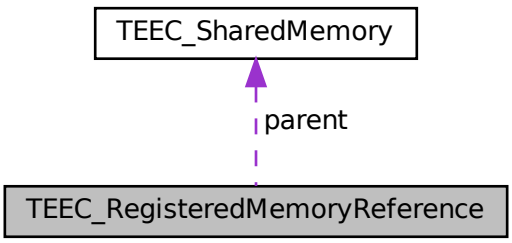
The documentation for this union was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.24 TEEC_RegisteredMemoryReference Struct Reference

`#include <tee_client_api.h>`

Collaboration diagram for TEEC_RegisteredMemoryReference:



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Public Attributes

- TEEC_SharedMemory * parent
- size_t size
- size_t offset

12.24.1 Detailed Description

struct TEEC_RegisteredMemoryReference - use a pre-registered or pre-allocated shared memory block of memory to transfer data between a client application and trusted code.

Parameters

parent	Points to a shared memory structure. The memory reference may utilize the whole shared memory or only a part of it. Must not be NULL
size	The size, in bytes, of the memory buffer.
offset	The offset, in bytes, of the referenced memory region from the start of the shared memory block.

12.24.2 Member Data Documentation

12.24.2.1 offset `size_t TEEC_RegisteredMemoryReference::offset`

12.24.2.2 parent `TEEC_SharedMemory* TEEC_RegisteredMemoryReference::parent`

12.24.2.3 size `size_t TEEC_RegisteredMemoryReference::size`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

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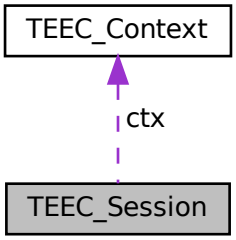
12.25 TEEC_Session Struct Reference

`#include <tee_client_api.h>`

Collaboration diagram for TEEC_Session:



Public Attributes

- TEEC_Context * ctx
- uint32_t session_id

12.25.1 Detailed Description

struct TEEC_Session - Represents a connection between a client application and a trusted application.

12.25.2 Member Data Documentation

12.25.2.1 ctx `TEEC_Context* TEEC_Session::ctx`

12.25.2.2 session_id `uint32_t TEEC_Session::session_id`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.26 TEEC_SharedMemory Struct Reference

`#include <tee_client_api.h>`

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Public Attributes

- void * buffer
- size_t size
- uint32_t flags
- int id
- size_t alloced_size
- void * shadow_buffer
- int registered_fd
- bool buffer_allocated

12.26.1 Detailed Description

struct TEEC_SharedMemory - Memory to transfer data between a client application and trusted code.

Parameters

buffer	The memory buffer which is to be, or has been, shared with the TEE.
size	The size, in bytes, of the memory buffer.
flags	Bit-vector which holds properties of buffer. The bit-vector can contain either or both of the TEEC_MEM_INPUT and TEEC_MEM_OUTPUT flags.

A shared memory block is a region of memory allocated in the context of the client application memory space that can be used to transfer data between that client application and a trusted application. The user of this struct is responsible to populate the buffer pointer.

12.26.2 Member Data Documentation

12.26.2.1 alloced_size `size_t TEEC_SharedMemory::alloced_size`

12.26.2.2 buffer `void* TEEC_SharedMemory::buffer`

12.26.2.3 buffer_allocated `bool TEEC_SharedMemory::buffer_allocated`

12.26.2.4 flags `uint32_t TEEC_SharedMemory::flags`

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12.26.2.5 id `int TEEC_SharedMemory::id`

12.26.2.6 registered_fd `int TEEC_SharedMemory::registered_fd`

12.26.2.7 shadow_buffer `void* TEEC_SharedMemory::shadow_buffer`

12.26.2.8 size `size_t TEEC_SharedMemory::size`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.27 TEEC_TempMemoryReference Struct Reference

`#include <tee_client_api.h>`

Public Attributes

- void * buffer
- size_t size

12.27.1 Detailed Description

struct TEEC_TempMemoryReference - Temporary memory to transfer data between a client application and trusted code, only used for the duration of the operation.

Parameters

buffer	The memory buffer which is to be, or has been shared with the TEE.
size	The size, in bytes, of the memory buffer.

A memory buffer that is registered temporarily for the duration of the operation to be called.

12.27.2 Member Data Documentation

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12.27.2.1 buffer `void* TEEC_TempMemoryReference::buffer`

12.27.2.2 size `size_t TEEC_TempMemoryReference::size`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.28 TEEC_UUID Struct Reference

`#include <tee_client_api.h>`

Public Attributes

- uint32_t timeLow
- uint16_t timeMid
- uint16_t timeHiAndVersion
- uint8_t clockSeqAndNode [8]

12.28.1 Detailed Description

This type contains a Universally Unique Resource Identifier (UUID) type as defined in RFC4122. These UUID values are used to identify Trusted Applications.

12.28.2 Member Data Documentation

12.28.2.1 clockSeqAndNode `uint8_t TEEC_UUID::clockSeqAndNode[8]`

12.28.2.2 timeHiAndVersion `uint16_t TEEC_UUID::timeHiAndVersion`

12.28.2.3 timeLow `uint32_t TEEC_UUID::timeLow`

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12.28.2.4 timeMid `uint16_t TEEC_UUID::timeMid`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

12.29 TEEC_Value Struct Reference

`#include <tee_client_api.h>`

Public Attributes

- uint32_t a
- uint32_t b

12.29.1 Detailed Description

struct TEEC_Value - Small raw data container

Instead of allocating a shared memory buffer this structure can be used to pass small raw data between a client application and trusted code.

Parameters

a	The first integer value.
b	The second second value.

12.29.2 Member Data Documentation

12.29.2.1 a `uint32_t TEEC_Value::a`

12.29.2.2 b `uint32_t TEEC_Value::b`

The documentation for this struct was generated from the following file:

- ta-ref/api/include/tee_client_api.h

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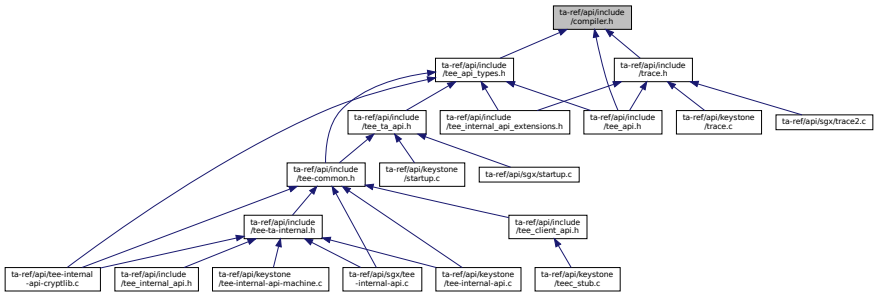
13 File Documentation

13.1 ta-ref/api/include/compiler.h File Reference

This graph shows which files directly or indirectly include this file:



13.2 compiler.h

Go to the documentation of this file.

```
1 /*
2  * Copyright (c) 2014, STMicroelectronics International N.V.
3  * All rights reserved.
4  *
5  * Redistribution and use in source and binary forms, with or without
6  * modification, are permitted provided that the following conditions are met:
7  *
8  * 1. Redistributions of source code must retain the above copyright notice,
9  * this list of conditions and the following disclaimer.
10 *
11 * 2. Redistributions in binary form must reproduce the above copyright notice,
12 * this list of conditions and the following disclaimer in the documentation
13 * and/or other materials provided with the distribution.
14 *
15 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
16 * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
17 * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
18 * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
19 * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
20 * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
21 * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
22 * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
23 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
24 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
25 * POSSIBILITY OF SUCH DAMAGE.
26 */
27
28 #ifndef COMPILER_H
29 #define COMPILER_H
30
31 #ifndef DOXYGEN_SHOULD_SKIP_THIS
32 /*
33  * Macros that should be used instead of using __attribute__ directly to
34  * ease portability and make the code easier to read.
35  */
36
37 #define __deprecated    __attribute__((deprecated))
38 #define __packed    __attribute__((packed))
39 #define __weak      __attribute__((weak))
40 #define __noreturn  __attribute__((noreturn))
41 #define __pure      __attribute__((pure))
42 #define __aligned(x)    __attribute__((aligned(x)))
43 #define __printf(a, b)  __attribute__((format(printf, a, b)))
44 #define __noinline  __attribute__((noinline))
45 #define __attr_const    __attribute__((__const__))
46 #define __unused    __attribute__((unused))
47 #define __maybe_unused  __attribute__((unused))
```

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```
48 #define __used      __attribute__((__used__))
49 #define __must_check    __attribute__((warn_unused_result))
50 #define __cold      __attribute__((__cold__))
51 #define __section(x)    __attribute__((section(x)))
52 #define __data      __section(".data")
53 #define __bss       __section(".bss")
54 #define __rodata    __section(".rodata")
55 #define __rodata_unpaged __section(".rodata.__unpaged")
56 #define __early_ta  __section(".rodata.early_ta")
57 #define __noprof    __attribute__((no_instrument_function))
58
59 #define __compiler_bswap64(x)   __builtin_bswap64((x))
60 #define __compiler_bswap32(x)   __builtin_bswap32((x))
61 #define __compiler_bswap16(x)   __builtin_bswap16((x))
62
63 #define __GCC_VERSION (__GNUC__ * 10000 + __GNUC_MINOR__ * 100 + \
64                __GNUC_PATCHLEVEL__)
65
66 #if __GCC_VERSION >= 50100 && !defined(__CHECKER__)
67 #define __HAVE_BUILTIN_OVERFLOW 1
68 #endif
69
70 #ifdef __HAVE_BUILTIN_OVERFLOW
71 #define __compiler_add_overflow(a, b, res) \
72     __builtin_add_overflow((a), (b), (res))
73
74 #define __compiler_sub_overflow(a, b, res) \
75     __builtin_sub_overflow((a), (b), (res))
76
77 #define __compiler_mul_overflow(a, b, res) \
78     __builtin_mul_overflow((a), (b), (res))
79 #else
80 /*
81  * Copied/inspired from https://www.fefe.de/intof.html
82  */
83 #define __INTOF_HALF_MAX_SIGNED(type) ((type)1 « (sizeof(type)*8-2))
84 #define __INTOF_MAX_SIGNED(type) (__INTOF_HALF_MAX_SIGNED(type) - 1 + \
85                 __INTOF_HALF_MAX_SIGNED(type))
86 #define __INTOF_MIN_SIGNED(type) (-1 - __INTOF_MAX_SIGNED(type))
87
88 #define __INTOF_MIN(type) ((type)-1 < 1?__INTOF_MIN_SIGNED(type):(type)0)
89 #define __INTOF_MAX(type) ((type)~__INTOF_MIN(type))
90
91 #define __INTOF_ASSIGN(dest, src) (__extension__({ \
92     typeof(src) __intof_x = (src); \
93     typeof(dest) __intof_y = __intof_x; \
94     (((uintmax_t)__intof_x == (uintmax_t)__intof_y) && \
95      ((__intof_x < 1) == (__intof_y < 1)) ? \
96         (void)((dest) = __intof_y) , 0 : 1); \
97 }))
98
99 #define __INTOF_ADD(c, a, b) (__extension__({ \
100     typeof(a) __intofa_a = (a); \
101     typeof(b) __intofa_b = (b); \
102     \
103     __intofa_b < 1 ? \
104         ((__INTOF_MIN(typeof(c)) - __intofa_b <= __intofa_a) ? \
105             __INTOF_ASSIGN((c), __intofa_a + __intofa_b) : 1) : \
106         ((__INTOF_MAX(typeof(c)) - __intofa_b >= __intofa_a) ? \
107             __INTOF_ASSIGN((c), __intofa_a + __intofa_b) : 1); \
108 }))
109
110 #define __INTOF_SUB(c, a, b) (__extension__({ \
111     typeof(a) __intofs_a = a; \
112     typeof(b) __intofs_b = b; \
113     \
114     __intofs_b < 1 ? \
115         ((__INTOF_MAX(typeof(c)) + __intofs_b >= __intofs_a) ? \
116             __INTOF_ASSIGN((c), __intofs_a - __intofs_b) : 1) : \
117         ((__INTOF_MIN(typeof(c)) + __intofs_b <= __intofs_a) ? \
118             __INTOF_ASSIGN((c), __intofs_a - __intofs_b) : 1); \
119 }))
120
121 /*
122  * Dealing with detecting overflow in multiplication of integers.
123  *
124  * First step is to remove two corner cases with the minum signed integer
125  * which can't be represented as a positive integer + sign.
126  * Multiply with 0 or 1 can't overflow, no checking needed of the operation,
127  * only if it can be assigned to the result.
128  *
129  * After the corner cases are eliminated we convert the two factors to
130  * positive unsigned values, keeping track of the original in another
131  * variable which is used at the end to determine the sign of the product.
132  *
133  *
```

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```
134  * The two terms (a and b) are divided into upper and lower half (x1 upper
135  * and x0 lower), so the product is:
136  * ((a1 « hshift) + a0) * ((b1 « hshift) + b0)
137  * which also is:
138  * ((a1 * b1) « (hshift * 2)) +                (T1)
139  * ((a1 * b0 + a0 * b1) « hshift) +                (T2)
140  * (a0 * b0)                              (T3)
141  *
142  * From this we can tell and (a1 * b1) has to be 0 or we'll overflow, that
143  * is, at least one of a1 or b1 has to be 0. Once this has been checked the
144  * addition: ((a1 * b0) « hshift) + ((a0 * b1) « hshift)
145  * isn't an addition as one of the terms will be 0.
146  *
147  * Since each factor in: (a0 * b0)
148  * only uses half the capicity of the underlaying type it can't overflow
149  *
150  * The addition of T2 and T3 can overflow so we use __INTOF_ADD() to
151  * perform that addition. If the addition succeeds without overflow the
152  * result is assigned the required sign and checked for overflow again.
153  */
154
155 #define __intof_mul_negate  ((__intof_oa < 1) != (__intof_ob < 1))
156 #define __intof_mul_hshift  (sizeof(uintmax_t) * 8 / 2)
157 #define __intof_mul_hmask   (UINTMAX_MAX » __intof_mul_hshift)
158 #define __intof_mul_a0      ((uintmax_t)(__intof_a) » __intof_mul_hshift)
159 #define __intof_mul_b0      ((uintmax_t)(__intof_b) » __intof_mul_hshift)
160 #define __intof_mul_a1      ((uintmax_t)(__intof_a) & __intof_mul_hmask)
161 #define __intof_mul_b1      ((uintmax_t)(__intof_b) & __intof_mul_hmask)
162 #define __intof_mul_t       (__intof_mul_a1 * __intof_mul_b0 + \
163                 __intof_mul_a0 * __intof_mul_b1)
164
165 #define __INTOF_MUL(c, a, b) (__extension__({ \
166     typeof(a) __intof_oa = (a); \
167     typeof(a) __intof_a = __intof_oa < 1 ? -__intof_oa : __intof_oa; \
168     typeof(b) __intof_ob = (b); \
169     typeof(b) __intof_b = __intof_ob < 1 ? -__intof_ob : __intof_ob; \
170     typeof(c) __intof_c; \
171     \
172     __intof_oa == 0 || __intof_ob == 0 || \
173     __intof_oa == 1 || __intof_ob == 1 ? \
174         __INTOF_ASSIGN((c), __intof_oa * __intof_ob) : \
175     (__intof_mul_a0 && __intof_mul_b0) || \
176      __intof_mul_t > __intof_mul_hmask ?  1 : \
177     __INTOF_ADD((__intof_c), __intof_mul_t « __intof_mul_hshift, \
178                 __intof_mul_a1 * __intof_mul_b1) ? 1 : \
179     __intof_mul_negate ? __INTOF_ASSIGN((c), -__intof_c) : \
180                 __INTOF_ASSIGN((c), __intof_c); \
181 }))
182
183 #define __compiler_add_overflow(a, b, res) __INTOF_ADD(*(res), (a), (b))
184 #define __compiler_sub_overflow(a, b, res) __INTOF_SUB(*(res), (a), (b))
185 #define __compiler_mul_overflow(a, b, res) __INTOF_MUL(*(res), (a), (b))
186
187 #endif
189 #define __compiler_compare_and_swap(p, oval, nval) \
190     __atomic_compare_exchange_n((p), (oval), (nval), true, \
191                     __ATOMIC_ACQUIRE, __ATOMIC_RELAXED) \
192
193 #define __compiler_atomic_load(p) __atomic_load_n((p), __ATOMIC_RELAXED)
194 #define __compiler_atomic_store(p, val) \
195     __atomic_store_n((p), (val), __ATOMIC_RELAXED)
196
197 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
198 #endif /*COMPILER_H*/
```

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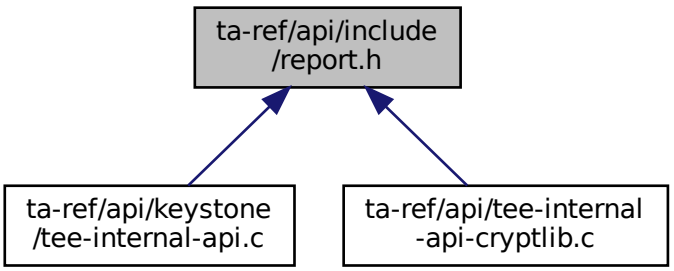
13.3 ta-ref/api/include/report.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

- struct enclave_report
- struct sm_report
- struct report

13.4 report.h

Go to the documentation of this file.

```
1
2 #ifndef _REPORT_H
3 #define _REPORT_H
4
5 #ifndef DOXYGEN_SHOULD_SKIP_THIS
6 #define MDSIZE  64
7 #define SIGNATURE_SIZE  64
8 #define PUBLIC_KEY_SIZE 32
9 #define ATTEST_DATA_MAXLEN  1024
10 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
11
12 /* attestation reports */
13 struct enclave_report
14 {
15   uint8_t hash[MDSIZE];
16   uint64_t data_len;
17   uint8_t data[ATTEST_DATA_MAXLEN];
18   uint8_t signature[SIGNATURE_SIZE];
19 };
20
21 struct sm_report
22 {
23   uint8_t hash[MDSIZE];
24   uint8_t public_key[PUBLIC_KEY_SIZE];
25   uint8_t signature[SIGNATURE_SIZE];
26 };
27
28 struct report
29 {
30   struct enclave_report enclave;
31   struct sm_report sm;
32   uint8_t dev_public_key[PUBLIC_KEY_SIZE];
33 };
34
35 #endif // _REPORT_H
```

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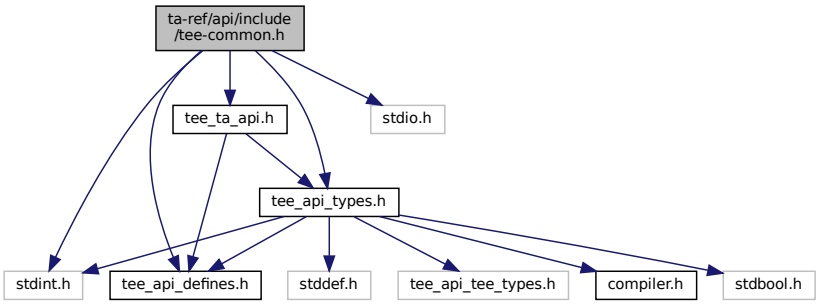
13.5 ta-ref/api/include/tee-common.h File Reference

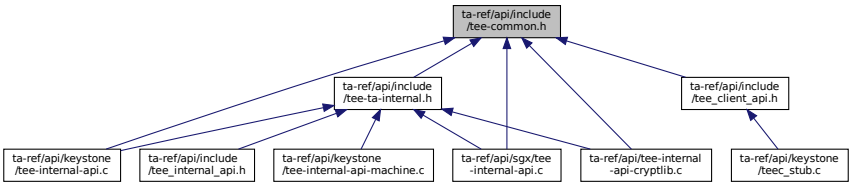
Common type and definitions of RISC-V TEE.

```
#include <stdint.h>
#include <stdio.h>
#include <tee_api_defines.h>
#include <tee_api_types.h>
#include <tee_ta_api.h>
```

Include dependency graph for tee-common.h:



This graph shows which files directly or indirectly include this file:



13.5.1 Detailed Description

Common type and definitions of RISC-V TEE.

draft RISC-V Internal TEE API

Author

Akira Tsukamoto, AIST

Date

2019/09/25

13.6 tee-common.h

Go to the documentation of this file.

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```
1 /*
2  * SPDX-License-Identifier: BSD-2-Clause
3  *
4  * Copyright (C) 2019 National Institute of Advanced Industrial Science
5  *                         and Technology (AIST)
6  * All rights reserved.
7  *
8  * Redistribution and use in source and binary forms, with or without
9  * modification, are permitted provided that the following conditions are met:
10  *
11  * 1. Redistributions of source code must retain the above copyright notice,
12  * this list of conditions and the following disclaimer.
13  *
14  * 2. Redistributions in binary form must reproduce the above copyright notice,
15  * this list of conditions and the following disclaimer in the documentation
16  * and/or other materials provided with the distribution.
17  *
18  * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
19  * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
20  * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
21  * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
22  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
23  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
24  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
25  * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
26  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
27  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
28  * POSSIBILITY OF SUCH DAMAGE.
29  */
38 #ifndef TEE_COMMON_H
39 #define TEE_COMMON_H
40
41 #include <stdint.h>
42 #include <stdio.h>
43
44 #ifdef __cplusplus
45 extern "C" {
46 #endif
47
48 #ifndef DOXYGEN_SHOULD_SKIP_THIS
49 #ifdef DEBUG
50 #define pr_deb(...)       do { printf(__VA_ARGS__); } while (0)
51 #else
52 #define pr_deb(...)       do { } while (0)
53 #endif /* DEBUG */
54 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
55
56 //#include <tee_api.h>
57 #include <tee_api_defines.h>
58 #include <tee_api_types.h>
59 #include <tee_ta_api.h>
60
61 //typedef uint32_t TEE_Result;
62
63 #ifdef __cplusplus
64 }
65 #endif
66
67 #endif /* TEE_COMMON_H */
```

13.7 ta-ref/api/include/tee-ta-internal.h File Reference

Candidate API list for Global Platform like RISC-V TEE.

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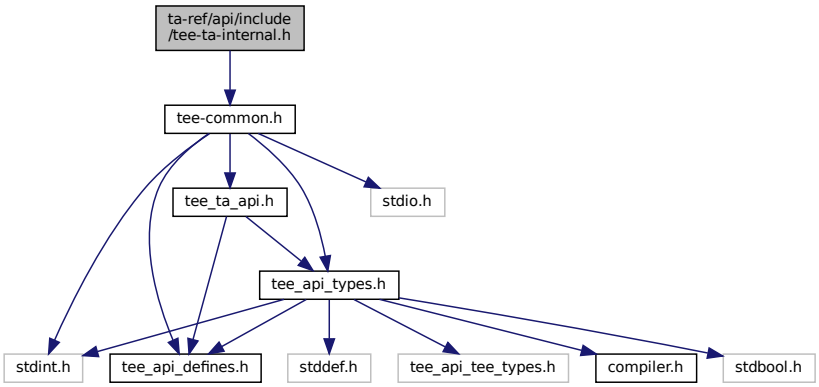
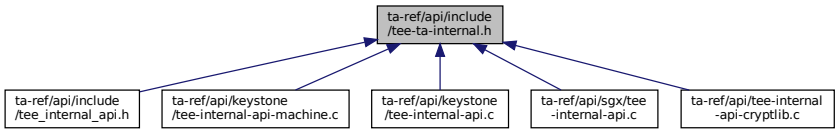
```
#include "tee-common.h"
```

Include dependency graph for tee-ta-internal.h:



This graph shows which files directly or indirectly include this file:



Functions

- void __attribute__ ((noreturn)) TEE_Panic(unsigned long code)
- void TEE_GetREETime (TEE_Time *time)

  Core Functions, Time Functions.
- void TEE_GetSystemTime (TEE_Time *time)

  Core Functions, Time Functions.
- TEE_Result GetRelTimeStart (uint64_t start)

  Core Functions, Time Functions.
- TEE_Result GetRelTimeEnd (uint64_t end)

  Core Functions, Time Functions.
- TEE_Result TEE_CreatePersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle attributes, const void *initialData, uint32_t initialDataLen, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_GetObjectInfo1 (TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_WriteObjectData (TEE_ObjectHandle object, const void *buffer, uint32_t size)

  Core Functions, Secure Storage Functions (data is isolated for each TA)

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- TEE_Result TEE_ReadObjectData (TEE_ObjectHandle object, void *buffer, uint32_t size, uint32_t *count)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_CloseObject (TEE_ObjectHandle object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_GenerateRandom (void *randomBuffer, uint32_t randomBufferLen)

  Crypto, common.
- TEE_Result TEE_AllocateOperation (TEE_OperationHandle *operation, uint32_t algorithm, uint32_t mode, uint32_t maxKeySize)

  Crypto, for all Crypto Functions.
- void TEE_FreeOperation (TEE_OperationHandle operation)

  Crypto, for all Crypto Functions.
- void TEE_DigestUpdate (TEE_OperationHandle operation, const void *chunk, uint32_t chunkSize)

  Crypto, Message Digest Functions.
- TEE_Result TEE_DigestDoFinal (TEE_OperationHandle operation, const void *chunk, uint32_t chunkLen, void *hash, uint32_t *hashLen)
- TEE_Result TEE_SetOperationKey (TEE_OperationHandle operation, TEE_ObjectHandle key)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEInit (TEE_OperationHandle operation, const void *nonce, uint32_t nonceLen, uint32_t tagLen, uint32_t AADLen, uint32_t payloadLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEUpdate (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- void TEE_AEUpdateAAD (TEE_OperationHandle operation, const void *AADdata, uint32_t AADdataLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEEncryptFinal (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen, void *tag, uint32_t *tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEDecryptFinal (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen, void *tag, uint32_t tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- void TEE_CipherInit (TEE_OperationHandle operation, const void *nonce, uint32_t nonceLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_CipherUpdate (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_GenerateKey (TEE_ObjectHandle object, uint32_t keySize, const TEE_Attribute *params, uint32_t paramCount)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AllocateTransientObject (TEE_ObjectType objectType, uint32_t maxKeySize, TEE_ObjectHandle *object)

  Crypto, Asymmetric key Verification Functions.
- void TEE_InitRefAttribute (TEE_Attribute *attr, uint32_t attributeID, const void *buffer, uint32_t length)

  Crypto, Asymmetric key Verification Functions.
- void TEE_InitValueAttribute (TEE_Attribute *attr, uint32_t attributeID, uint32_t a, uint32_t b)

  Crypto, Asymmetric key Verification Functions.
- void TEE_FreeTransientObject (TEE_ObjectHandle object)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AsymmetricSignDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, void *signature, uint32_t *signatureLen)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AsymmetricVerifyDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, const void *signature, uint32_t signatureLen)

  Crypto, Asymmetric key Verification Functions.

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13.7.1 Detailed Description

Candidate API list for Global Platform like RISC-V TEE.

draft RISC-V Internal TEE API

Author

Akira Tsukamoto, AIST

Date

2019/09/25

13.7.2 Function Documentation

13.7.2.1 __attribute__() `void __attribute__ ( (noreturn) )`

TEE_Panic() - Raises a panic in the Trusted Application instance.

When a Trusted Application calls the TEE_Panic function, the current instance shall be destroyed and all the resources opened by the instance shall be reclaimed. All sessions opened from the panicking instance on another TA shall be gracefully closed and all cryptographic objects and operations shall be closed properly.

Parameters

code	An informative panic code defined by the TA.

Returns

panic code will be returned.

TEE_Panic() - Raises a Panic in the Trusted Application instance

When a Trusted Application calls the TEE_Panic function, the current instance shall be destroyed and all the resources opened by the instance shall be reclaimed.

Parameters

ec	An informative panic code defined by the TA. May be displayed in traces if traces are available.

13.7.2.2 GetRelTimeEnd() `TEE_Result GetRelTimeEnd (`

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```
uint64_t end )
```

Core Functions, Time Functions.

Return the elapsed.

GetRelTimeEnd() - finds the real time of the end timing.

This function prints the ending time.

Parameters

end	End timing

Returns

0 If success

GetRelTimeStart() - find the real time of the end timing.

This function prints the End timing.

Parameters

end	End timing

Returns

0 if success else error occured

13.7.2.3 GetRelTimeStart()

```
TEE_Result GetRelTimeStart (
uint64_t start )
```

Core Functions, Time Functions.

Fast relative Time function which guarantees no hart switch or context switch between Trusted and Untrusted sides.

Most of the time ending up writing similar functions when only measuring the relative time in usec resolution which do not require the quality of the time itself but the distance of the two points.
For the usage above, the function does not have to return wall clock time.
Not prepared in both Keystone and GP.

GetRelTimeStart() - Gets the real time of the start timing.

This function prints the starting time.

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Parameters

start	Start timing

Returns

0 on success

GetRelTimeStart() - Gets the real time of the start timing.

Ths function prints the start timing.

Parameters

start	start timing

Returns

0 if success else error occured.

13.7.2.4 TEE_AEDecryptFinal()

```
TEE_Result TEE_AEDecryptFinal (
        TEE_OperationHandle operation,
        const void * srcData,
        uint32_t srcLen,
        void * destData,
        uint32_t * destLen,
        void * tag,
        uint32_t tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CCM, TEE_ALG_AES_GCM.

TEE_AEDecryptFinal() - Processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData.

This function completes the AE operation and compares the computed tag with the tag supplied in the parameter tag .The operation handle can be reused or newly initialized.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output

TEE_ERROR_MAC_INVALID If the computed tag does not match the supplied tag

13.7.2.5 TEE_AEEncryptFinal()

```
TEE_Result TEE_AEEncryptFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen,
    void * tag,
    uint32_t * tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CCM, TEE_ALG_AES_GCM.

TEE_AEEncryptFinal() - processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData .

TEE_AEEncryptFinal completes the AE operation and computes the tag. The operation handle can be reused or newly initialized. The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output or tag buffer is not large enoughto contain the output.

13.7.2.6 TEE_AEInit()

```
TEE_Result TEE_AEInit (
    TEE_OperationHandle operation,
    const void * nonce,
    uint32_t nonceLen,
    uint32_t tagLen,
```

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```
uint32_t AADLen,
uint32_t payloadLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CCM, TEE_ALG_AES_GCM.

TEE_AEInit() - Initializes an Authentication Encryption operation.

The operation must be in initial state and remains in the initial state afterwards.

Parameters

operation	A handle on the operation.
nonce	The operation nonce or IV
nonceLen	length of nonce
tagLen	Size in bits of the tag
AADLen	Length in bytes of the AAD
payloadLen	Length in bytes of the payload.

Returns

0 on success.

TEE_ERROR_NOT_SUPPORTED If the tag length is not supported by the algorithm.

13.7.2.7 TEE_AEUpdate()

```
TEE_Result TEE_AEUpdate (
TEE_OperationHandle operation,
const void * srcData,
uint32_t srcLen,
void * destData,
uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CCM, TEE_ALG_AES_GCM.

TEE_AEUpdate() - Accumulates data for an Authentication Encryption operation

This function describes Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data,no output is generated. when using this routine to decrypt the returned data may be corrupt since the integrity check is not performed until all the data has been processed. If this is a concern then only use the TEE_AEDecryptFinal routine.

Parameters

operation	Handle of a running AE operation.
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of the input buffer.
destData	Output buffer
destLen	length of the out put buffer.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER if the output buffer is not large enough to contain the output.

13.7.2.8 TEE_AEUpdateAAD()

```
void TEE_AEUpdateAAD (
        TEE_OperationHandle operation,
        const void * AADdata,
        uint32_t AADdataLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CCM, TEE_ALG_AES_GCM.

TEE_AEUpdateAAD() - Feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.

The TEE_AEUpdateAAD function feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation SHALL be in initial state and remains in initial state afterwards.

Parameters

operation	Handle on the AE operation
AADdata	Input buffer containing the chunk of AAD
AADdataLen	length of the chunk of AAD.

13.7.2.9 TEE_AllocateOperation()

```
TEE_Result TEE_AllocateOperation (
        TEE_OperationHandle * operation,
        uint32_t algorithm,
        uint32_t mode,
        uint32_t maxKeySize )
```

Crypto, for all Crypto Functions.

All Crypto Functions use TEE_OperationHandle∗ operation instances.
Create Crypto instance.

TEE_AllocateOperation() - Allocates a handle for a new cryptographic operation and sets the mode and algorithm type.

If this function does not return with TEE_SUCCESS then there is no valid handle value.Once a cryptographic operation has been created, the implementation shall guarantee that all resources necessary for the operation are allocated and that any operation with a key of at most maxKeySize bits can be performed. For algorithms that take multiple keys, for example the AES XTS algorithm, the maxKeySize parameter specifies the size of the largest key. It is up to the implementation to properly allocate space for multiple keys if the algorithm so requires.

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Parameters

operation	reference to generated operation handle.
algorithm	One of the cipher algorithms.
mode	The operation mode.
maxKeySize	Maximum key size in bits for the operation.

Returns

0 in case of success

TEE_ERROR_OUT_OF_MEMORY If there are not enough resources to allocate the operation.

TEE_ERROR_NOT_SUPPORTED If the mode is not compatible with the algorithm or key size or if the algorithm is not one of the listed algorithms or if maxKeySize is not appropriate for the algorithm.

13.7.2.10 TEE_AllocateTransientObject()

```
TEE_Result TEE_AllocateTransientObject (
    TEE_ObjectType objectType,
    uint32_t maxKeySize,
    TEE_ObjectHandle * object )
```

Crypto, Asymmetric key Verification Functions.

Create object storing asymmetric key.

TEE_AllocateTransientObject() - Allocates an uninitialized transient object. Transient objects are used to hold a cryptographic object (key or key-pair).

The value TEE_KEYSIZE_NO_KEY should be used for maxObjectSize for object types that do not require a key so that all the container resources can be pre-allocated. As allocated, the container is uninitialized. It can be initialized by subsequently importing the object material,generating an object, deriving an object, or loading an object from the Trusted Storage.

Parameters

objectType	Type of uninitialized object container to be created
maxKeySize	Key Size of the object.
object	Filled with a handle on the newly created key container.

Returns

0 on success

TEE_ERROR_OUT_OF_MEMORY If not enough resources are available to allocate the object handle.

TEE_ERROR_NOT_SUPPORTED If the key size is not supported or the object type is not supported.

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13.7.2.11 TEE_AsymmetricSignDigest()

```
TEE_Result TEE_AsymmetricSignDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    void * signature,
    uint32_t * signatureLen )
```

Crypto, Asymmetric key Verification Functions.

Sign a message digest within an asymmetric key operation.
Keystone has ed25519_sign().
Equivalent in openssl is EVP_DigestSign().

TEE_AsymmetricSignDigest() - Signs a message digest within an asymmetric operation.

Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

0 on sccess

TEE_ERROR_SHORT_BUFFER If the signature buffer is not large enough to hold the result

13.7.2.12 TEE_AsymmetricVerifyDigest()

```
TEE_Result TEE_AsymmetricVerifyDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    const void * signature,
    uint32_t signatureLen )
```

Crypto, Asymmetric key Verification Functions.

Verifies a message digest signature within an asymmetric key operation.
Keystone has ed25519_verify().
Equivalent in openssl is EVP_DigestVerify().

TEE_AsymmetricVerifyDigest() - verifies a message digest signature within an asymmetric operation.

This function describes the message digest signature verify by calling ed25519_verify().

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Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param.
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

TEE_SUCCESS on success

TEE_ERROR_SIGNATURE_INVALID if the signature is invalid.

13.7.2.13 TEE_CipherInit() `void TEE_CipherInit (`

```
TEE_OperationHandle operation,
const void * nonce,
uint32_t nonceLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Supports TEE_ALG_AES_CBC.

TEE_CipherInit() - starts the symmetric cipher operation.

The operation shall have been associated with a key. If the operation is in active state, it is reset and then initialized. If the operation is in initial state, it is moved to active state.

Parameters

operation	A handle on an opened cipher operation setup with a key
nonce	Buffer containing the operation Initialization Vector as appropriate.
nonceLen	length of the buffer

13.7.2.14 TEE_CipherUpdate() `TEE_Result TEE_CipherUpdate (`

```
TEE_OperationHandle operation,
const void * srcData,
uint32_t srcLen,
void * destData,
uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

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Supports TEE_ALG_AES_CBC.

TEE_CipherUpdate() - encrypts or decrypts input data.

Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data, no output is generated. The cipher operation is finalized with a call to TEE_CipherDoFinal .The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation SHALL be in active state.

Parameters

operation	Handle of a running Cipher operation
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of input buffer
destData	output buffer
destLen	ouput buffer length.

Returns

0 on success else

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output. In this case, the input is not fed into the algorithm.

13.7.2.15 TEE_CloseObject() `void TEE_CloseObject ( TEE_ObjectHandle object )`

Core Functions, Secure Storage Functions (data is isolated for each TA)

Destroy object (key, key-pair or Data).

TEE_CloseObject() - Closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

Parameters

object	Handle of the object.

Returns

TEE_SUCCESS if success else error occured.

TEE_CloseObject() - Function closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

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Parameters

object	Handle of the object

Returns

TEE_SUCCESS if success else error occured.

13.7.2.16 TEE_CreatePersistentObject()

```
TEE_Result TEE_CreatePersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle attributes,
    const void * initialData,
    uint32_t initialDataLen,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

Create persistent object (key, key-pair or Data).
For the people who have not written code on GP then probably do not need to care the meaning of what is Persistent Object is, since the following are enough to use secure storage feature.

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

In this function an initial data stream content returns either a handle on the created object or TEE_HANDLE_NULL upon failure.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle which contains the opened handle upon successful completion

Returns

0 if success else error occured.

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

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An initial data stream content, and optionally returns either a handle on the created object, or TEE_HANDLE_NULL upon failure.

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Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success, else error occured.

13.7.2.17 TEE_DigestDoFinal()

```
TEE_Result TEE_DigestDoFinal (
    TEE_OperationHandle operation,
    const void * chunk,
    uint32_t chunkLen,
    void * hash,
    uint32_t * hashLen )
```

Function accumulates message data for hashing.

TEE_DigestDoFinal() - Finalizes the message digest operation and produces the message hash.

This function finalizes the message digest operation and produces the message hash. Afterwards the Message Digest operation is reset to initial state and can be reused.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed.
chunkLen	size of the chunk.
hash	Output buffer filled with the message hash.
hashLen	lenth of the mesaage hash.

Returns

0 on success

TEE_ERROR_SHORT_BUFFER If the output buffer is too small. In this case, the operation is not finalized.

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13.7.2.18 TEE_DigestUpdate() `void TEE_DigestUpdate (`

```
TEE_OperationHandle operation,
const void * chunk,
uint32_t chunkSize )
```

Crypto, Message Digest Functions.

Function accumulates message data for hashing.

TEE_DigestUpdate()- Accumulates message data for hashing.

This function describes the message does not have to be block aligned. Subsequent calls to this function are possible.The operation may be in either initial or active state and becomes active.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed
chunkSize	size of the chunk.

13.7.2.19 TEE_FreeOperation() `void TEE_FreeOperation (`

```
TEE_OperationHandle operation )
```

Crypto, for all Crypto Functions.

All Crypto Functions use TEE_OperationHandle∗ operation instances.
Destroy Crypto instance.

TEE_FreeOperation() - Deallocates all resources associated with an operation handle.

This function deallocates all resources associated with an operation handle. After this function is called, the operation handle is no longer valid. All cryptographic material in the operation is destroyed. The function does nothing if operation is TEE_HANDLE_NULL.

Parameters

operation	Reference to operation handle.

Returns

nothing after the operation free.

13.7.2.20 TEE_FreeTransientObject() `void TEE_FreeTransientObject (`

```
TEE_ObjectHandle object )
```

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Crypto, Asymmetric key Verification Functions.

Destroy object storing asymmetric key.

TEE_FreeTransientObject() - Deallocates a transient object previously allocated with TEE_AllocateTransientObject .

this function describes the object handle is no longer valid and all resources associated with the transient object shall have been reclaimed after the TEE_AllocateTransientObject() call.

Parameters

object	Handle on the object to free.

13.7.2.21 TEE_GenerateKey()

```
TEE_Result TEE_GenerateKey (
    TEE_ObjectHandle object,
    uint32_t keySize,
    const TEE_Attribute * params,
    uint32_t paramCount )
```

Crypto, Asymmetric key Verification Functions.

Generate asymmetric keypair.

TEE_GenerateKey () - Generates a random key or a key-pair and populates a transient key object with the generated key material.

The size of the desired key is passed in the keySize parameter and shall be less than or equal to the maximum key size specified when the transient object was created.

Parameters

object	Handle on an uninitialized transient key to populate with the generated key.
keySize	Requested key size shall be less than or equal to the maximum key size specified when the object container was created
params	Parameters for the key generation.
paramCount	The values of all parameters are copied nto the object so that the params array and all the memory buffers it points to may be freed after this routine returns without affecting the object.

Returns

0 on succes

TEE_ERROR_BAD_PARAMETERS If an incorrect or inconsistent attribute is detected. The checks that are performed depend on the implementation.

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13.7.2.22 TEE_GenerateRandom() `void TEE_GenerateRandom (`

```
    void * randomBuffer,
    uint32_t randomBufferLen )
```

Crypto, common.

Random Data Generation Function. The quality of the random is implementation dependent.
I am not sure this should be in Keystone or not, but it is very handy.
Good to have adding a way to check the quality of the random implementation.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random buffer length and is stored in to random Buffer by calling wc_↩
RNG_GenerateBlock().If ret is not equal
to 0 then TEE_Panic is called.

Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

Returns

random data random data will be returned.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random bufferlength and is stored in to randomBuffer by calling sgx_read↩
_rand().

Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

13.7.2.23 TEE_GetObjectInfo1() `TEE_Result TEE_GetObjectInfo1 (`

```
    TEE_ObjectHandle object,
    TEE_ObjectInfo * objectInfo )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

Get length of object required before reading the object.

TEE_GetObjectInfo1() - Returns the characteristics of an object.

This function returns a handle which can be used to access the object's attributes and data stream.

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Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

TEE_GetObjectInfo1() - Function returns the characteristics of an object.

It returns a handle that can be used to access the object's attributes and data stream.

Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

13.7.2.24 TEE_GetREETime() `void TEE_GetREETime ( TEE_Time * time )`

Core Functions, Time Functions.

Wall clock time of host OS, expressed in the number of seconds since 1970-01-01 UTC.
This could be implemented on Keystone using ocall.

TEE_GetREETime() - Retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of
the REE.

Parameters

time	Filled with the number of seconds and milliseconds

TEE_GetREETime() - Function retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of the REE.

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Parameters

time	Filled with the number of seconds and milliseconds.

13.7.2.25 TEE_GetSystemTime() `void TEE_GetSystemTime (`

```
TEE_Time * time )
```

Core Functions, Time Functions.

Time of TEE-controlled secure timer or Host OS time, implementation dependent.

TEE_GetSystemTime() - Retrieves the current system time.

This function describes the system time has an arbitrary implementation
defined origin that can vary across TA instances. The minimum guarantee
is that the system time shall be monotonic for a given TA instance.

Parameters

time	Filled with the number of seconds and milliseconds

TEE_GetSystemTime() - Retrieves the current system time.

The system time has an arbitrary implementation-defined origin that can vary across TA instances

Parameters

time	Filled with the number of seconds and milliseconds.

13.7.2.26 TEE_InitRefAttribute() `void TEE_InitRefAttribute (`

```
TEE_Attribute * attr,
uint32_t attributeID,
const void * buffer,
uint32_t length )
```

Crypto, Asymmetric key Verification Functions.

Storing asymmetric key.

TEE_InitRefAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

In TEE_InitRefAttribute () only the buffer pointer is copied, not the content of the buffer. This means that the attribute structure maintains a pointer back to the supplied buffer. It is the responsibility of the TA author to ensure that the contents of the buffer maintain their value until the attributes array is no longer in use.

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Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
buffer	input buffer that holds the content of the attribute.
length	buffer length.

13.7.2.27 TEE_InitValueAttribute()

```
void TEE_InitValueAttribute (
    TEE_Attribute * attr,
    uint32_t attributeID,
    uint32_t a,
    uint32_t b )
```

Crypto, Asymmetric key Verification Functions.

Storing asymmetric key.

TEE_InitValueAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
a	unsigned integer value to assign to the a member of the attribute structure.
b	unsigned integer value to assign to the b member of the attribute structure

13.7.2.28 TEE_OpenPersistentObject()

```
TEE_Result TEE_OpenPersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

Open persistent object.

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle which can be used to access the object's attributes and data stream.

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Parameters

storageID	The storage to use
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success else error occured.

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle that can be used to access the object's attributes and data stream.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success, else error occured.

13.7.2.29 TEE_ReadObjectData()

```
TEE_Result TEE_ReadObjectData (
    TEE_ObjectHandle object,
    void * buffer,
    uint32_t size,
    uint32_t * count )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

Read object.

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion of TEE_ReadObjectData sets the number of bytes actually read in the "uint32_t" pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

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Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

Returns

TEE_SUCCESS if success else error occured.

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion TEE_ReadObjectData sets the number of bytes actually read in the uint32_t pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

Returns

TEE_SUCCESS if success, else error occured.

13.7.2.30 TEE_SetOperationKey() `TEE_Result TEE_SetOperationKey ( TEE_OperationHandle operation, TEE_ObjectHandle key )`

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

Set symmetric key used in operation.

TEE_SetOperationKey() - Programs the key of an operation; that is, it associates an operation with a key.

The key material is copied from the key object handle into the operation. After the key has been set, there is no longer any link between the operation and the key object. The object handle can be closed or reset and this will not affect the operation. This copied material exists until the operation is freed using TEE_FreeOperation or another key is set into the operation.

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Parameters

operation	Operation handle.
key	A handle on a key object.

Returns

0 on success return

TEE_ERROR_CORRUPT_OBJECT If the object is corrupt. The object handle is closed.

TEE_ERROR_STORAGE_NOT_AVAILABLE If the persistent object is stored in a storage area which is currently inaccessible.

13.7.2.31 TEE_WriteObjectData()

```
TEE_Result TEE_WriteObjectData (
    TEE_ObjectHandle object,
    const void * buffer,
    uint32_t size )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

Write object.

TEE_WriteObjectData() - Writes the buffer data in to persistent objects.

In this function it checks if object is present or not, the encryption/ decryption buffer is taken by calling mbedtls_aes↩_crypt_cbc() then that buffer data is encrypted and mapped to object.On the base of object creation TEE_SUCCESS appears else TEE_ERROR_GENERIC appears.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

TEE_WriteObjectData() - writes size bytes from the buffer pointed to by buffer to the data stream associated with the open object handle object.

If the current data position points before the end-of-stream, then size bytes are written to the data stream, overwriting bytes starting at the current data position. If the current data position points beyond the stream's end, then the data stream is first extended with zero bytes until the length indicated by the data position indicator is reached, and then size bytes are written to the stream.

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Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

13.8 tee-ta-internal.h

Go to the documentation of this file.

```
1 /*
2  * SPDX-License-Identifier: BSD-2-Clause
3  *
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24  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
25  * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
26  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
27  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
28  * POSSIBILITY OF SUCH DAMAGE.
29  */
37 #ifndef TA_INTERNAL_TEE_H
38 #define TA_INTERNAL_TEE_H
39
40 #include "tee-common.h"
41
42 #ifdef __cplusplus
43 extern "C" {
44 #endif
45
46 void __attribute__((noreturn)) TEE_Panic(unsigned long code);
47
49
53 void TEE_GetREETime(TEE_Time *time);
54
56
58 /* Wall clock time is important for verifying certificates. */
59 void TEE_GetSystemTime(TEE_Time *time);
60
62
69 /* Start timer */
70 TEE_Result GetRelTimeStart(uint64_t start);
71
73
76 TEE_Result GetRelTimeEnd(uint64_t end);
77
79
85 TEE_Result TEE_CreatePersistentObject(uint32_t storageID, const void *objectID,
86                                       uint32_t objectIDLen, uint32_t flags,
87                                       TEE_ObjectHandle attributes,
88                                       const void *initialData,
```

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```
89                                      uint32_t initialDataLen,
90                                      TEE_ObjectHandle *object);
92
93 TEE_Result TEE_OpenPersistentObject(uint32_t storageID, const void *objectID,
94                                     uint32_t objectIDLen, uint32_t flags,
95                                     TEE_ObjectHandle *object);
97
98 TEE_Result TEE_GetObjectInfo1(TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo);
100
101 TEE_Result TEE_WriteObjectData(TEE_ObjectHandle object, const void *buffer,
102                                uint32_t size);
105 TEE_Result TEE_ReadObjectData(TEE_ObjectHandle object, void *buffer,
106                               uint32_t size, uint32_t *count);
108
109 void TEE_CloseObject(TEE_ObjectHandle object);
110
111
113
119 void TEE_GenerateRandom(void *randomBuffer, uint32_t randomBufferLen);
120
122
124 TEE_Result TEE_AllocateOperation(TEE_OperationHandle *operation,
125                                  uint32_t algorithm, uint32_t mode,
126                                  uint32_t maxKeySize);
128
130 void TEE_FreeOperation(TEE_OperationHandle operation);
131
132
134
135 void TEE_DigestUpdate(TEE_OperationHandle operation,
136                       const void *chunk, uint32_t chunkSize);
138 TEE_Result TEE_DigestDoFinal(TEE_OperationHandle operation, const void *chunk,
139                              uint32_t chunkLen, void *hash, uint32_t *hashLen);
140
142
143 TEE_Result TEE_SetOperationKey(TEE_OperationHandle operation,
144                     TEE_ObjectHandle key);
146
147 TEE_Result TEE_AEInit(TEE_OperationHandle operation, const void *nonce,
148                       uint32_t nonceLen, uint32_t tagLen, uint32_t AADLen,
149                       uint32_t payloadLen);
151
152 TEE_Result TEE_AEUpdate(TEE_OperationHandle operation, const void *srcData,
153                         uint32_t srcLen, void *destData, uint32_t *destLen);
155
156 void TEE_AEUpdateAAD(TEE_OperationHandle operation, const void *AADdata,
157              uint32_t AADdataLen);
159
160 TEE_Result TEE_AEEncryptFinal(TEE_OperationHandle operation,
161                               const void *srcData, uint32_t srcLen,
162                               void *destData, uint32_t *destLen, void *tag,
163                               uint32_t *tagLen);
165
166 TEE_Result TEE_AEDecryptFinal(TEE_OperationHandle operation,
167                               const void *srcData, uint32_t srcLen,
168                               void *destData, uint32_t *destLen, void *tag,
169                               uint32_t tagLen);
170
172
173 void TEE_CipherInit(TEE_OperationHandle operation, const void *nonce,
174            uint32_t nonceLen);
176
177 TEE_Result TEE_CipherUpdate(TEE_OperationHandle operation, const void *srcData,
178                 uint32_t srcLen, void *destData, uint32_t *destLen);
179
181
182 TEE_Result TEE_GenerateKey(TEE_ObjectHandle object, uint32_t keySize,
183                const TEE_Attribute *params, uint32_t paramCount);
185
186 TEE_Result TEE_AllocateTransientObject(TEE_ObjectType objectType,
187                                        uint32_t maxKeySize,
188                                        TEE_ObjectHandle *object);
190
191 void TEE_InitRefAttribute(TEE_Attribute *attr, uint32_t attributeID,
192                           const void *buffer, uint32_t length);
194
195 void TEE_InitValueAttribute(TEE_Attribute *attr, uint32_t attributeID,
196                 uint32_t a, uint32_t b);
198
199 void TEE_FreeTransientObject(TEE_ObjectHandle object);
200
202
206 TEE_Result TEE_AsymmetricSignDigest(TEE_OperationHandle operation,
207                                     const TEE_Attribute *params,
208                                     uint32_t paramCount, const void *digest,
```

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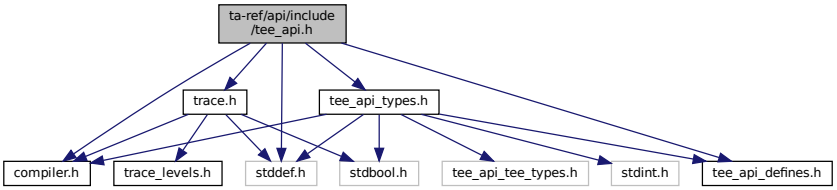
```
209                                     uint32_t digestLen, void *signature,
210                                     uint32_t *signatureLen);
212
216 TEE_Result TEE_AsymmetricVerifyDigest(TEE_OperationHandle operation,
217                                       const TEE_Attribute *params,
218                                       uint32_t paramCount, const void *digest,
219                                       uint32_t digestLen, const void *signature,
220                                       uint32_t signatureLen);
221
222 #ifdef __cplusplus
223 }
224 #endif
225
226 #endif /* TA_INTERNAL_TEE_H */
```

13.9 ta-ref/api/include/tee_api.h File Reference

```
#include <stddef.h>
#include <compiler.h>
#include <tee_api_defines.h>
#include <tee_api_types.h>
#include <trace.h>
```

Include dependency graph for tee_api.h:



Functions

- TEE_Result TEE_GetPropertyAsString (TEE_PropSetHandle propsetOrEnumerator, const char *name, char *valueBuffer, uint32_t *valueBufferLen)
- TEE_Result TEE_GetPropertyAsBool (TEE_PropSetHandle propsetOrEnumerator, const char *name, bool *value)
- TEE_Result TEE_GetPropertyAsU32 (TEE_PropSetHandle propsetOrEnumerator, const char *name, uint32_t *value)
- TEE_Result TEE_GetPropertyAsBinaryBlock (TEE_PropSetHandle propsetOrEnumerator, const char *name, void *valueBuffer, uint32_t *valueBufferLen)
- TEE_Result TEE_GetPropertyAsUUID (TEE_PropSetHandle propsetOrEnumerator, const char *name, TEE_UUID *value)
- TEE_Result TEE_GetPropertyAsIdentity (TEE_PropSetHandle propsetOrEnumerator, const char *name, TEE_Identity *value)
- TEE_Result TEE_AllocatePropertyEnumerator (TEE_PropSetHandle *enumerator)
- void TEE_FreePropertyEnumerator (TEE_PropSetHandle enumerator)
- void TEE_StartPropertyEnumerator (TEE_PropSetHandle enumerator, TEE_PropSetHandle propSet)
- void TEE_ResetPropertyEnumerator (TEE_PropSetHandle enumerator)
- TEE_Result TEE_GetPropertyName (TEE_PropSetHandle enumerator, void *nameBuffer, uint32_t *name↩ BufferLen)
- TEE_Result TEE_GetNextProperty (TEE_PropSetHandle enumerator)
- void TEE_Panic (TEE_Result panicCode)

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- TEE_Result TEE_OpenTASession (const TEE_UUID *destination, uint32_t cancellationRequestTimeout, uint32_t paramTypes, TEE_Param params[TEE_NUM_PARAMS], TEE_TASessionHandle *session, uint32_t *returnOrigin)
- void TEE_CloseTASession (TEE_TASessionHandle session)
- TEE_Result TEE_InvokeTACommand (TEE_TASessionHandle session, uint32_t cancellationRequestTimeout, uint32_t commandID, uint32_t paramTypes, TEE_Param params[TEE_NUM_PARAMS], uint32_t *returnOrigin)
- bool TEE_GetCancellationFlag (void)
- bool TEE_UnmaskCancellation (void)
- bool TEE_MaskCancellation (void)
- TEE_Result TEE_CheckMemoryAccessRights (uint32_t accessFlags, void *buffer, uint32_t size)
- void TEE_SetInstanceData (const void *instanceData)
- const void * TEE_GetInstanceData (void)
- void * TEE_Malloc (uint32_t size, uint32_t hint)
- void * TEE_Realloc (void *buffer, uint32_t newSize)
- void TEE_Free (void *buffer)
- void * TEE_MemMove (void *dest, const void *src, uint32_t size)
- int32_t TEE_MemCompare (const void *buffer1, const void *buffer2, uint32_t size)
- void * TEE_MemFill (void *buff, uint32_t x, uint32_t size)
- void TEE_GetObjectInfo (TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo)
- TEE_Result TEE_GetObjectInfo1 (TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_RestrictObjectUsage (TEE_ObjectHandle object, uint32_t objectUsage)
- TEE_Result TEE_RestrictObjectUsage1 (TEE_ObjectHandle object, uint32_t objectUsage)
- TEE_Result TEE_GetObjectBufferAttribute (TEE_ObjectHandle object, uint32_t attributeID, void *buffer, uint32_t *size)
- TEE_Result TEE_GetObjectValueAttribute (TEE_ObjectHandle object, uint32_t attributeID, uint32_t *a, uint32_t *b)
- void TEE_CloseObject (TEE_ObjectHandle object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_AllocateTransientObject (TEE_ObjectType objectType, uint32_t maxKeySize, TEE_ObjectHandle *object)

  Crypto, Asymmetric key Verification Functions.
- void TEE_FreeTransientObject (TEE_ObjectHandle object)

  Crypto, Asymmetric key Verification Functions.
- void TEE_ResetTransientObject (TEE_ObjectHandle object)
- TEE_Result TEE_PopulateTransientObject (TEE_ObjectHandle object, const TEE_Attribute *attrs, uint32_t attrCount)
- void TEE_InitRefAttribute (TEE_Attribute *attr, uint32_t attributeID, const void *buffer, uint32_t length)

  Crypto, Asymmetric key Verification Functions.
- void TEE_InitValueAttribute (TEE_Attribute *attr, uint32_t attributeID, uint32_t a, uint32_t b)

  Crypto, Asymmetric key Verification Functions.
- void TEE_CopyObjectAttributes (TEE_ObjectHandle destObject, TEE_ObjectHandle srcObject)
- TEE_Result TEE_CopyObjectAttributes1 (TEE_ObjectHandle destObject, TEE_ObjectHandle srcObject)
- TEE_Result TEE_GenerateKey (TEE_ObjectHandle object, uint32_t keySize, const TEE_Attribute *params, uint32_t paramCount)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_CreatePersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle attributes, const void *initialData, uint32_t initialDataLen, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)

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- void TEE_CloseAndDeletePersistentObject (TEE_ObjectHandle object)
- TEE_Result TEE_CloseAndDeletePersistentObject1 (TEE_ObjectHandle object)
- TEE_Result TEE_RenamePersistentObject (TEE_ObjectHandle object, const void *newObjectID, uint32_t newObjectIDLen)
- TEE_Result TEE_AllocatePersistentObjectEnumerator (TEE_ObjectEnumHandle *objectEnumerator)
- void TEE_FreePersistentObjectEnumerator (TEE_ObjectEnumHandle objectEnumerator)
- void TEE_ResetPersistentObjectEnumerator (TEE_ObjectEnumHandle objectEnumerator)
- TEE_Result TEE_StartPersistentObjectEnumerator (TEE_ObjectEnumHandle objectEnumerator, uint32_t storageID)
- TEE_Result TEE_GetNextPersistentObject (TEE_ObjectEnumHandle objectEnumerator, TEE_ObjectInfo *objectInfo, void *objectID, uint32_t *objectIDLen)
- TEE_Result TEE_ReadObjectData (TEE_ObjectHandle object, void *buffer, uint32_t size, uint32_t *count)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_WriteObjectData (TEE_ObjectHandle object, const void *buffer, uint32_t size)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_TruncateObjectData (TEE_ObjectHandle object, uint32_t size)
- TEE_Result TEE_SeekObjectData (TEE_ObjectHandle object, int32_t offset, TEE_Whence whence)
- TEE_Result TEE_AllocateOperation (TEE_OperationHandle *operation, uint32_t algorithm, uint32_t mode, uint32_t maxKeySize)

  Crypto, for all Crypto Functions.
- void TEE_FreeOperation (TEE_OperationHandle operation)

  Crypto, for all Crypto Functions.
- void TEE_GetOperationInfo (TEE_OperationHandle operation, TEE_OperationInfo *operationInfo)
- TEE_Result TEE_GetOperationInfoMultiple (TEE_OperationHandle operation, TEE_OperationInfoMultiple *operationInfoMultiple, uint32_t *operationSize)
- void TEE_ResetOperation (TEE_OperationHandle operation)
- TEE_Result TEE_SetOperationKey (TEE_OperationHandle operation, TEE_ObjectHandle key)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_SetOperationKey2 (TEE_OperationHandle operation, TEE_ObjectHandle key1, TEE_ObjectHandle key2)
- void TEE_CopyOperation (TEE_OperationHandle dstOperation, TEE_OperationHandle srcOperation)
- TEE_Result TEE_IsAlgorithmSupported (uint32_t algId, uint32_t element)
- void TEE_DigestUpdate (TEE_OperationHandle operation, const void *chunk, uint32_t chunkSize)

  Crypto, Message Digest Functions.
- TEE_Result TEE_DigestDoFinal (TEE_OperationHandle operation, const void *chunk, uint32_t chunkLen, void *hash, uint32_t *hashLen)
- void TEE_CipherInit (TEE_OperationHandle operation, const void *IV, uint32_t IVLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_CipherUpdate (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_CipherDoFinal (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)
- void TEE_MACInit (TEE_OperationHandle operation, const void *IV, uint32_t IVLen)
- void TEE_MACUpdate (TEE_OperationHandle operation, const void *chunk, uint32_t chunkSize)
- TEE_Result TEE_MACComputeFinal (TEE_OperationHandle operation, const void *message, uint32_t messageLen, void *mac, uint32_t *macLen)
- TEE_Result TEE_MACCompareFinal (TEE_OperationHandle operation, const void *message, uint32_t messageLen, const void *mac, uint32_t macLen)
- TEE_Result TEE_AEInit (TEE_OperationHandle operation, const void *nonce, uint32_t nonceLen, uint32_t tagLen, uint32_t AADLen, uint32_t payloadLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- void TEE_AEUpdateAAD (TEE_OperationHandle operation, const void *AADdata, uint32_t AADdataLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.

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- TEE_Result TEE_AEUpdate (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEEncryptFinal (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen, void *tag, uint32_t *tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEDecryptFinal (TEE_OperationHandle operation, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen, void *tag, uint32_t tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AsymmetricEncrypt (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)
- TEE_Result TEE_AsymmetricDecrypt (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *srcData, uint32_t srcLen, void *destData, uint32_t *destLen)
- TEE_Result TEE_AsymmetricSignDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, void *signature, uint32_t *signatureLen)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AsymmetricVerifyDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, const void *signature, uint32_t signatureLen)

  Crypto, Asymmetric key Verification Functions.
- void TEE_DeriveKey (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, TEE_ObjectHandle derivedKey)
- void TEE_GenerateRandom (void *randomBuffer, uint32_t randomBufferLen)

  Crypto, common.
- void TEE_GetSystemTime (TEE_Time *time)

  Core Functions, Time Functions.
- TEE_Result TEE_Wait (uint32_t timeout)
- TEE_Result TEE_GetTAPersistentTime (TEE_Time *time)
- TEE_Result TEE_SetTAPersistentTime (const TEE_Time *time)
- void TEE_GetREETime (TEE_Time *time)

  Core Functions, Time Functions.
- uint32_t TEE_BigIntFMMSizeInU32 (uint32_t modulusSizeInBits)
- uint32_t TEE_BigIntFMMContextSizeInU32 (uint32_t modulusSizeInBits)
- void TEE_BigIntInit (TEE_BigInt *bigInt, uint32_t len)
- void TEE_BigIntInitFMMContext (TEE_BigIntFMMContext *context, uint32_t len, const TEE_BigInt *modulus)
- void TEE_BigIntInitFMM (TEE_BigIntFMM *bigIntFMM, uint32_t len)
- TEE_Result TEE_BigIntConvertFromOctetString (TEE_BigInt *dest, const uint8_t *buffer, uint32_t bufferLen, int32_t sign)
- TEE_Result TEE_BigIntConvertToOctetString (uint8_t *buffer, uint32_t *bufferLen, const TEE_BigInt *bigInt)
- void TEE_BigIntConvertFromS32 (TEE_BigInt *dest, int32_t shortVal)
- TEE_Result TEE_BigIntConvertToS32 (int32_t *dest, const TEE_BigInt *src)
- int32_t TEE_BigIntCmp (const TEE_BigInt *op1, const TEE_BigInt *op2)
- int32_t TEE_BigIntCmpS32 (const TEE_BigInt *op, int32_t shortVal)
- void TEE_BigIntShiftRight (TEE_BigInt *dest, const TEE_BigInt *op, size_t bits)
- bool TEE_BigIntGetBit (const TEE_BigInt *src, uint32_t bitIndex)
- uint32_t TEE_BigIntGetBitCount (const TEE_BigInt *src)
- void TEE_BigIntAdd (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2)
- void TEE_BigIntSub (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2)
- void TEE_BigIntNeg (TEE_BigInt *dest, const TEE_BigInt *op)
- void TEE_BigIntMul (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2)
- void TEE_BigIntSquare (TEE_BigInt *dest, const TEE_BigInt *op)
- void TEE_BigIntDiv (TEE_BigInt *dest_q, TEE_BigInt *dest_r, const TEE_BigInt *op1, const TEE_BigInt *op2)
- void TEE_BigIntMod (TEE_BigInt *dest, const TEE_BigInt *op, const TEE_BigInt *n)

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- void TEE_BigIntAddMod (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2, const TEE_BigInt *n)
- void TEE_BigIntSubMod (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2, const TEE_BigInt *n)
- void TEE_BigIntMulMod (TEE_BigInt *dest, const TEE_BigInt *op1, const TEE_BigInt *op2, const TEE_BigInt *n)
- void TEE_BigIntSquareMod (TEE_BigInt *dest, const TEE_BigInt *op, const TEE_BigInt *n)
- void TEE_BigIntInvMod (TEE_BigInt *dest, const TEE_BigInt *op, const TEE_BigInt *n)
- bool TEE_BigIntRelativePrime (const TEE_BigInt *op1, const TEE_BigInt *op2)
- void TEE_BigIntComputeExtendedGcd (TEE_BigInt *gcd, TEE_BigInt *u, TEE_BigInt *v, const TEE_BigInt *op1, const TEE_BigInt *op2)
- int32_t TEE_BigIntIsProbablePrime (const TEE_BigInt *op, uint32_t confidenceLevel)
- void TEE_BigIntConvertToFMM (TEE_BigIntFMM *dest, const TEE_BigInt *src, const TEE_BigInt *n, const TEE_BigIntFMMContext *context)
- void TEE_BigIntConvertFromFMM (TEE_BigInt *dest, const TEE_BigIntFMM *src, const TEE_BigInt *n, const TEE_BigIntFMMContext *context)
- void TEE_BigIntFMMConvertToBigInt (TEE_BigInt *dest, const TEE_BigIntFMM *src, const TEE_BigInt *n, const TEE_BigIntFMMContext *context)
- void TEE_BigIntComputeFMM (TEE_BigIntFMM *dest, const TEE_BigIntFMM *op1, const TEE_BigIntFMM *op2, const TEE_BigInt *n, const TEE_BigIntFMMContext *context)

13.9.1 Function Documentation

13.9.1.1 TEE_AEDecryptFinal()

```
TEE_Result TEE_AEDecryptFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen,
    void * tag,
    uint32_t tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEDecryptFinal() - Processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData.

This function completes the AE operation and compares the computed tag with the tag supplied in the parameter tag .The operation handle can be reused or newly initialized.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output

TEE_ERROR_MAC_INVALID If the computed tag does not match the supplied tag

13.9.1.2 TEE_AEEncryptFinal()

```
TEE_Result TEE_AEEncryptFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen,
    void * tag,
    uint32_t * tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEEncryptFinal() - processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData .

TEE_AEEncryptFinal completes the AE operation and computes the tag. The operation handle can be reused or newly initialized. The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output or tag buffer is not large enoughto contain the output.

13.9.1.3 TEE_AEInit()

```
TEE_Result TEE_AEInit (
    TEE_OperationHandle operation,
    const void * nonce,
    uint32_t nonceLen,
    uint32_t tagLen,
    uint32_t AADLen,
    uint32_t payloadLen )
```

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Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEInit() - Initializes an Authentication Encryption operation.

The operation must be in initial state and remains in the initial state afterwards.

Parameters

operation	A handle on the operation.
nonce	The operation nonce or IV
nonceLen	length of nonce
tagLen	Size in bits of the tag
AADLen	Length in bytes of the AAD
payloadLen	Length in bytes of the payload.

Returns

0 on success.

TEE_ERROR_NOT_SUPPORTED If the tag length is not supported by the algorithm.

13.9.1.4 TEE_AEUpdate()

```
TEE_Result TEE_AEUpdate (
        TEE_OperationHandle operation,
        const void * srcData,
        uint32_t srcLen,
        void * destData,
        uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEUpdate() - Accumulates data for an Authentication Encryption operation

This function describes Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data,no output is generated. when using this routine to decrypt the returned data may be corrupt since the integrity check is not performed until all the data has been processed. If this is a concern then only use the TEE_AEDecryptFinal routine.

Parameters

operation	Handle of a running AE operation.
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of the input buffer.
destData	Output buffer
destLen	length of the out put buffer.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER if the output buffer is not large enough to contain the output.

13.9.1.5 TEE_AEUpdateAAD()

```
void TEE_AEUpdateAAD (
        TEE_OperationHandle operation,
        const void * AADdata,
        uint32_t AADdataLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEUpdateAAD() - Feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.

The TEE_AEUpdateAAD function feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation SHALL be in initial state and remains in initial state afterwards.

Parameters

operation	Handle on the AE operation
AADdata	Input buffer containing the chunk of AAD
AADdataLen	length of the chunk of AAD.

13.9.1.6 TEE_AllocateOperation()

```
TEE_Result TEE_AllocateOperation (
        TEE_OperationHandle * operation,
        uint32_t algorithm,
        uint32_t mode,
        uint32_t maxKeySize )
```

Crypto, for all Crypto Functions.

TEE_AllocateOperation() - Allocates a handle for a new cryptographic operation and sets the mode and algorithm type.

If this function does not return with TEE_SUCCESS then there is no valid handle value.Once a cryptographic operation has been created, the implementation shall guarantee that all resources necessary for the operation are allocated and that any operation with a key of at most maxKeySize bits can be performed. For algorithms that take multiple keys, for example the AES XTS algorithm, the maxKeySize parameter specifies the size of the largest key. It is up to the implementation to properly allocate space for multiple keys if the algorithm so requires.

Parameters

operation	reference to generated operation handle.
algorithm	One of the cipher algorithms.
mode	The operation mode.
maxKeySize	Maximum key size in bits for the operation.

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Returns

0 in case of success

TEE_ERROR_OUT_OF_MEMORY If there are not enough resources to allocate the operation.

TEE_ERROR_NOT_SUPPORTED If the mode is not compatible with the algorithm or key size or if the algorithm is not one of the listed algorithms or if maxKeySize is not appropriate for the algorithm.

13.9.1.7 TEE_AllocatePersistentObjectEnumerator() TEE_Result

```
TEE_AllocatePersistentObjectEnumerator (
            TEE_ObjectEnumHandle * objectEnumerator )
```

13.9.1.8 TEE_AllocatePropertyEnumerator() TEE_Result TEE_AllocatePropertyEnumerator (

```
            TEE_PropSetHandle * enumerator )
```

13.9.1.9 TEE_AllocateTransientObject() TEE_Result TEE_AllocateTransientObject (

```
            TEE_ObjectType objectType,
            uint32_t maxKeySize,
            TEE_ObjectHandle * object )
```

Crypto, Asymmetric key Verification Functions.

TEE_AllocateTransientObject() - Allocates an uninitialized transient object. Transient objects are used to hold a cryptographic object (key or key-pair).

The value TEE_KEYSIZE_NO_KEY should be used for maxObjectSize for object types that do not require a key so that all the container resources can be pre-allocated. As allocated, the container is uninitialized. It can be initialized by subsequently importing the object material,generating an object, deriving an object, or loading an object from the Trusted Storage.

Parameters

objectType	Type of uninitialized object container to be created
maxKeySize	Key Size of the object.
object	Filled with a handle on the newly created key container.

Returns

0 on success

TEE_ERROR_OUT_OF_MEMORY If not enough resources are available to allocate the object handle.

TEE_ERROR_NOT_SUPPORTED If the key size is not supported or the object type is not supported.

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13.9.1.10 TEE_AsymmetricDecrypt()

```
TEE_Result TEE_AsymmetricDecrypt (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

13.9.1.11 TEE_AsymmetricEncrypt()

```
TEE_Result TEE_AsymmetricEncrypt (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

13.9.1.12 TEE_AsymmetricSignDigest()

```
TEE_Result TEE_AsymmetricSignDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    void * signature,
    uint32_t * signatureLen )
```

Crypto, Asymmetric key Verification Functions.

TEE_AsymmetricSignDigest() - Signs a message digest within an asymmetric operation.

Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

0 on sccess

TEE_ERROR_SHORT_BUFFER If the signature buffer is not large enough to hold the result

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13.9.1.13 TEE_AsymmetricVerifyDigest()

```
TEE_Result TEE_AsymmetricVerifyDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    const void * signature,
    uint32_t signatureLen )
```

Crypto, Asymmetric key Verification Functions.

TEE_AsymmetricVerifyDigest() - verifies a message digest signature within an asymmetric operation.

This function describes the message digest signature verify by calling ed25519_verify().

Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param.
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

TEE_SUCCESS on success

TEE_ERROR_SIGNATURE_INVALID if the signature is invalid.

13.9.1.14 TEE_BigIntAdd()

```
void TEE_BigIntAdd (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.15 TEE_BigIntAddMod()

```
void TEE_BigIntAddMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2,
    const TEE_BigInt * n )
```

13.9.1.16 TEE_BigIntCmp()

```
int32_t TEE_BigIntCmp (
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

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13.9.1.17 TEE_BigIntCmpS32()

```
int32_t TEE_BigIntCmpS32 (
    const TEE_BigInt * op,
    int32_t shortVal )
```

13.9.1.18 TEE_BigIntComputeExtendedGcd()

```
void TEE_BigIntComputeExtendedGcd (
    TEE_BigInt * gcd,
    TEE_BigInt * u,
    TEE_BigInt * v,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.19 TEE_BigIntComputeFMM()

```
void TEE_BigIntComputeFMM (
    TEE_BigIntFMM * dest,
    const TEE_BigIntFMM * op1,
    const TEE_BigIntFMM * op2,
    const TEE_BigInt * n,
    const TEE_BigIntFMMContext * context )
```

13.9.1.20 TEE_BigIntConvertFromFMM()

```
void TEE_BigIntConvertFromFMM (
    TEE_BigInt * dest,
    const TEE_BigIntFMM * src,
    const TEE_BigInt * n,
    const TEE_BigIntFMMContext * context )
```

13.9.1.21 TEE_BigIntConvertFromOctetString()

```
TEE_Result TEE_BigIntConvertFromOctetString (
    TEE_BigInt * dest,
    const uint8_t * buffer,
    uint32_t bufferLen,
    int32_t sign )
```

13.9.1.22 TEE_BigIntConvertFromS32()

```
void TEE_BigIntConvertFromS32 (
    TEE_BigInt * dest,
    int32_t shortVal )
```

13.9.1.23 TEE_BigIntConvertToFMM()

```
void TEE_BigIntConvertToFMM (
    TEE_BigIntFMM * dest,
    const TEE_BigInt * src,
    const TEE_BigInt * n,
    const TEE_BigIntFMMContext * context )
```

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13.9.1.24 TEE_BigIntConvertToOctetString()

```
TEE_Result TEE_BigIntConvertToOctetString (
    uint8_t * buffer,
    uint32_t * bufferLen,
    const TEE_BigInt * bigInt )
```

13.9.1.25 TEE_BigIntConvertToS32()

```
TEE_Result TEE_BigIntConvertToS32 (
    int32_t * dest,
    const TEE_BigInt * src )
```

13.9.1.26 TEE_BigIntDiv()

```
void TEE_BigIntDiv (
    TEE_BigInt * dest_q,
    TEE_BigInt * dest_r,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.27 TEE_BigIntFMMContextSizeInU32()

```
uint32_t TEE_BigIntFMMContextSizeInU32 (
    uint32_t modulusSizeInBits )
```

13.9.1.28 TEE_BigIntFMMConvertToBigInt()

```
void TEE_BigIntFMMConvertToBigInt (
    TEE_BigInt * dest,
    const TEE_BigIntFMM * src,
    const TEE_BigInt * n,
    const TEE_BigIntFMMContext * context )
```

13.9.1.29 TEE_BigIntFMMSizeInU32()

```
uint32_t TEE_BigIntFMMSizeInU32 (
    uint32_t modulusSizeInBits )
```

13.9.1.30 TEE_BigIntGetBit()

```
bool TEE_BigIntGetBit (
    const TEE_BigInt * src,
    uint32_t bitIndex )
```

13.9.1.31 TEE_BigIntGetBitCount()

```
uint32_t TEE_BigIntGetBitCount (
    const TEE_BigInt * src )
```

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13.9.1.32 TEE_BigIntInit()

```
void TEE_BigIntInit (
    TEE_BigInt * bigInt,
    uint32_t len )
```

13.9.1.33 TEE_BigIntInitFMM()

```
void TEE_BigIntInitFMM (
    TEE_BigIntFMM * bigIntFMM,
    uint32_t len )
```

13.9.1.34 TEE_BigIntInitFMMContext()

```
void TEE_BigIntInitFMMContext (
    TEE_BigIntFMMContext * context,
    uint32_t len,
    const TEE_BigInt * modulus )
```

13.9.1.35 TEE_BigIntInvMod()

```
void TEE_BigIntInvMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op,
    const TEE_BigInt * n )
```

13.9.1.36 TEE_BigIntIsProbablePrime()

```
int32_t TEE_BigIntIsProbablePrime (
    const TEE_BigInt * op,
    uint32_t confidenceLevel )
```

13.9.1.37 TEE_BigIntMod()

```
void TEE_BigIntMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op,
    const TEE_BigInt * n )
```

13.9.1.38 TEE_BigIntMul()

```
void TEE_BigIntMul (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.39 TEE_BigIntMulMod()

```
void TEE_BigIntMulMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2,
    const TEE_BigInt * n )
```

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13.9.1.40 TEE_BigIntNeg()

```
void TEE_BigIntNeg (
    TEE_BigInt * dest,
    const TEE_BigInt * op )
```

13.9.1.41 TEE_BigIntRelativePrime()

```
bool TEE_BigIntRelativePrime (
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.42 TEE_BigIntShiftRight()

```
void TEE_BigIntShiftRight (
    TEE_BigInt * dest,
    const TEE_BigInt * op,
    size_t bits )
```

13.9.1.43 TEE_BigIntSquare()

```
void TEE_BigIntSquare (
    TEE_BigInt * dest,
    const TEE_BigInt * op )
```

13.9.1.44 TEE_BigIntSquareMod()

```
void TEE_BigIntSquareMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op,
    const TEE_BigInt * n )
```

13.9.1.45 TEE_BigIntSub()

```
void TEE_BigIntSub (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2 )
```

13.9.1.46 TEE_BigIntSubMod()

```
void TEE_BigIntSubMod (
    TEE_BigInt * dest,
    const TEE_BigInt * op1,
    const TEE_BigInt * op2,
    const TEE_BigInt * n )
```

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13.9.1.47 TEE_CheckMemoryAccessRights()

```
TEE_Result TEE_CheckMemoryAccessRights (
    uint32_t accessFlags,
    void * buffer,
    uint32_t size )
```

13.9.1.48 TEE_CipherDoFinal()

```
TEE_Result TEE_CipherDoFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

TEE_CipherDoFinal() - Finalizes the cipher operation, processing data that has not been processed by previous calls to TEE_CipherUpdate as well as data supplied in srcData .

This function describes The operation handle can be reused or re-initialized. The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation SHALL be in active state and is set to initial state afterwards.

Parameters

operation	Handle of a running Cipher operation
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of input buffer
destData	output buffer
destLen	ouput buffer length.

Returns

0 on success

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output

13.9.1.49 TEE_CipherInit()

```
void TEE_CipherInit (
    TEE_OperationHandle operation,
    const void * nonce,
    uint32_t nonceLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_CipherInit() - starts the symmetric cipher operation.

The operation shall have been associated with a key. If the operation is in active state, it is reset and then initialized. If the operation is in initial state, it is moved to active state.

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Parameters

operation	A handle on an opened cipher operation setup with a key
nonce	Buffer containing the operation Initialization Vector as appropriate.
nonceLen	length of the buffer

13.9.1.50 TEE_CipherUpdate()

```
TEE_Result TEE_CipherUpdate (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_CipherUpdate() - encrypts or decrypts input data.

Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data, no output is generated. The cipher operation is finalized with a call to TEE_CipherDoFinal .The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation SHALL be in active state.

Parameters

operation	Handle of a running Cipher operation
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of input buffer
destData	output buffer
destLen	ouput buffer length.

Returns

0 on success else

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output. In this case, the input is not fed into the algorithm.

13.9.1.51 TEE_CloseAndDeletePersistentObject()

```
void TEE_CloseAndDeletePersistentObject (
    TEE_ObjectHandle object )
```

13.9.1.52 TEE_CloseAndDeletePersistentObject1()

```
TEE_Result TEE_CloseAndDeletePersistentObject1
(
    TEE_ObjectHandle object )
```

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13.9.1.53 TEE_CloseObject() void TEE_CloseObject (TEE_ObjectHandle *object*)

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CloseObject() - Closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

Parameters

object	Handle of the object.

Returns

TEE_SUCCESS if success else error occured.

TEE_CloseObject() - Function closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

Parameters

object	Handle of the object

Returns

TEE_SUCCESS if success else error occured.

13.9.1.54 TEE_CloseTASession() void TEE_CloseTASession (TEE_TASessionHandle *session*)

13.9.1.55 TEE_CopyObjectAttributes() void TEE_CopyObjectAttributes (TEE_ObjectHandle *destObject*, TEE_ObjectHandle *srcObject*)

13.9.1.56 TEE_CopyObjectAttributes1() TEE_Result TEE_CopyObjectAttributes1 (TEE_ObjectHandle *destObject*, TEE_ObjectHandle *srcObject*)

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13.9.1.57 TEE_CopyOperation()

```
void TEE_CopyOperation (
    TEE_OperationHandle dstOperation,
    TEE_OperationHandle srcOperation )
```

13.9.1.58 TEE_CreatePersistentObject()

```
TEE_Result TEE_CreatePersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle attributes,
    const void * initialData,
    uint32_t initialDataLen,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

In this function an initial data stream content returns either a handle on the created object or TEE_HANDLE_NULL upon failure.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle which contains the opened handle upon successful completion

Returns

0 if success else error occured.

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

An initial data stream content, and optionally returns either a handle on the created object, or TEE_HANDLE_NULL upon failure.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.

Paramter list continued on next page

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attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success, else error occured.

13.9.1.59 TEE_DeriveKey()

```
void TEE_DeriveKey (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    TEE_ObjectHandle derivedKey )
```

13.9.1.60 TEE_DigestDoFinal()

```
TEE_Result TEE_DigestDoFinal (
    TEE_OperationHandle operation,
    const void * chunk,
    uint32_t chunkLen,
    void * hash,
    uint32_t * hashLen )
```

TEE_DigestDoFinal() - Finalizes the message digest operation and produces the message hash.

This function finalizes the message digest operation and produces the message hash. Afterwards the Message Digest operation is reset to initial state and can be reused.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed.
chunkLen	size of the chunk.
hash	Output buffer filled with the message hash.
hashLen	lenth of the mesaage hash.

Returns

0 on success

TEE_ERROR_SHORT_BUFFER If the output buffer is too small. In this case, the operation is not finalized.

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13.9.1.61 TEE_DigestUpdate()

```
void TEE_DigestUpdate (
    TEE_OperationHandle operation,
    const void * chunk,
    uint32_t chunkSize )
```

Crypto, Message Digest Functions.

TEE_DigestUpdate()- Accumulates message data for hashing.

This function describes the message does not have to be block aligned. Subsequent calls to this function are possible.The operation may be in either initial or active state and becomes active.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed
chunkSize	size of the chunk.

13.9.1.62 TEE_Free()

```
void TEE_Free (
    void * buffer )
```

TEE_Free() - causes the space pointed to by buffer to be deallocated;that is made available for further allocation.

This function describes if buffer is a NULL pointer, TEE_Free does nothing. Otherwise, it is a Programmer Error if the argument does not match a pointer previously returned by the TEE_Malloc or TEE_Realloc if the space has been deallocated by a call to TEE_Free or TEE_Realloc.

Parameters

buffer	The pointer to the memory block to be freed.

13.9.1.63 TEE_FreeOperation()

```
void TEE_FreeOperation (
    TEE_OperationHandle operation )
```

Crypto, for all Crypto Functions.

TEE_FreeOperation() - Deallocates all resources associated with an operation handle.

This function deallocates all resources associated with an operation handle. After this function is called, the operation handle is no longer valid. All cryptographic material in the operation is destroyed. The function does nothing if operation is TEE_HANDLE_NULL.

Parameters

operation	Reference to operation handle.

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Returns

nothing after the operation free.

13.9.1.64 TEE_FreePersistentObjectEnumerator()

```
void TEE_FreePersistentObjectEnumerator (
    TEE_ObjectEnumHandle objectEnumerator )
```

13.9.1.65 TEE_FreePropertyEnumerator()

```
void TEE_FreePropertyEnumerator (
    TEE_PropSetHandle enumerator )
```

13.9.1.66 TEE_FreeTransientObject()

```
void TEE_FreeTransientObject (
    TEE_ObjectHandle object )
```

Crypto, Asymmetric key Verification Functions.

TEE_FreeTransientObject() - Deallocates a transient object previously allocated with TEE_AllocateTransientObject .

this function describes the object handle is no longer valid and all resources associated with the transient object shall have been reclaimed after the TEE_AllocateTransientObject() call.

Parameters

object	Handle on the object to free.

13.9.1.67 TEE_GenerateKey()

```
TEE_Result TEE_GenerateKey (
    TEE_ObjectHandle object,
    uint32_t keySize,
    const TEE_Attribute * params,
    uint32_t paramCount )
```

Crypto, Asymmetric key Verification Functions.

TEE_GenerateKey () - Generates a random key or a key-pair and populates a transient key object with the generated key material.

The size of the desired key is passed in the keySize parameter and shall be less than or equal to the maximum key size specified when the transient object was created.

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Parameters

object	Handle on an uninitialized transient key to populate with the generated key.
keySize	Requested key size shall be less than or equal to the maximum key size specified when the object container was created
params	Parameters for the key generation.
paramCount	The values of all parameters are copied nto the object so that the params array and all the memory buffers it points to may be freed after this routine returns without affecting the object.

Returns

0 on succes

TEE_ERROR_BAD_PARAMETERS If an incorrect or inconsistent attribute is detected. The checks that are performed depend on the implementation.

13.9.1.68 TEE_GenerateRandom() `void TEE_GenerateRandom (`

```
void * randomBuffer,
uint32_t randomBufferLen )
```

Crypto, common.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random buffer length and is stored in to random Buffer by calling wc_↩ RNG_GenerateBlock().If ret is not equal
to 0 then TEE_Panic is called.

Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

Returns

random data random data will be returned.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random bufferlength and is stored in to randomBuffer by calling sgx_read↩ _rand().

Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

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13.9.1.69 TEE_GetCancellationFlag()

```
bool TEE_GetCancellationFlag (
    void  )
```

13.9.1.70 TEE_GetInstanceData()

```
const void * TEE_GetInstanceData (
    void  )
```

13.9.1.71 TEE_GetNextPersistentObject()

```
TEE_Result TEE_GetNextPersistentObject (
    TEE_ObjectEnumHandle objectEnumerator,
    TEE_ObjectInfo * objectInfo,
    void * objectID,
    uint32_t * objectIDLen )
```

13.9.1.72 TEE_GetNextProperty()

```
TEE_Result TEE_GetNextProperty (
    TEE_PropSetHandle enumerator )
```

13.9.1.73 TEE_GetObjectBufferAttribute()

```
TEE_Result TEE_GetObjectBufferAttribute (
    TEE_ObjectHandle object,
    uint32_t attributeID,
    void * buffer,
    uint32_t * size )
```

13.9.1.74 TEE_GetObjectInfo()

```
void TEE_GetObjectInfo (
    TEE_ObjectHandle object,
    TEE_ObjectInfo * objectInfo )
```

13.9.1.75 TEE_GetObjectInfo1()

```
TEE_Result TEE_GetObjectInfo1 (
    TEE_ObjectHandle object,
    TEE_ObjectInfo * objectInfo )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_GetObjectInfo1() - Returns the characteristics of an object.

This function returns a handle which can be used to access the object's attributes and data stream.

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Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

TEE_GetObjectInfo1() - Function returns the characteristics of an object.

It returns a handle that can be used to access the object's attributes and data stream.

Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

13.9.1.76 TEE_GetObjectValueAttribute()

```
TEE_Result TEE_GetObjectValueAttribute (
    TEE_ObjectHandle object,
    uint32_t attributeID,
    uint32_t * a,
    uint32_t * b )
```

13.9.1.77 TEE_GetOperationInfo()

```
void TEE_GetOperationInfo (
    TEE_OperationHandle operation,
    TEE_OperationInfo * operationInfo )
```

13.9.1.78 TEE_GetOperationInfoMultiple()

```
TEE_Result TEE_GetOperationInfoMultiple (
    TEE_OperationHandle operation,
    TEE_OperationInfoMultiple * operationInfoMultiple,
    uint32_t * operationSize )
```

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13.9.1.79 TEE_GetPropertyAsBinaryBlock()

```
TEE_Result TEE_GetPropertyAsBinaryBlock (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    void * valueBuffer,
    uint32_t * valueBufferLen )
```

13.9.1.80 TEE_GetPropertyAsBool()

```
TEE_Result TEE_GetPropertyAsBool (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    bool * value )
```

13.9.1.81 TEE_GetPropertyAsIdentity()

```
TEE_Result TEE_GetPropertyAsIdentity (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    TEE_Identity * value )
```

13.9.1.82 TEE_GetPropertyAsString()

```
TEE_Result TEE_GetPropertyAsString (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    char * valueBuffer,
    uint32_t * valueBufferLen )
```

13.9.1.83 TEE_GetPropertyAsU32()

```
TEE_Result TEE_GetPropertyAsU32 (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    uint32_t * value )
```

13.9.1.84 TEE_GetPropertyAsUUID()

```
TEE_Result TEE_GetPropertyAsUUID (
    TEE_PropSetHandle propsetOrEnumerator,
    const char * name,
    TEE_UUID * value )
```

13.9.1.85 TEE_GetPropertyName()

```
TEE_Result TEE_GetPropertyName (
    TEE_PropSetHandle enumerator,
    void * nameBuffer,
    uint32_t * nameBufferLen )
```

13.9.1.86 TEE_GetREETime()

```
void TEE_GetREETime (
    TEE_Time * time )
```

Core Functions, Time Functions.

TEE_GetREETime() - Retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of the REE.

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Parameters

time	Filled with the number of seconds and milliseconds

TEE_GetREETime() - Function retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of the REE.

Parameters

time	Filled with the number of seconds and milliseconds.

13.9.1.87 TEE_GetSystemTime() `void TEE_GetSystemTime ( TEE_Time * time )`

Core Functions, Time Functions.

TEE_GetSystemTime() - Retrieves the current system time.

This function describes the system time has an arbitrary implementation defined origin that can vary across TA instances. The minimum guarantee is that the system time shall be monotonic for a given TA instance.

Parameters

time	Filled with the number of seconds and milliseconds

TEE_GetSystemTime() - Retrieves the current system time.

The system time has an arbitrary implementation-defined origin that can vary across TA instances

Parameters

time	Filled with the number of seconds and milliseconds.

13.9.1.88 TEE_GetTAPersistentTime() `TEE_Result TEE_GetTAPersistentTime ( TEE_Time * time )`

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13.9.1.89 TEE_InitRefAttribute()

```
void TEE_InitRefAttribute (
    TEE_Attribute * attr,
    uint32_t attributeID,
    const void * buffer,
    uint32_t length )
```

Crypto, Asymmetric key Verification Functions.

TEE_InitRefAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

In TEE_InitRefAttribute () only the buffer pointer is copied, not the content of the buffer. This means that the attribute structure maintains a pointer back to the supplied buffer. It is the responsibility of the TA author to ensure that the contents of the buffer maintain their value until the attributes array is no longer in use.

Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
buffer	input buffer that holds the content of the attribute.
length	buffer length.

13.9.1.90 TEE_InitValueAttribute()

```
void TEE_InitValueAttribute (
    TEE_Attribute * attr,
    uint32_t attributeID,
    uint32_t a,
    uint32_t b )
```

Crypto, Asymmetric key Verification Functions.

TEE_InitValueAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
a	unsigned integer value to assign to the a member of the attribute structure.
b	unsigned integer value to assign to the b member of the attribute structure

13.9.1.91 TEE_InvokeTACommand()

```
TEE_Result TEE_InvokeTACommand (
    TEE_TASessionHandle session,
    uint32_t cancellationRequestTimeout,
    uint32_t commandID,
    uint32_t paramTypes,
```

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```
TEE_Param params[TEE_NUM_PARAMS],
uint32_t * returnOrigin )
```

13.9.1.92 TEE_IsAlgorithmSupported()

```
TEE_Result TEE_IsAlgorithmSupported (
uint32_t algId,
uint32_t element )
```

13.9.1.93 TEE_MACCompareFinal()

```
TEE_Result TEE_MACCompareFinal (
TEE_OperationHandle operation,
const void * message,
uint32_t messageLen,
const void * mac,
uint32_t macLen )
```

13.9.1.94 TEE_MACComputeFinal()

```
TEE_Result TEE_MACComputeFinal (
TEE_OperationHandle operation,
const void * message,
uint32_t messageLen,
void * mac,
uint32_t * macLen )
```

13.9.1.95 TEE_MACInit()

```
void TEE_MACInit (
TEE_OperationHandle operation,
const void * IV,
uint32_t IVLen )
```

13.9.1.96 TEE_MACUpdate()

```
void TEE_MACUpdate (
TEE_OperationHandle operation,
const void * chunk,
uint32_t chunkSize )
```

13.9.1.97 TEE_Malloc()

```
void * TEE_Malloc (
uint32_t size,
uint32_t hint )
```

TEE_Malloc() - Allocates space for an object whose size in bytes is specified in the parameter size.

This function describes the pointer returned is guaranteed to be aligned
such that it may be assigned as a pointer to any basic C type.The valid hint values are a bitmask and can be independently set. This parameter allows Trusted Applications to refer to various pools of memory or to request special characteristics for the allocated memory by using an implementation-defined hint. Future versions of this specification may introduce additional standard hints.

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Parameters

size	The size of the buffer to be allocated.
hint	A hint to the allocator.

Returns

Upon successful completion, with size not equal to zero, the function returns a pointer to the allocated space.

13.9.1.98 TEE_MaskCancellation()

```
bool TEE_MaskCancellation (
    void  )
```

13.9.1.99 TEE_MemCompare()

```
int32_t TEE_MemCompare (
    const void * buffer1,
    const void * buffer2,
    uint32_t size )
```

13.9.1.100 TEE_MemFill()

```
void * TEE_MemFill (
    void * buff,
    uint32_t x,
    uint32_t size )
```

13.9.1.101 TEE_MemMove()

```
void * TEE_MemMove (
    void * dest,
    const void * src,
    uint32_t size )
```

13.9.1.102 TEE_OpenPersistentObject()

```
TEE_Result TEE_OpenPersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle which can be used to access the object's attributes and data stream.

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Parameters

storageID	The storage to use
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success else error occured.

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle that can be used to access the object's attributes and data stream.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success, else error occured.

13.9.1.103 TEE_OpenTASession()

```
TEE_Result TEE_OpenTASession (
    const TEE_UUID * destination,
    uint32_t cancellationRequestTimeout,
    uint32_t paramTypes,
    TEE_Param params[TEE_NUM_PARAMS],
    TEE_TASessionHandle * session,
    uint32_t * returnOrigin )
```

13.9.1.104 TEE_Panic()

```
void TEE_Panic (
    TEE_Result panicCode )
```

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13.9.1.105 TEE_PopulateTransientObject()

```
TEE_Result TEE_PopulateTransientObject (
    TEE_ObjectHandle object,
    const TEE_Attribute * attrs,
    uint32_t attrCount )
```

13.9.1.106 TEE_ReadObjectData()

```
TEE_Result TEE_ReadObjectData (
    TEE_ObjectHandle object,
    void * buffer,
    uint32_t size,
    uint32_t * count )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion of TEE_ReadObjectData sets the number of bytes actually read in the "uint32_t" pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

Returns

TEE_SUCCESS if success else error occured.

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion TEE_ReadObjectData sets the number of bytes actually read in the uint32_t pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

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Returns

TEE_SUCCESS if success, else error occured.

13.9.1.107 TEE_Realloc()

```
void * TEE_Realloc (
    void * buffer,
    uint32_t newSize )
```

TEE_Realloc() - Changes the size of the memory object pointed to by buffer to the size specified by new size.

This function describes the content of the object remains unchanged up to the lesser of the new and old sizes. Space in excess of the old size contains unspecified content. If the new size of the memory object requires movement of the object, the space for the previous instantiation of the object is deallocated. If the space cannot be allocated, the original object remains allocated, and this function returns a NULL pointer.

Parameters

buffer	The pointer to the object to be reallocated.
newSize	The new size required for the object

Returns

Upon successful completion, TEE_Realloc returns a pointer to the (possibly moved) allocated space. If there is not enough available memory, TEE_Realloc returns a NULL pointer and the original buffer is still allocated and unchanged.

13.9.1.108 TEE_RenamePersistentObject()

```
TEE_Result TEE_RenamePersistentObject (
    TEE_ObjectHandle object,
    const void * newObjectID,
    uint32_t newObjectIDLen )
```

13.9.1.109 TEE_ResetOperation()

```
void TEE_ResetOperation (
    TEE_OperationHandle operation )
```

13.9.1.110 TEE_ResetPersistentObjectEnumerator()

```
void TEE_ResetPersistentObjectEnumerator (
    TEE_ObjectEnumHandle objectEnumerator )
```

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13.9.1.111 TEE_ResetPropertyEnumerator()

```
void TEE_ResetPropertyEnumerator (
  TEE_PropSetHandle enumerator )
```

13.9.1.112 TEE_ResetTransientObject()

```
void TEE_ResetTransientObject (
  TEE_ObjectHandle object )
```

13.9.1.113 TEE_RestrictObjectUsage()

```
void TEE_RestrictObjectUsage (
  TEE_ObjectHandle object,
  uint32_t objectUsage )
```

13.9.1.114 TEE_RestrictObjectUsage1()

```
TEE_Result TEE_RestrictObjectUsage1 (
  TEE_ObjectHandle object,
  uint32_t objectUsage )
```

13.9.1.115 TEE_SeekObjectData()

```
TEE_Result TEE_SeekObjectData (
  TEE_ObjectHandle object,
  int32_t offset,
  TEE_Whence whence )
```

13.9.1.116 TEE_SetInstanceData()

```
void TEE_SetInstanceData (
  const void * instanceData )
```

13.9.1.117 TEE_SetOperationKey()

```
TEE_Result TEE_SetOperationKey (
  TEE_OperationHandle operation,
  TEE_ObjectHandle key )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_SetOperationKey() - Programs the key of an operation; that is, it associates an operation with a key.

The key material is copied from the key object handle into the operation. After the key has been set, there is no longer any link between the operation and the key object. The object handle can be closed or reset and this will not affect the operation. This copied material exists until the operation is freed using TEE_FreeOperation or another key is set into the operation.

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Parameters

operation	Operation handle.
key	A handle on a key object.

Returns

0 on success return

TEE_ERROR_CORRUPT_OBJECT If the object is corrupt. The object handle is closed.

TEE_ERROR_STORAGE_NOT_AVAILABLE If the persistent object is stored in a storage area which is currently inaccessible.

13.9.1.118 TEE_SetOperationKey2()

```
TEE_Result TEE_SetOperationKey2 (
    TEE_OperationHandle operation,
    TEE_ObjectHandle key1,
    TEE_ObjectHandle key2 )
```

13.9.1.119 TEE_SetTAPersistentTime()

```
TEE_Result TEE_SetTAPersistentTime (
    const TEE_Time * time )
```

13.9.1.120 TEE_StartPersistentObjectEnumerator()

```
TEE_Result TEE_StartPersistentObjectEnumerator
(
    TEE_ObjectEnumHandle objectEnumerator,
    uint32_t storageID )
```

13.9.1.121 TEE_StartPropertyEnumerator()

```
void TEE_StartPropertyEnumerator (
    TEE_PropSetHandle enumerator,
    TEE_PropSetHandle propSet )
```

13.9.1.122 TEE_TruncateObjectData()

```
TEE_Result TEE_TruncateObjectData (
    TEE_ObjectHandle object,
    uint32_t size )
```

13.9.1.123 TEE_UnmaskCancellation()

```
bool TEE_UnmaskCancellation (
    void  )
```

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13.9.1.124 TEE_Wait()

```
TEE_Result TEE_Wait (
    uint32_t timeout )
```

13.9.1.125 TEE_WriteObjectData()

```
TEE_Result TEE_WriteObjectData (
    TEE_ObjectHandle object,
    const void * buffer,
    uint32_t size )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_WriteObjectData() - Writes the buffer data in to persistent objects.

In this function it checks if object is present or not, the encryption/ decryption buffer is taken by calling mbedtls_aes↩_crypt_cbc() then that buffer data is encrypted and mapped to object.On the base of object creation TEE_SUCCESS appears else TEE_ERROR_GENERIC appears.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

TEE_WriteObjectData() - writes size bytes from the buffer pointed to by buffer to the data stream associated with the open object handle object.

If the current data position points before the end-of-stream, then size bytes are written to the data stream, overwriting bytes starting at the current data position. If the current data position points beyond the stream's end, then the data stream is first extended with zero bytes until the length indicated by the data position indicator is reached, and then size bytes are written to the stream.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

13.10 tee_api.h

Go to the documentation of this file.

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```
1 /* SPDX-License-Identifier: BSD-2-Clause */
2 /*
3  * Copyright (c) 2014, STMicroelectronics International N.V.
4  */
5
6 /* Based on GP TEE Internal API Specification Version 1.1 */
7 #ifndef TEE_API_H
8 #define TEE_API_H
9
10 #include <stddef.h>
11 #include <compiler.h>
12 #include <tee_api_defines.h>
13 #include <tee_api_types.h>
14 #include <trace.h>
15
16 /* Property access functions */
17
18 TEE_Result TEE_GetPropertyAsString(TEE_PropSetHandle propsetOrEnumerator,
19                    const char *name, char *valueBuffer,
20                    uint32_t *valueBufferLen);
21
22 TEE_Result TEE_GetPropertyAsBool(TEE_PropSetHandle propsetOrEnumerator,
23                  const char *name, bool *value);
24
25 TEE_Result TEE_GetPropertyAsU32(TEE_PropSetHandle propsetOrEnumerator,
26                 const char *name, uint32_t *value);
27
28 TEE_Result TEE_GetPropertyAsBinaryBlock(TEE_PropSetHandle propsetOrEnumerator,
29                     const char *name, void *valueBuffer,
30                     uint32_t *valueBufferLen);
31
32 TEE_Result TEE_GetPropertyAsUUID(TEE_PropSetHandle propsetOrEnumerator,
33                  const char *name, TEE_UUID *value);
34
35 TEE_Result TEE_GetPropertyAsIdentity(TEE_PropSetHandle propsetOrEnumerator,
36                      const char *name, TEE_Identity *value);
37
38 TEE_Result TEE_AllocatePropertyEnumerator(TEE_PropSetHandle *enumerator);
39
40 void TEE_FreePropertyEnumerator(TEE_PropSetHandle enumerator);
41
42 void TEE_StartPropertyEnumerator(TEE_PropSetHandle enumerator,
43                  TEE_PropSetHandle propSet);
44
45 void TEE_ResetPropertyEnumerator(TEE_PropSetHandle enumerator);
46
47 TEE_Result TEE_GetPropertyName(TEE_PropSetHandle enumerator,
48                    void *nameBuffer, uint32_t *nameBufferLen);
49
50 TEE_Result TEE_GetNextProperty(TEE_PropSetHandle enumerator);
51
52 /* System API - Misc */
53
54 void TEE_Panic(TEE_Result panicCode);
55
56 /* System API - Internal Client API */
57
58 TEE_Result TEE_OpenTASession(const TEE_UUID *destination,
59                 uint32_t cancellationRequestTimeout,
60                 uint32_t paramTypes,
61                 TEE_Param params[TEE_NUM_PARAMS],
62                 TEE_TASessionHandle *session,
63                 uint32_t *returnOrigin);
64
65 void TEE_CloseTASession(TEE_TASessionHandle session);
66
67 TEE_Result TEE_InvokeTACommand(TEE_TASessionHandle session,
68                 uint32_t cancellationRequestTimeout,
69                 uint32_t commandID, uint32_t paramTypes,
70                 TEE_Param params[TEE_NUM_PARAMS],
71                 uint32_t *returnOrigin);
72
73 /* System API - Cancellations */
74
75 bool TEE_GetCancellationFlag(void);
76
77 bool TEE_UnmaskCancellation(void);
78
79 bool TEE_MaskCancellation(void);
80
81 /* System API - Memory Management */
82
83 TEE_Result TEE_CheckMemoryAccessRights(uint32_t accessFlags, void *buffer,
84                        uint32_t size);
85
```

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```
86 void TEE_SetInstanceData(const void *instanceData);
87
88 const void *TEE_GetInstanceData(void);
89
90 void *TEE_Malloc(uint32_t size, uint32_t hint);
91
92 void *TEE_Realloc(void *buffer, uint32_t newSize);
93
94 void TEE_Free(void *buffer);
95
96 void *TEE_MemMove(void *dest, const void *src, uint32_t size);
97
98 /*
99  * Note: TEE_MemCompare() has a constant-time implementation (execution time
100  * does not depend on buffer content but only on buffer size). It is the main
101  * difference with memcmp().
102  */
103 int32_t TEE_MemCompare(const void *buffer1, const void *buffer2, uint32_t size);
104
105 void *TEE_MemFill(void *buff, uint32_t x, uint32_t size);
106
107 /* Data and Key Storage API  - Generic Object Functions */
108
109 void TEE_GetObjectInfo(TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo);
110 TEE_Result TEE_GetObjectInfo1(TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo);
111
112 void TEE_RestrictObjectUsage(TEE_ObjectHandle object, uint32_t objectUsage);
113 TEE_Result TEE_RestrictObjectUsage1(TEE_ObjectHandle object, uint32_t objectUsage);
114
115 TEE_Result TEE_GetObjectBufferAttribute(TEE_ObjectHandle object,
116                     uint32_t attributeID, void *buffer,
117                     uint32_t *size);
118
119 TEE_Result TEE_GetObjectValueAttribute(TEE_ObjectHandle object,
120                       uint32_t attributeID, uint32_t *a,
121                       uint32_t *b);
122
123 void TEE_CloseObject(TEE_ObjectHandle object);
124
125 /* Data and Key Storage API  - Transient Object Functions */
126
127 TEE_Result TEE_AllocateTransientObject(TEE_ObjectType objectType,
128                       uint32_t maxKeySize,
129                       TEE_ObjectHandle *object);
130
131 void TEE_FreeTransientObject(TEE_ObjectHandle object);
132
133 void TEE_ResetTransientObject(TEE_ObjectHandle object);
134
135 TEE_Result TEE_PopulateTransientObject(TEE_ObjectHandle object,
136                       const TEE_Attribute *attrs,
137                       uint32_t attrCount);
138
139 void TEE_InitRefAttribute(TEE_Attribute *attr, uint32_t attributeID,
140               const void *buffer, uint32_t length);
141
142 void TEE_InitValueAttribute(TEE_Attribute *attr, uint32_t attributeID,
143                 uint32_t a, uint32_t b);
144
145 void TEE_CopyObjectAttributes(TEE_ObjectHandle destObject,
146                   TEE_ObjectHandle srcObject);
147
148 TEE_Result TEE_CopyObjectAttributes1(TEE_ObjectHandle destObject,
149                   TEE_ObjectHandle srcObject);
150
151 TEE_Result TEE_GenerateKey(TEE_ObjectHandle object, uint32_t keySize,
152                const TEE_Attribute *params, uint32_t paramCount);
153
154 /* Data and Key Storage API  - Persistent Object Functions */
155
156 TEE_Result TEE_OpenPersistentObject(uint32_t storageID, const void *objectID,
157                     uint32_t objectIDLen, uint32_t flags,
158                     TEE_ObjectHandle *object);
159
160 TEE_Result TEE_CreatePersistentObject(uint32_t storageID, const void *objectID,
161                       uint32_t objectIDLen, uint32_t flags,
162                       TEE_ObjectHandle attributes,
163                       const void *initialData,
164                       uint32_t initialDataLen,
165                       TEE_ObjectHandle *object);
166
167 void TEE_CloseAndDeletePersistentObject(TEE_ObjectHandle object);
168
169 TEE_Result TEE_CloseAndDeletePersistentObject1(TEE_ObjectHandle object);
170
```

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```
171 TEE_Result TEE_RenamePersistentObject(TEE_ObjectHandle object,
172                       const void *newObjectID,
173                       uint32_t newObjectIDLen);
174
175 TEE_Result TEE_AllocatePersistentObjectEnumerator(TEE_ObjectEnumHandle *
176                           objectEnumerator);
177
178 void TEE_FreePersistentObjectEnumerator(TEE_ObjectEnumHandle objectEnumerator);
179
180 void TEE_ResetPersistentObjectEnumerator(TEE_ObjectEnumHandle objectEnumerator);
181
182 TEE_Result TEE_StartPersistentObjectEnumerator(TEE_ObjectEnumHandle
183                            objectEnumerator,
184                            uint32_t storageID);
185
186 TEE_Result TEE_GetNextPersistentObject(TEE_ObjectEnumHandle objectEnumerator,
187                        TEE_ObjectInfo *objectInfo,
188                        void *objectID, uint32_t *objectIDLen);
189
190 /* Data and Key Storage API  - Data Stream Access Functions */
191
192 TEE_Result TEE_ReadObjectData(TEE_ObjectHandle object, void *buffer,
193                   uint32_t size, uint32_t *count);
194
195 TEE_Result TEE_WriteObjectData(TEE_ObjectHandle object, const void *buffer,
196                    uint32_t size);
197
198 TEE_Result TEE_TruncateObjectData(TEE_ObjectHandle object, uint32_t size);
199
200 TEE_Result TEE_SeekObjectData(TEE_ObjectHandle object, int32_t offset,
201                   TEE_Whence whence);
202
203 /* Cryptographic Operations API - Generic Operation Functions */
204
205 TEE_Result TEE_AllocateOperation(TEE_OperationHandle *operation,
206                  uint32_t algorithm, uint32_t mode,
207                  uint32_t maxKeySize);
208
209 void TEE_FreeOperation(TEE_OperationHandle operation);
210
211 void TEE_GetOperationInfo(TEE_OperationHandle operation,
212               TEE_OperationInfo *operationInfo);
213
214 TEE_Result TEE_GetOperationInfoMultiple(TEE_OperationHandle operation,
215               TEE_OperationInfoMultiple *operationInfoMultiple,
216               uint32_t *operationSize);
217
218 void TEE_ResetOperation(TEE_OperationHandle operation);
219
220 TEE_Result TEE_SetOperationKey(TEE_OperationHandle operation,
221                    TEE_ObjectHandle key);
222
223 TEE_Result TEE_SetOperationKey2(TEE_OperationHandle operation,
224                 TEE_ObjectHandle key1, TEE_ObjectHandle key2);
225
226 void TEE_CopyOperation(TEE_OperationHandle dstOperation,
227                TEE_OperationHandle srcOperation);
228
229 TEE_Result TEE_IsAlgorithmSupported(uint32_t algId, uint32_t element);
230
231 /* Cryptographic Operations API - Message Digest Functions */
232
233 void TEE_DigestUpdate(TEE_OperationHandle operation,
234               const void *chunk, uint32_t chunkSize);
235
236 TEE_Result TEE_DigestDoFinal(TEE_OperationHandle operation, const void *chunk,
237                  uint32_t chunkLen, void *hash, uint32_t *hashLen);
238
239 /* Cryptographic Operations API - Symmetric Cipher Functions */
240
241 void TEE_CipherInit(TEE_OperationHandle operation, const void *IV,
242             uint32_t IVLen);
243
244 TEE_Result TEE_CipherUpdate(TEE_OperationHandle operation, const void *srcData,
245                 uint32_t srcLen, void *destData, uint32_t *destLen);
246
247 TEE_Result TEE_CipherDoFinal(TEE_OperationHandle operation,
248                  const void *srcData, uint32_t srcLen,
249                  void *destData, uint32_t *destLen);
250
251 /* Cryptographic Operations API - MAC Functions */
252
253 void TEE_MACInit(TEE_OperationHandle operation, const void *IV,
254          uint32_t IVLen);
255
```

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```
256 void TEE_MACUpdate(TEE_OperationHandle operation, const void *chunk,
257             uint32_t chunkSize);
258
259 TEE_Result TEE_MACComputeFinal(TEE_OperationHandle operation,
260                     const void *message, uint32_t messageLen,
261                     void *mac, uint32_t *macLen);
262
263 TEE_Result TEE_MACCompareFinal(TEE_OperationHandle operation,
264                     const void *message, uint32_t messageLen,
265                     const void *mac, uint32_t macLen);
266
267 /* Cryptographic Operations API - Authenticated Encryption Functions */
268
269 TEE_Result TEE_AEInit(TEE_OperationHandle operation, const void *nonce,
270                uint32_t nonceLen, uint32_t tagLen, uint32_t AADLen,
271                uint32_t payloadLen);
272
273 void TEE_AEUpdateAAD(TEE_OperationHandle operation, const void *AADdata,
274                uint32_t AADdataLen);
275
276 TEE_Result TEE_AEUpdate(TEE_OperationHandle operation, const void *srcData,
277              uint32_t srcLen, void *destData, uint32_t *destLen);
278
279 TEE_Result TEE_AEEncryptFinal(TEE_OperationHandle operation,
280                     const void *srcData, uint32_t srcLen,
281                     void *destData, uint32_t *destLen, void *tag,
282                     uint32_t *tagLen);
283
284 TEE_Result TEE_AEDecryptFinal(TEE_OperationHandle operation,
285                     const void *srcData, uint32_t srcLen,
286                     void *destData, uint32_t *destLen, void *tag,
287                     uint32_t tagLen);
288
289 /* Cryptographic Operations API - Asymmetric Functions */
290
291 TEE_Result TEE_AsymmetricEncrypt(TEE_OperationHandle operation,
292                   const TEE_Attribute *params,
293                   uint32_t paramCount, const void *srcData,
294                   uint32_t srcLen, void *destData,
295                   uint32_t *destLen);
296
297 TEE_Result TEE_AsymmetricDecrypt(TEE_OperationHandle operation,
298                   const TEE_Attribute *params,
299                   uint32_t paramCount, const void *srcData,
300                   uint32_t srcLen, void *destData,
301                   uint32_t *destLen);
302
303 TEE_Result TEE_AsymmetricSignDigest(TEE_OperationHandle operation,
304                     const TEE_Attribute *params,
305                     uint32_t paramCount, const void *digest,
306                     uint32_t digestLen, void *signature,
307                     uint32_t *signatureLen);
308
309 TEE_Result TEE_AsymmetricVerifyDigest(TEE_OperationHandle operation,
310                       const TEE_Attribute *params,
311                       uint32_t paramCount, const void *digest,
312                       uint32_t digestLen, const void *signature,
313                       uint32_t signatureLen);
314
315 /* Cryptographic Operations API - Key Derivation Functions */
316
317 void TEE_DeriveKey(TEE_OperationHandle operation,
318             const TEE_Attribute *params, uint32_t paramCount,
319             TEE_ObjectHandle derivedKey);
320
321 /* Cryptographic Operations API - Random Number Generation Functions */
322
323 void TEE_GenerateRandom(void *randomBuffer, uint32_t randomBufferLen);
324
325 /* Date & Time API */
326
327 void TEE_GetSystemTime(TEE_Time *time);
328
329 TEE_Result TEE_Wait(uint32_t timeout);
330
331 TEE_Result TEE_GetTAPersistentTime(TEE_Time *time);
332
333 TEE_Result TEE_SetTAPersistentTime(const TEE_Time *time);
334
335 void TEE_GetREETime(TEE_Time *time);
336
337 /* TEE Arithmetical API - Memory allocation and size of objects */
338
339 uint32_t TEE_BigIntFMMSizeInU32(uint32_t modulusSizeInBits);
340
```

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```
341 uint32_t TEE_BigIntFMMContextSizeInU32(uint32_t modulusSizeInBits);
342
343 /* TEE Arithmetical API - Initialization functions */
344
345 void TEE_BigIntInit(TEE_BigInt *bigInt, uint32_t len);
346
347 void TEE_BigIntInitFMMContext(TEE_BigIntFMMContext *context, uint32_t len,
348                   const TEE_BigInt *modulus);
349
350 void TEE_BigIntInitFMM(TEE_BigIntFMM *bigIntFMM, uint32_t len);
351
352 /* TEE Arithmetical API - Converter functions */
353
354 TEE_Result TEE_BigIntConvertFromOctetString(TEE_BigInt *dest,
355                         const uint8_t *buffer,
356                         uint32_t bufferLen,
357                         int32_t sign);
358
359 TEE_Result TEE_BigIntConvertToOctetString(uint8_t *buffer, uint32_t *bufferLen,
360                       const TEE_BigInt *bigInt);
361
362 void TEE_BigIntConvertFromS32(TEE_BigInt *dest, int32_t shortVal);
363
364 TEE_Result TEE_BigIntConvertToS32(int32_t *dest, const TEE_BigInt *src);
365
366 /* TEE Arithmetical API - Logical operations */
367
368 int32_t TEE_BigIntCmp(const TEE_BigInt *op1, const TEE_BigInt *op2);
369
370 int32_t TEE_BigIntCmpS32(const TEE_BigInt *op, int32_t shortVal);
371
372 void TEE_BigIntShiftRight(TEE_BigInt *dest, const TEE_BigInt *op,
373               size_t bits);
374
375 bool TEE_BigIntGetBit(const TEE_BigInt *src, uint32_t bitIndex);
376
377 uint32_t TEE_BigIntGetBitCount(const TEE_BigInt *src);
378
379 void TEE_BigIntAdd(TEE_BigInt *dest, const TEE_BigInt *op1,
380            const TEE_BigInt *op2);
381
382 void TEE_BigIntSub(TEE_BigInt *dest, const TEE_BigInt *op1,
383            const TEE_BigInt *op2);
384
385 void TEE_BigIntNeg(TEE_BigInt *dest, const TEE_BigInt *op);
386
387 void TEE_BigIntMul(TEE_BigInt *dest, const TEE_BigInt *op1,
388            const TEE_BigInt *op2);
389
390 void TEE_BigIntSquare(TEE_BigInt *dest, const TEE_BigInt *op);
391
392 void TEE_BigIntDiv(TEE_BigInt *dest_q, TEE_BigInt *dest_r,
393            const TEE_BigInt *op1, const TEE_BigInt *op2);
394
395 /* TEE Arithmetical API - Modular arithmetic operations */
396
397 void TEE_BigIntMod(TEE_BigInt *dest, const TEE_BigInt *op,
398            const TEE_BigInt *n);
399
400 void TEE_BigIntAddMod(TEE_BigInt *dest, const TEE_BigInt *op1,
401               const TEE_BigInt *op2, const TEE_BigInt *n);
402
403 void TEE_BigIntSubMod(TEE_BigInt *dest, const TEE_BigInt *op1,
404               const TEE_BigInt *op2, const TEE_BigInt *n);
405
406 void TEE_BigIntMulMod(TEE_BigInt *dest, const  TEE_BigInt *op1,
407               const TEE_BigInt *op2, const TEE_BigInt *n);
408
409 void TEE_BigIntSquareMod(TEE_BigInt *dest, const TEE_BigInt *op,
410              const TEE_BigInt *n);
411
412 void TEE_BigIntInvMod(TEE_BigInt *dest, const TEE_BigInt *op,
413               const TEE_BigInt *n);
414
415 /* TEE Arithmetical API - Other arithmetic operations */
416
417 bool TEE_BigIntRelativePrime(const TEE_BigInt *op1, const TEE_BigInt *op2);
418
419 void TEE_BigIntComputeExtendedGcd(TEE_BigInt *gcd, TEE_BigInt *u,
420                   TEE_BigInt *v, const TEE_BigInt *op1,
421                   const TEE_BigInt *op2);
422
423 int32_t TEE_BigIntIsProbablePrime(const TEE_BigInt *op,
424                   uint32_t confidenceLevel);
425
```

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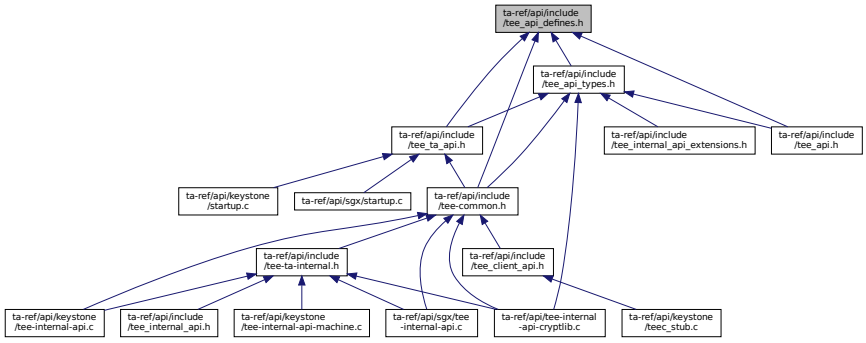
```
426 /* TEE Arithmetical API - Fast modular multiplication operations */
427
428 void TEE_BigIntConvertToFMM(TEE_BigIntFMM *dest, const TEE_BigInt *src,
429                 const TEE_BigInt *n,
430                 const TEE_BigIntFMMContext *context);
431
432 void TEE_BigIntConvertFromFMM(TEE_BigInt *dest, const TEE_BigIntFMM *src,
433                   const TEE_BigInt *n,
434                   const TEE_BigIntFMMContext *context);
435
436 void TEE_BigIntFMMConvertToBigInt(TEE_BigInt *dest, const TEE_BigIntFMM *src,
437                   const TEE_BigInt *n,
438                   const TEE_BigIntFMMContext *context);
439
440 void TEE_BigIntComputeFMM(TEE_BigIntFMM *dest, const TEE_BigIntFMM *op1,
441               const TEE_BigIntFMM *op2, const TEE_BigInt *n,
442               const TEE_BigIntFMMContext *context);
443
444 #endif /* TEE_API_H */
```

13.11 ta-ref/api/include/tee_api_defines.h File Reference

This graph shows which files directly or indirectly include this file:



13.12 tee_api_defines.h

Go to the documentation of this file.

```
1 /*
2  * Copyright (c) 2014, STMicroelectronics International N.V.
3  * All rights reserved.
4  *
5  * Redistribution and use in source and binary forms, with or without
6  * modification, are permitted provided that the following conditions are met:
7  *
8  * 1. Redistributions of source code must retain the above copyright notice,
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17  * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
18  * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
19  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
20  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
21  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
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23  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
24  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
```

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```
 * POSSIBILITY OF SUCH DAMAGE.
 */

/* Based on GP TEE Internal Core API Specification Version 1.1 */

#ifndef TEE_API_DEFINES_H
#define TEE_API_DEFINES_H

#ifndef DOXYGEN_SHOULD_SKIP_THIS
#define TEE_INT_CORE_API_SPEC_VERSION     0x0000000A

#define TEE_HANDLE_NULL                   0

#define TEE_TIMEOUT_INFINITE              0xFFFFFFFF

/* API Error Codes */
#define TEE_SUCCESS                       0x00000000
#define TEE_ERROR_CORRUPT_OBJECT          0xF0100001
#define TEE_ERROR_CORRUPT_OBJECT_2        0xF0100002
#define TEE_ERROR_STORAGE_NOT_AVAILABLE   0xF0100003
#define TEE_ERROR_STORAGE_NOT_AVAILABLE_2 0xF0100004
#define TEE_ERROR_GENERIC                 0xFFFF0000
#define TEE_ERROR_ACCESS_DENIED           0xFFFF0001
#define TEE_ERROR_CANCEL                  0xFFFF0002
#define TEE_ERROR_ACCESS_CONFLICT         0xFFFF0003
#define TEE_ERROR_EXCESS_DATA             0xFFFF0004
#define TEE_ERROR_BAD_FORMAT              0xFFFF0005
#define TEE_ERROR_BAD_PARAMETERS          0xFFFF0006
#define TEE_ERROR_BAD_STATE               0xFFFF0007
#define TEE_ERROR_ITEM_NOT_FOUND          0xFFFF0008
#define TEE_ERROR_NOT_IMPLEMENTED         0xFFFF0009
#define TEE_ERROR_NOT_SUPPORTED           0xFFFF000A
#define TEE_ERROR_NO_DATA                 0xFFFF000B
#define TEE_ERROR_OUT_OF_MEMORY           0xFFFF000C
#define TEE_ERROR_BUSY                    0xFFFF000D
#define TEE_ERROR_COMMUNICATION           0xFFFF000E
#define TEE_ERROR_SECURITY                0xFFFF000F
#define TEE_ERROR_SHORT_BUFFER            0xFFFF0010
#define TEE_ERROR_EXTERNAL_CANCEL         0xFFFF0011
#define TEE_ERROR_OVERFLOW                0xFFFF300F
#define TEE_ERROR_TARGET_DEAD             0xFFFF3024
#define TEE_ERROR_STORAGE_NO_SPACE        0xFFFF3041
#define TEE_ERROR_MAC_INVALID             0xFFFF3071
#define TEE_ERROR_SIGNATURE_INVALID       0xFFFF3072
#define TEE_ERROR_TIME_NOT_SET            0xFFFF5000
#define TEE_ERROR_TIME_NEEDS_RESET        0xFFFF5001

/* Parameter Type Constants */
#define TEE_PARAM_TYPE_NONE             0
#define TEE_PARAM_TYPE_VALUE_INPUT      1
#define TEE_PARAM_TYPE_VALUE_OUTPUT     2
#define TEE_PARAM_TYPE_VALUE_INOUT      3
#define TEE_PARAM_TYPE_MEMREF_INPUT     5
#define TEE_PARAM_TYPE_MEMREF_OUTPUT    6
#define TEE_PARAM_TYPE_MEMREF_INOUT     7

/* Login Type Constants */
#define TEE_LOGIN_PUBLIC                0x00000000
#define TEE_LOGIN_USER                  0x00000001
#define TEE_LOGIN_GROUP                 0x00000002
#define TEE_LOGIN_APPLICATION           0x00000004
#define TEE_LOGIN_APPLICATION_USER      0x00000005
#define TEE_LOGIN_APPLICATION_GROUP     0x00000006
#define TEE_LOGIN_TRUSTED_APP           0xF0000000

/* Origin Code Constants */
#define TEE_ORIGIN_API                  0x00000001
#define TEE_ORIGIN_COMMS                0x00000002
#define TEE_ORIGIN_TEE                  0x00000003
#define TEE_ORIGIN_TRUSTED_APP          0x00000004

/* Property Sets pseudo handles */
#define TEE_PROPSET_TEE_IMPLEMENTATION  (TEE_PropSetHandle)0xFFFFFFFD
#define TEE_PROPSET_CURRENT_CLIENT      (TEE_PropSetHandle)0xFFFFFFFE
#define TEE_PROPSET_CURRENT_TA          (TEE_PropSetHandle)0xFFFFFFFF

/* Memory Access Rights Constants */
#define TEE_MEMORY_ACCESS_READ             0x00000001
#define TEE_MEMORY_ACCESS_WRITE            0x00000002
#define TEE_MEMORY_ACCESS_ANY_OWNER        0x00000004

/* Memory Management Constant */
#define TEE_MALLOC_FILL_ZERO               0x00000000

/* Other constants */
```

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```
110 #define TEE_STORAGE_PRIVATE                0x00000001
111
112 #define TEE_DATA_FLAG_ACCESS_READ          0x00000001
113 #define TEE_DATA_FLAG_ACCESS_WRITE         0x00000002
114 #define TEE_DATA_FLAG_ACCESS_WRITE_META    0x00000004
115 #define TEE_DATA_FLAG_SHARE_READ           0x00000010
116 #define TEE_DATA_FLAG_SHARE_WRITE          0x00000020
117 #define TEE_DATA_FLAG_OVERWRITE            0x00000400
118 #define TEE_DATA_MAX_POSITION              0xFFFFFFFF
119 #define TEE_OBJECT_ID_MAX_LEN              64
120 #define TEE_USAGE_EXTRACTABLE              0x00000001
121 #define TEE_USAGE_ENCRYPT                  0x00000002
122 #define TEE_USAGE_DECRYPT                  0x00000004
123 #define TEE_USAGE_MAC                      0x00000008
124 #define TEE_USAGE_SIGN                     0x00000010
125 #define TEE_USAGE_VERIFY                   0x00000020
126 #define TEE_USAGE_DERIVE                   0x00000040
127 #define TEE_HANDLE_FLAG_PERSISTENT         0x00010000
128 #define TEE_HANDLE_FLAG_INITIALIZED        0x00020000
129 #define TEE_HANDLE_FLAG_KEY_SET            0x00040000
130 #define TEE_HANDLE_FLAG_EXPECT_TWO_KEYS    0x00080000
131 #define TEE_OPERATION_CIPHER               1
132 #define TEE_OPERATION_MAC                  3
133 #define TEE_OPERATION_AE                   4
134 #define TEE_OPERATION_DIGEST               5
135 #define TEE_OPERATION_ASYMMETRIC_CIPHER    6
136 #define TEE_OPERATION_ASYMMETRIC_SIGNATURE 7
137 #define TEE_OPERATION_KEY_DERIVATION       8
138 #define TEE_OPERATION_STATE_INITIAL        0x00000000
139 #define TEE_OPERATION_STATE_ACTIVE         0x00000001
140
141 /* Algorithm Identifiers */
142 #define TEE_ALG_AES_ECB_NOPAD                   0x10000010
143 #define TEE_ALG_AES_CBC_NOPAD                   0x10000110
144 #define TEE_ALG_AES_CTR                         0x10000210
145 #define TEE_ALG_AES_CTS                         0x10000310
146 #define TEE_ALG_AES_XTS                         0x10000410
147 #define TEE_ALG_AES_CBC_MAC_NOPAD               0x30000110
148 #define TEE_ALG_AES_CBC_MAC_PKCS5               0x30000510
149 #define TEE_ALG_AES_CMAC                        0x30000610
150 #define TEE_ALG_AES_CCM                         0x40000710
151 #define TEE_ALG_AES_GCM                         0x40000810
152 #define TEE_ALG_DES_ECB_NOPAD                   0x10000011
153 #define TEE_ALG_DES_CBC_NOPAD                   0x10000111
154 #define TEE_ALG_DES_CBC_MAC_NOPAD               0x30000111
155 #define TEE_ALG_DES_CBC_MAC_PKCS5               0x30000511
156 #define TEE_ALG_DES3_ECB_NOPAD                  0x10000013
157 #define TEE_ALG_DES3_CBC_NOPAD                  0x10000113
158 #define TEE_ALG_DES3_CBC_MAC_NOPAD              0x30000113
159 #define TEE_ALG_DES3_CBC_MAC_PKCS5              0x30000513
160 #define TEE_ALG_RSASSA_PKCS1_V1_5_MD5           0x70001830
161 #define TEE_ALG_RSASSA_PKCS1_V1_5_SHA1          0x70002830
162 #define TEE_ALG_RSASSA_PKCS1_V1_5_SHA224        0x70003830
163 #define TEE_ALG_RSASSA_PKCS1_V1_5_SHA256        0x70004830
164 #define TEE_ALG_RSASSA_PKCS1_V1_5_SHA384        0x70005830
165 #define TEE_ALG_RSASSA_PKCS1_V1_5_SHA512        0x70006830
166 #define TEE_ALG_RSASSA_PKCS1_V1_5_MD5SHA1       0x7000F830
167 #define TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA1      0x70212930
168 #define TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA224    0x70313930
169 #define TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA256    0x70414930
170 #define TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA384    0x70515930
171 #define TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA512    0x70616930
172 #define TEE_ALG_RSAES_PKCS1_V1_5                0x60000130
173 #define TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA1      0x60210230
174 #define TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA224    0x60310230
175 #define TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA256    0x60410230
176 #define TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA384    0x60510230
177 #define TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA512    0x60610230
178 #define TEE_ALG_RSA_NOPAD                       0x60000030
179 #define TEE_ALG_DSA_SHA1                        0x70002131
180 #define TEE_ALG_DSA_SHA224                      0x70003131
181 #define TEE_ALG_DSA_SHA256                      0x70004131
182 #define TEE_ALG_DH_DERIVE_SHARED_SECRET         0x80000032
183 #define TEE_ALG_MD5                             0x50000001
184 #define TEE_ALG_SHA1                            0x50000002
185 #define TEE_ALG_SHA224                          0x50000003
186 #define TEE_ALG_SHA256                          0x50000004
187 #define TEE_ALG_SHA384                          0x50000005
188 #define TEE_ALG_SHA512                          0x50000006
189 #define TEE_ALG_MD5SHA1                         0x5000000F
190 #define TEE_ALG_HMAC_MD5                        0x30000001
191 #define TEE_ALG_HMAC_SHA1                       0x30000002
192 #define TEE_ALG_HMAC_SHA224                     0x30000003
193 #define TEE_ALG_HMAC_SHA256                     0x30000004
194 #define TEE_ALG_HMAC_SHA384                     0x30000005
```

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```
195 #define TEE_ALG_HMAC_SHA512                     0x30000006
196 /*
197  * Fix GP Internal Core API v1.1
198  *     "Table 6-12:  Structure of Algorithm Identifier"
199  *     indicates ECDSA have the algorithm "0x41" and ECDH "0x42"
200  * whereas
201  *     "Table 6-11:  List of Algorithm Identifiers" defines
202  *     TEE_ALG_ECDSA_P192 as 0x70001042
203  *
204  * We chose to define TEE_ALG_ECDSA_P192 as 0x70001041 (conform to table 6-12)
205  */
206 #define TEE_ALG_ECDSA_P192                      0x70001041
207 #define TEE_ALG_ECDSA_P224                      0x70002041
208 #define TEE_ALG_ECDSA_P256                      0x70003041
209 #define TEE_ALG_ECDSA_P384                      0x70004041
210 #define TEE_ALG_ECDSA_P521                      0x70005041
211 #define TEE_ALG_ECDH_P192                       0x80001042
212 #define TEE_ALG_ECDH_P224                       0x80002042
213 #define TEE_ALG_ECDH_P256                       0x80003042
214 #define TEE_ALG_ECDH_P384                       0x80004042
215 #define TEE_ALG_ECDH_P521                       0x80005042
216
217 /* Object Types */
218
219 #define TEE_TYPE_AES                            0xA0000010
220 #define TEE_TYPE_DES                            0xA0000011
221 #define TEE_TYPE_DES3                           0xA0000013
222 #define TEE_TYPE_HMAC_MD5                       0xA0000001
223 #define TEE_TYPE_HMAC_SHA1                      0xA0000002
224 #define TEE_TYPE_HMAC_SHA224                    0xA0000003
225 #define TEE_TYPE_HMAC_SHA256                    0xA0000004
226 #define TEE_TYPE_HMAC_SHA384                    0xA0000005
227 #define TEE_TYPE_HMAC_SHA512                    0xA0000006
228 #define TEE_TYPE_RSA_PUBLIC_KEY                 0xA0000030
229 #define TEE_TYPE_RSA_KEYPAIR                    0xA1000030
230 #define TEE_TYPE_DSA_PUBLIC_KEY                 0xA0000031
231 #define TEE_TYPE_DSA_KEYPAIR                    0xA1000031
232 #define TEE_TYPE_DH_KEYPAIR                     0xA1000032
233 #define TEE_TYPE_ECDSA_PUBLIC_KEY               0xA0000041
234 #define TEE_TYPE_ECDSA_KEYPAIR                  0xA1000041
235 #define TEE_TYPE_ECDH_PUBLIC_KEY                0xA0000042
236 #define TEE_TYPE_ECDH_KEYPAIR                   0xA1000042
237 #define TEE_TYPE_GENERIC_SECRET                 0xA0000000
238 #define TEE_TYPE_CORRUPTED_OBJECT               0xA00000BE
239 #define TEE_TYPE_DATA                           0xA00000BF
240
241 /* List of Object or Operation Attributes */
242
243 #define TEE_ATTR_SECRET_VALUE                   0xC0000000
244 #define TEE_ATTR_RSA_MODULUS                    0xD0000130
245 #define TEE_ATTR_RSA_PUBLIC_EXPONENT            0xD0000230
246 #define TEE_ATTR_RSA_PRIVATE_EXPONENT           0xC0000330
247 #define TEE_ATTR_RSA_PRIME1                     0xC0000430
248 #define TEE_ATTR_RSA_PRIME2                     0xC0000530
249 #define TEE_ATTR_RSA_EXPONENT1                  0xC0000630
250 #define TEE_ATTR_RSA_EXPONENT2                  0xC0000730
251 #define TEE_ATTR_RSA_COEFFICIENT                0xC0000830
252 #define TEE_ATTR_DSA_PRIME                      0xD0001031
253 #define TEE_ATTR_DSA_SUBPRIME                   0xD0001131
254 #define TEE_ATTR_DSA_BASE                       0xD0001231
255 #define TEE_ATTR_DSA_PUBLIC_VALUE               0xD0000131
256 #define TEE_ATTR_DSA_PRIVATE_VALUE              0xC0000231
257 #define TEE_ATTR_DH_PRIME                       0xD0001032
258 #define TEE_ATTR_DH_SUBPRIME                    0xD0001132
259 #define TEE_ATTR_DH_BASE                        0xD0001232
260 #define TEE_ATTR_DH_X_BITS                      0xF0001332
261 #define TEE_ATTR_DH_PUBLIC_VALUE                0xD0000132
262 #define TEE_ATTR_DH_PRIVATE_VALUE               0xC0000232
263 #define TEE_ATTR_RSA_OAEP_LABEL                 0xD0000930
264 #define TEE_ATTR_RSA_PSS_SALT_LENGTH            0xF0000A30
265 #define TEE_ATTR_ECC_PUBLIC_VALUE_X             0xD0000141
266 #define TEE_ATTR_ECC_PUBLIC_VALUE_Y             0xD0000241
267 #define TEE_ATTR_ECC_PRIVATE_VALUE              0xC0000341
268 #define TEE_ATTR_ECC_CURVE                      0xF0000441
269
270 #define TEE_ATTR_BIT_PROTECTED      (1 « 28)
271 #define TEE_ATTR_BIT_VALUE      (1 « 29)
272
273 /* List of Supported ECC Curves */
274 #define TEE_ECC_CURVE_NIST_P192                 0x00000001
275 #define TEE_ECC_CURVE_NIST_P224                 0x00000002
276 #define TEE_ECC_CURVE_NIST_P256                 0x00000003
277 #define TEE_ECC_CURVE_NIST_P384                 0x00000004
278 #define TEE_ECC_CURVE_NIST_P521                 0x00000005
279
```

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```
280
281 /* Panicked Functions Identification */
282 /* TA Interface */
283 #define TEE_PANIC_ID_TA_CLOSESESSIONENTRYPOINT      0x00000101
284 #define TEE_PANIC_ID_TA_CREATEENTRYPOINT            0x00000102
285 #define TEE_PANIC_ID_TA_DESTROYENTRYPOINT           0x00000103
286 #define TEE_PANIC_ID_TA_INVOKECOMMANDENTRYPOINT     0x00000104
287 #define TEE_PANIC_ID_TA_OPENSESSIONENTRYPOINT       0x00000105
288 /* Property Access */
289 #define TEE_PANIC_ID_TEE_ALLOCATEPROPERTYENUMERATOR 0x00000201
290 #define TEE_PANIC_ID_TEE_FREEPROPERTYENUMERATOR     0x00000202
291 #define TEE_PANIC_ID_TEE_GETNEXTPROPERTY            0x00000203
292 #define TEE_PANIC_ID_TEE_GETPROPERTYASBINARYBLOCK   0x00000204
293 #define TEE_PANIC_ID_TEE_GETPROPERTYASBOOL          0x00000205
294 #define TEE_PANIC_ID_TEE_GETPROPERTYASIDENTITY      0x00000206
295 #define TEE_PANIC_ID_TEE_GETPROPERTYASSTRING        0x00000207
296 #define TEE_PANIC_ID_TEE_GETPROPERTYASU32           0x00000208
297 #define TEE_PANIC_ID_TEE_GETPROPERTYASUUID          0x00000209
298 #define TEE_PANIC_ID_TEE_GETPROPERTYNAME            0x0000020A
299 #define TEE_PANIC_ID_TEE_RESETPROPERTYENUMERATOR    0x0000020B
300 #define TEE_PANIC_ID_TEE_STARTPROPERTYENUMERATOR    0x0000020C
301 /* Panic Function */
302 #define TEE_PANIC_ID_TEE_PANIC                      0x00000301
303 /* Internal Client API */
304 #define TEE_PANIC_ID_TEE_CLOSETASESSION             0x00000401
305 #define TEE_PANIC_ID_TEE_INVOKETACOMMAND            0x00000402
306 #define TEE_PANIC_ID_TEE_OPENTASESSION              0x00000403
307 /* Cancellation */
308 #define TEE_PANIC_ID_TEE_GETCANCELLATIONFLAG        0x00000501
309 #define TEE_PANIC_ID_TEE_MASKCANCELLATION           0x00000502
310 #define TEE_PANIC_ID_TEE_UNMASKCANCELLATION         0x00000503
311 /* Memory Management */
312 #define TEE_PANIC_ID_TEE_CHECKMEMORYACCESSRIGHTS    0x00000601
313 #define TEE_PANIC_ID_TEE_FREE                       0x00000602
314 #define TEE_PANIC_ID_TEE_GETINSTANCEDATA            0x00000603
315 #define TEE_PANIC_ID_TEE_MALLOC                     0x00000604
316 #define TEE_PANIC_ID_TEE_MEMCOMPARE                 0x00000605
317 #define TEE_PANIC_ID_TEE_MEMFILL                    0x00000606
318 #define TEE_PANIC_ID_TEE_MEMMOVE                    0x00000607
319 #define TEE_PANIC_ID_TEE_REALLOC                    0x00000608
320 #define TEE_PANIC_ID_TEE_SETINSTANCEDATA            0x00000609
321 /* Generic Object */
322 #define TEE_PANIC_ID_TEE_CLOSEOBJECT                0x00000701
323 #define TEE_PANIC_ID_TEE_GETOBJECTBUFFERATTRIBUTE   0x00000702
324 /* deprecated */
325 #define TEE_PANIC_ID_TEE_GETOBJECTINFO              0x00000703
326 #define TEE_PANIC_ID_TEE_GETOBJECTVALUEATTRIBUTE    0x00000704
327 /* deprecated */
328 #define TEE_PANIC_ID_TEE_RESTRICTOBJECTUSAGE        0x00000705
329 #define TEE_PANIC_ID_TEE_GETOBJECTINFO1             0x00000706
330 #define TEE_PANIC_ID_TEE_RESTRICTOBJECTUSAGE1       0x00000707
331 /* Transient Object */
332 #define TEE_PANIC_ID_TEE_ALLOCATETRANSIENTOBJECT    0x00000801
333 /* deprecated */
334 #define TEE_PANIC_ID_TEE_COPYOBJECTATTRIBUTES       0x00000802
335 #define TEE_PANIC_ID_TEE_FREETRANSIENTOBJECT        0x00000803
336 #define TEE_PANIC_ID_TEE_GENERATEKEY                0x00000804
337 #define TEE_PANIC_ID_TEE_INITREFATTRIBUTE           0x00000805
338 #define TEE_PANIC_ID_TEE_INITVALUEATTRIBUTE         0x00000806
339 #define TEE_PANIC_ID_TEE_POPULATETRANSIENTOBJECT    0x00000807
340 #define TEE_PANIC_ID_TEE_RESETTRANSIENTOBJECT       0x00000808
341 #define TEE_PANIC_ID_TEE_COPYOBJECTATTRIBUTES1      0x00000809
342 /* Persistent Object */
343 /* deprecated */
344 #define TEE_PANIC_ID_TEE_CLOSEANDDELETEPERSISTENTOBJECT  0x00000901
345 #define TEE_PANIC_ID_TEE_CREATEPERSISTENTOBJECT          0x00000902
346 #define TEE_PANIC_ID_TEE_OPENPERSISTENTOBJECT            0x00000903
347 #define TEE_PANIC_ID_TEE_RENAMEPERSISTENTOBJECT          0x00000904
348 #define TEE_PANIC_ID_TEE_CLOSEANDDELETEPERSISTENTOBJECT1 0x00000905
349 /* Persistent Object Enumeration */
350 #define TEE_PANIC_ID_TEE_ALLOCATEPERSISTENTOBJECTENUMERATOR 0x00000A01
351 #define TEE_PANIC_ID_TEE_FREEPERSISTENTOBJECTENUMERATOR     0x00000A02
352 #define TEE_PANIC_ID_TEE_GETNEXTPERSISTENTOBJECT            0x00000A03
353 #define TEE_PANIC_ID_TEE_RESETPERSISTENTOBJECTENUMERATOR    0x00000A04
354 #define TEE_PANIC_ID_TEE_STARTPERSISTENTOBJECTENUMERATOR    0x00000A05
355 /* Data Stream Access */
356 #define TEE_PANIC_ID_TEE_READOBJECTDATA             0x00000B01
357 #define TEE_PANIC_ID_TEE_SEEKOBJECTDATA             0x00000B02
358 #define TEE_PANIC_ID_TEE_TRUNCATEOBJECTDATA         0x00000B03
359 #define TEE_PANIC_ID_TEE_WRITEOBJECTDATA            0x00000B04
360 /* Generic Operation */
361 #define TEE_PANIC_ID_TEE_ALLOCATEOPERATION          0x00000C01
362 #define TEE_PANIC_ID_TEE_COPYOPERATION              0x00000C02
363 #define TEE_PANIC_ID_TEE_FREEOPERATION              0x00000C03
364 #define TEE_PANIC_ID_TEE_GETOPERATIONINFO           0x00000C04
```

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```
365 #define TEE_PANIC_ID_TEE_RESETOPERATION             0x00000C05
366 #define TEE_PANIC_ID_TEE_SETOPERATIONKEY            0x00000C06
367 #define TEE_PANIC_ID_TEE_SETOPERATIONKEY2           0x00000C07
368 #define TEE_PANIC_ID_TEE_GETOPERATIONINFOMULTIPLE   0x00000C08
369 /* Message Digest */
370 #define TEE_PANIC_ID_TEE_DIGESTDOFINAL              0x00000D01
371 #define TEE_PANIC_ID_TEE_DIGESTUPDATE               0x00000D02
372 /* Symmetric Cipher */
373 #define TEE_PANIC_ID_TEE_CIPHERDOFINAL              0x00000E01
374 #define TEE_PANIC_ID_TEE_CIPHERINIT                 0x00000E02
375 #define TEE_PANIC_ID_TEE_CIPHERUPDATE               0x00000E03
376 /* MAC */
377 #define TEE_PANIC_ID_TEE_MACCOMPAREFINAL            0x00000F01
378 #define TEE_PANIC_ID_TEE_MACCOMPUTEFINAL            0x00000F02
379 #define TEE_PANIC_ID_TEE_MACINIT                    0x00000F03
380 #define TEE_PANIC_ID_TEE_MACUPDATE                  0x00000F04
381 /* Authenticated Encryption */
382 #define TEE_PANIC_ID_TEE_AEDECRYPTFINAL             0x00001001
383 #define TEE_PANIC_ID_TEE_AEENCRYPTFINAL             0x00001002
384 #define TEE_PANIC_ID_TEE_AEINIT                     0x00001003
385 #define TEE_PANIC_ID_TEE_AEUPDATE                   0x00001004
386 #define TEE_PANIC_ID_TEE_AEUPDATEAAD                0x00001005
387 /* Asymmetric */
388 #define TEE_PANIC_ID_TEE_ASYMMETRICDECRYPT          0x00001101
389 #define TEE_PANIC_ID_TEE_ASYMMETRICENCRYPT          0x00001102
390 #define TEE_PANIC_ID_TEE_ASYMMETRICSIGNDIGEST       0x00001103
391 #define TEE_PANIC_ID_TEE_ASYMMETRICVERIFYDIGEST     0x00001104
392 /* Key Derivation */
393 #define TEE_PANIC_ID_TEE_DERIVEKEY                  0x00001201
394 /* Random Data Generation */
395 #define TEE_PANIC_ID_TEE_GENERATERANDOM             0x00001301
396 /* Time */
397 #define TEE_PANIC_ID_TEE_GETREETIME                 0x00001401
398 #define TEE_PANIC_ID_TEE_GETSYSTEMTIME              0x00001402
399 #define TEE_PANIC_ID_TEE_GETTAPERSISTENTTIME        0x00001403
400 #define TEE_PANIC_ID_TEE_SETTAPERSISTENTTIME        0x00001404
401 #define TEE_PANIC_ID_TEE_WAIT                       0x00001405
402 /* Memory Allocation and Size of Objects */
403 #define TEE_PANIC_ID_TEE_BIGINTFMMCONTEXTSIZEINU32  0x00001501
404 #define TEE_PANIC_ID_TEE_BIGINTFMMSIZEINU32         0x00001502
405 /* Initialization */
406 #define TEE_PANIC_ID_TEE_BIGINTINIT                 0x00001601
407 #define TEE_PANIC_ID_TEE_BIGINTINITFMM              0x00001602
408 #define TEE_PANIC_ID_TEE_BIGINTINITFMMCONTEXT       0x00001603
409 /* Converter */
410 #define TEE_PANIC_ID_TEE_BIGINTCONVERTFROMOCTETSTRING 0x00001701
411 #define TEE_PANIC_ID_TEE_BIGINTCONVERTFROMS32         0x00001702
412 #define TEE_PANIC_ID_TEE_BIGINTCONVERTTOOCTETSTRING   0x00001703
413 #define TEE_PANIC_ID_TEE_BIGINTCONVERTTOS32           0x00001704
414 /* Logical Operation */
415 #define TEE_PANIC_ID_TEE_BIGINTCMP                  0x00001801
416 #define TEE_PANIC_ID_TEE_BIGINTCMPS32               0x00001802
417 #define TEE_PANIC_ID_TEE_BIGINTGETBIT               0x00001803
418 #define TEE_PANIC_ID_TEE_BIGINTGETBITCOUNT          0x00001804
419 #define TEE_PANIC_ID_TEE_BIGINTSHIFTRIGHT           0x00001805
420 /* Basic Arithmetic */
421 #define TEE_PANIC_ID_TEE_BIGINTADD                  0x00001901
422 #define TEE_PANIC_ID_TEE_BIGINTDIV                  0x00001902
423 #define TEE_PANIC_ID_TEE_BIGINTMUL                  0x00001903
424 #define TEE_PANIC_ID_TEE_BIGINTNEG                  0x00001904
425 #define TEE_PANIC_ID_TEE_BIGINTSQUARE               0x00001905
426 #define TEE_PANIC_ID_TEE_BIGINTSUB                  0x00001906
427 /* Modular Arithmetic */
428 #define TEE_PANIC_ID_TEE_BIGINTADDMOD               0x00001A01
429 #define TEE_PANIC_ID_TEE_BIGINTINVMOD               0x00001A02
430 #define TEE_PANIC_ID_TEE_BIGINTMOD                  0x00001A03
431 #define TEE_PANIC_ID_TEE_BIGINTMULMOD               0x00001A04
432 #define TEE_PANIC_ID_TEE_BIGINTSQUAREMOD            0x00001A05
433 #define TEE_PANIC_ID_TEE_BIGINTSUBMOD               0x00001A06
434 /* Other Arithmetic */
435 #define TEE_PANIC_ID_TEE_BIGINTCOMPUTEEXTENDEDGCD   0x00001B01
436 #define TEE_PANIC_ID_TEE_BIGINTISPROBABLEPRIME      0x00001B02
437 #define TEE_PANIC_ID_TEE_BIGINTRELATIVEPRIME        0x00001B03
438 /* Fast Modular Multiplication */
439 #define TEE_PANIC_ID_TEE_BIGINTCOMPUTEFMM           0x00001C01
440 #define TEE_PANIC_ID_TEE_BIGINTCONVERTFROMFMM       0x00001C02
441 #define TEE_PANIC_ID_TEE_BIGINTCONVERTTOFMM         0x00001C03
442
443 /*
444  * The macro TEE_PARAM_TYPES can be used to construct a value that you can
445  * compare against an incoming paramTypes to check the type of all the
446  * parameters in one comparison, like in the following example:
447  * if (paramTypes != TEE_PARAM_TYPES(TEE_PARAM_TYPE_MEMREF_INPUT,
448  *                                   TEE_PARAM_TYPE_MEMREF_OUPUT,
449  *                                   TEE_PARAM_TYPE_NONE, TEE_PARAM_TYPE_NONE)) {
```

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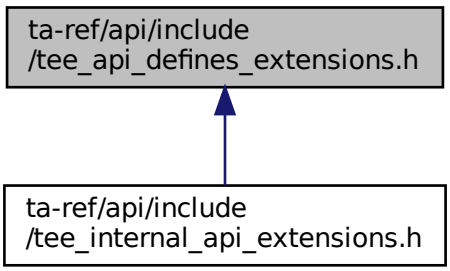
```
450  *      return TEE_ERROR_BAD_PARAMETERS;
451  *  }
452  */
453 #define TEE_PARAM_TYPES(t0,t1,t2,t3) \
454    ((t0) | ((t1) « 4) | ((t2) « 8) | ((t3) « 12))
455
456 /*
457  * The macro TEE_PARAM_TYPE_GET can be used to extract the type of a given
458  * parameter from paramTypes if you need more fine-grained type checking.
459  */
460 #define TEE_PARAM_TYPE_GET(t, i) ((((uint32_t)t) » ((i)*4)) & 0xF)
461
462 /*
463  * The macro TEE_PARAM_TYPE_SET can be used to load the type of a given
464  * parameter from paramTypes without specifying all types (TEE_PARAM_TYPES)
465  */
466 #define TEE_PARAM_TYPE_SET(t, i) (((uint32_t)(t) & 0xF) « ((i)*4))
467
468 /* Not specified in the standard */
469 #define TEE_NUM_PARAMS  4
470
471 /* TEE Arithmetical APIs */
472
473 #define TEE_BigIntSizeInU32(n) ((((n)+31)/32)+2)
474
475 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
476 #endif /* TEE_API_DEFINES_H */
```

13.13 ta-ref/api/include/tee_api_defines_extensions.h File Reference

This graph shows which files directly or indirectly include this file:



13.14 tee_api_defines_extensions.h

Go to the documentation of this file.

```
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4  *
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```
 *
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 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
 * POSSIBILITY OF SUCH DAMAGE.
 */

#ifndef TEE_API_DEFINES_EXTENSIONS_H
#define TEE_API_DEFINES_EXTENSIONS_H
#ifndef DOXYGEN_SHOULD_SKIP_THIS

/*
 * HMAC-based Extract-and-Expand Key Derivation Function (HKDF)
 */

#define TEE_ALG_HKDF_MD5_DERIVE_KEY     0x800010C0
#define TEE_ALG_HKDF_SHA1_DERIVE_KEY    0x800020C0
#define TEE_ALG_HKDF_SHA224_DERIVE_KEY  0x800030C0
#define TEE_ALG_HKDF_SHA256_DERIVE_KEY  0x800040C0
#define TEE_ALG_HKDF_SHA384_DERIVE_KEY  0x800050C0
#define TEE_ALG_HKDF_SHA512_DERIVE_KEY  0x800060C0

#define TEE_TYPE_HKDF_IKM               0xA10000C0

#define TEE_ATTR_HKDF_IKM               0xC00001C0
#define TEE_ATTR_HKDF_SALT              0xD00002C0
#define TEE_ATTR_HKDF_INFO              0xD00003C0
#define TEE_ATTR_HKDF_OKM_LENGTH        0xF00004C0

/*
 * Concatenation Key Derivation Function (Concat KDF)
 * NIST SP 800-56A section 5.8.1
 */

#define TEE_ALG_CONCAT_KDF_SHA1_DERIVE_KEY    0x800020C1
#define TEE_ALG_CONCAT_KDF_SHA224_DERIVE_KEY  0x800030C1
#define TEE_ALG_CONCAT_KDF_SHA256_DERIVE_KEY  0x800040C1
#define TEE_ALG_CONCAT_KDF_SHA384_DERIVE_KEY  0x800050C1
#define TEE_ALG_CONCAT_KDF_SHA512_DERIVE_KEY  0x800060C1

#define TEE_TYPE_CONCAT_KDF_Z                 0xA10000C1

#define TEE_ATTR_CONCAT_KDF_Z                 0xC00001C1
#define TEE_ATTR_CONCAT_KDF_OTHER_INFO        0xD00002C1
#define TEE_ATTR_CONCAT_KDF_DKM_LENGTH        0xF00003C1

/*
 * PKCS #5 v2.0 Key Derivation Function 2 (PBKDF2)
 * RFC 2898 section 5.2
 * https://www.ietf.org/rfc/rfc2898.txt
 */

#define TEE_ALG_PBKDF2_HMAC_SHA1_DERIVE_KEY 0x800020C2

#define TEE_TYPE_PBKDF2_PASSWORD            0xA10000C2

#define TEE_ATTR_PBKDF2_PASSWORD            0xC00001C2
#define TEE_ATTR_PBKDF2_SALT                0xD00002C2
#define TEE_ATTR_PBKDF2_ITERATION_COUNT     0xF00003C2
#define TEE_ATTR_PBKDF2_DKM_LENGTH          0xF00004C2

/*
 * Implementation-specific object storage constants
 */

/* Storage is provided by the Rich Execution Environment (REE) */
#define TEE_STORAGE_PRIVATE_REE  0x80000000
/* Storage is the Replay Protected Memory Block partition of an eMMC device */
#define TEE_STORAGE_PRIVATE_RPMB 0x80000100
/* Was TEE_STORAGE_PRIVATE_SQL, which isn't supported any longer */
#define TEE_STORAGE_PRIVATE_SQL_RESERVED  0x80000200

/*
 * Extension of "Memory Access Rights Constants"
 * #define TEE_MEMORY_ACCESS_READ             0x00000001
 * #define TEE_MEMORY_ACCESS_WRITE            0x00000002
 * #define TEE_MEMORY_ACCESS_ANY_OWNER        0x00000004
 *
```

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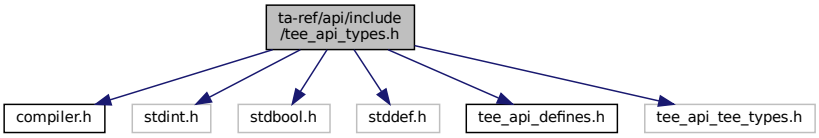
```
99  * TEE_MEMORY_ACCESS_NONSECURE : if set TEE_CheckMemoryAccessRights()
100  * successfully returns only if target vmem range is mapped non-secure.
101  *
102  * TEE_MEMORY_ACCESS_SECURE : if set TEE_CheckMemoryAccessRights()
103  * successfully returns only if target vmem range is mapped secure.
104
105  */
106 #define TEE_MEMORY_ACCESS_NONSECURE          0x10000000
107 #define TEE_MEMORY_ACCESS_SECURE             0x20000000
108
109 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
110 #endif /* TEE_API_DEFINES_EXTENSIONS_H */
```

13.15 ta-ref/api/include/tee_api_types.h File Reference

```
#include <compiler.h>
#include <stdint.h>
#include <stdbool.h>
#include <stddef.h>
#include <tee_api_defines.h>
#include "tee_api_tee_types.h"
```

Include dependency graph for tee_api_types.h:



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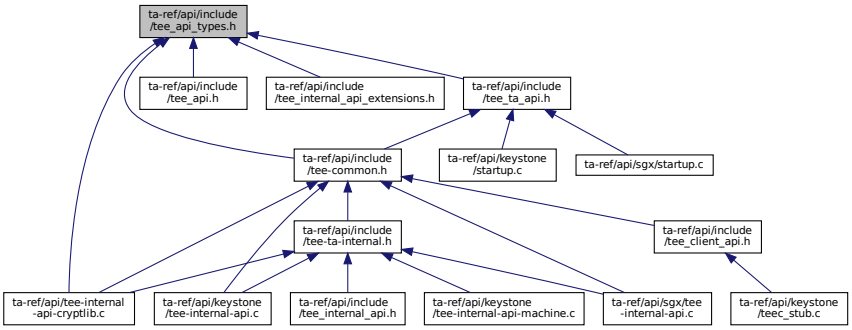

Classes

- struct TEE_UUID
- struct TEE_Identity
- union TEE_Param
- struct TEE_ObjectInfo
- struct TEE_Attribute

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- struct TEE_OperationInfo
- struct TEE_OperationInfoKey
- struct TEE_OperationInfoMultiple
- struct TEE_Time
- struct TEE_SEReaderProperties
- struct TEE_SEAID
- struct pollfd
- struct addrinfo

Typedefs

- typedef uint32_t TEE_Result
- typedef struct __TEE_TASessionHandle * TEE_TASessionHandle
- typedef struct __TEE_PropSetHandle * TEE_PropSetHandle
- typedef struct __TEE_ObjectHandle * TEE_ObjectHandle
- typedef struct __TEE_ObjectEnumHandle * TEE_ObjectEnumHandle
- typedef struct __TEE_OperationHandle * TEE_OperationHandle
- typedef uint32_t TEE_ObjectType
- typedef uint32_t TEE_BigInt
- typedef uint32_t TEE_BigIntFMM
- typedef uint32_t TEE_BigIntFMMContext __aligned(__alignof__(void *))
- typedef struct __TEE_SEServiceHandle * TEE_SEServiceHandle
- typedef struct __TEE_SEReaderHandle * TEE_SEReaderHandle
- typedef struct __TEE_SESessionHandle * TEE_SESessionHandle
- typedef struct __TEE_SEChannelHandle * TEE_SEChannelHandle
- typedef uint32_t TEE_ErrorOrigin
- typedef void * TEE_Session
- typedef unsigned long int nfds_t
- typedef uint32_t socklen_t

Enumerations

- enum TEE_Whence { TEE_DATA_SEEK_SET = 0 , TEE_DATA_SEEK_CUR = 1 , TEE_DATA_SEEK_END = 2 }
- enum TEE_OperationMode {
  TEE_MODE_ENCRYPT = 0 , TEE_MODE_DECRYPT = 1 , TEE_MODE_SIGN = 2 , TEE_MODE_VERIFY = 3 ,
  TEE_MODE_MAC = 4 , TEE_MODE_DIGEST = 5 , TEE_MODE_DERIVE = 6 }

13.15.1 Typedef Documentation

13.15.1.1 __aligned `typedef uint32_t TEE_BigIntFMMContext __aligned(__alignof__(void *))`

13.15.1.2 nfds_t `typedef unsigned long int nfds_t`

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13.15.1.3 socklen_t typedef uint32_t socklen_t

13.15.1.4 TEE_BigInt typedef uint32_t TEE_BigInt

13.15.1.5 TEE_BigIntFMM typedef uint32_t TEE_BigIntFMM

13.15.1.6 TEE_ErrorOrigin typedef uint32_t TEE_ErrorOrigin

13.15.1.7 TEE_ObjectEnumHandle typedef struct __TEE_ObjectEnumHandle* TEE_ObjectEnumHandle

13.15.1.8 TEE_ObjectHandle typedef struct __TEE_ObjectHandle* TEE_ObjectHandle

13.15.1.9 TEE_ObjectType typedef uint32_t TEE_ObjectType

13.15.1.10 TEE_OperationHandle typedef struct __TEE_OperationHandle* TEE_OperationHandle

13.15.1.11 TEE_PropSetHandle typedef struct __TEE_PropSetHandle* TEE_PropSetHandle

13.15.1.12 TEE_Result typedef uint32_t TEE_Result

13.15.1.13 TEE_SEChannelHandle typedef struct __TEE_SEChannelHandle* TEE_SEChannelHandle

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13.15.1.14 TEE_SEReaderHandle `typedef struct __TEE_SEReaderHandle* TEE_SEReaderHandle`

13.15.1.15 TEE_SEServiceHandle `typedef struct __TEE_SEServiceHandle* TEE_SEServiceHandle`

13.15.1.16 TEE_SESessionHandle `typedef struct __TEE_SESessionHandle* TEE_SESessionHandle`

13.15.1.17 TEE_Session `typedef void* TEE_Session`

13.15.1.18 TEE_TASessionHandle `typedef struct __TEE_TASessionHandle* TEE_TASessionHandle`

13.15.2 Enumeration Type Documentation

13.15.2.1 TEE_OperationMode `enum TEE_OperationMode`

Enumerator

TEE_MODE_ENCRYPT	
TEE_MODE_DECRYPT	
TEE_MODE_SIGN	
TEE_MODE_VERIFY	
TEE_MODE_MAC	
TEE_MODE_DIGEST	
TEE_MODE_DERIVE	

13.15.2.2 TEE_Whence `enum TEE_Whence`

Enumerator

TEE_DATA_SEEK_SET	
TEE_DATA_SEEK_CUR	
TEE_DATA_SEEK_END	

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13.16 tee_api_types.h

Go to the documentation of this file.

```
1 /*
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4  *
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6  * modification, are permitted provided that the following conditions are met:
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23 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
24 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
25 * POSSIBILITY OF SUCH DAMAGE.
26 */
27
28 /* Based on GP TEE Internal API Specification Version 0.11 */
29 #ifndef TEE_API_TYPES_H
30 #define TEE_API_TYPES_H
31
32 #include <compiler.h>
33 #include <stdint.h>
34 #include <stdbool.h>
35 #include <stddef.h>
36 #include <tee_api_defines.h>
37 #include "tee_api_tee_types.h"
38
39 /*
40  * Common Definitions
41  */
42
43 typedef uint32_t TEE_Result;
44
45 typedef struct {
46     uint32_t timeLow;
47     uint16_t timeMid;
48     uint16_t timeHiAndVersion;
49     uint8_t clockSeqAndNode[8];
50 } TEE_UUID;
51
52 /*
53  * The TEE_Identity structure defines the full identity of a Client:
54  * - login is one of the TEE_LOGIN_XXX constants
55  * - uuid contains the client UUID or Nil if not applicable
56  */
57 typedef struct {
58     uint32_t login;
59     TEE_UUID uuid;
60 } TEE_Identity;
61
62 /*
63  * This union describes one parameter passed by the Trusted Core Framework
64  * to the entry points TA_OpenSessionEntryPoint or
65  * TA_InvokeCommandEntryPoint or by the TA to the functions
66  * TEE_OpenTASession or TEE_InvokeTACommand.
67  *
68  * Which of the field value or memref to select is determined by the
69  * parameter type specified in the argument paramTypes passed to the entry
70  * point.
71 */
72 typedef union {
73     struct {
74         void *buffer;
75         uint32_t size;
76     } memref;
77     struct {
78         uint32_t a;
79         uint32_t b;
80     } value;
81 } TEE_Param;
```

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```
82
83 /*
84  * The type of opaque handles on TA Session. These handles are returned by
85  * the function TEE_OpenTASession.
86  */
87 typedef struct __TEE_TASessionHandle *TEE_TASessionHandle;
88
89 /*
90  * The type of opaque handles on property sets or enumerators. These
91  * handles are either one of the pseudo handles TEE_PROPSET_XXX or are
92  * returned by the function TEE_AllocatePropertyEnumerator.
93 */
94 typedef struct __TEE_PropSetHandle *TEE_PropSetHandle;
95
96 typedef struct __TEE_ObjectHandle *TEE_ObjectHandle;
97 typedef struct __TEE_ObjectEnumHandle *TEE_ObjectEnumHandle;
98 typedef struct __TEE_OperationHandle *TEE_OperationHandle;
99
100 /*
101  * Storage Definitions
102  */
103
104 typedef uint32_t TEE_ObjectType;
105
106 typedef struct {
107     uint32_t objectType;
108     __extension__ union {
109         uint32_t keySize;    /* used in 1.1 spec */
110         uint32_t objectSize;  /* used in 1.1.1 spec */
111     };
112     __extension__ union {
113         uint32_t maxKeySize;  /* used in 1.1 spec */
114         uint32_t maxObjectSize;    /* used in 1.1.1 spec */
115     };
116     uint32_t objectUsage;
117     uint32_t dataSize;
118     uint32_t dataPosition;
119     uint32_t handleFlags;
120 } TEE_ObjectInfo;
121
122 typedef enum {
123     TEE_DATA_SEEK_SET = 0,
124     TEE_DATA_SEEK_CUR = 1,
125     TEE_DATA_SEEK_END = 2
126 } TEE_Whence;
127
128 typedef struct {
129     uint32_t attributeID;
130     union {
131         struct {
132             void *buffer;
133             uint32_t length;
134         } ref;
135         struct {
136             uint32_t a, b;
137         } value;
138     } content;
139 } TEE_Attribute;
140
141 #ifndef DOXYGEN_SHOULD_SKIP_THIS
142 #define DMREQ_FINISH 0
143 #define DMREQ_WRITE 1
144 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
145
146 /* Cryptographic Operations API */
147
148 typedef enum {
149     TEE_MODE_ENCRYPT = 0,
150     TEE_MODE_DECRYPT = 1,
151     TEE_MODE_SIGN = 2,
152     TEE_MODE_VERIFY = 3,
153     TEE_MODE_MAC = 4,
154     TEE_MODE_DIGEST = 5,
155     TEE_MODE_DERIVE = 6
156 } TEE_OperationMode;
157
158 typedef struct {
159     uint32_t algorithm;
160     uint32_t operationClass;
161     uint32_t mode;
162     uint32_t digestLength;
163     uint32_t maxKeySize;
164     uint32_t keySize;
165     uint32_t requiredKeyUsage;
166     uint32_t handleState;
```

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```
167 } TEE_OperationInfo;
168
169 typedef struct {
170     uint32_t keySize;
171     uint32_t requiredKeyUsage;
172 } TEE_OperationInfoKey;
173
174 typedef struct {
175     uint32_t algorithm;
176     uint32_t operationClass;
177     uint32_t mode;
178     uint32_t digestLength;
179     uint32_t maxKeySize;
180     uint32_t handleState;
181     uint32_t operationState;
182     uint32_t numberOfKeys;
183     TEE_OperationInfoKey keyInformation[];
184 } TEE_OperationInfoMultiple;
185
186 /* Time & Date API */
187
188 typedef struct {
189     uint32_t seconds;
190     uint32_t millis;
191 } TEE_Time;
192
193 /* TEE Arithmetical APIs */
194
195 typedef uint32_t TEE_BigInt;
196
197 typedef uint32_t TEE_BigIntFMM;
198
199 typedef uint32_t TEE_BigIntFMMContext __aligned(__alignof__(void *));
200
201 /* Tee Secure Element APIs */
202
203 typedef struct __TEE_SEServiceHandle *TEE_SEServiceHandle;
204 typedef struct __TEE_SEReaderHandle *TEE_SEReaderHandle;
205 typedef struct __TEE_SESessionHandle *TEE_SESessionHandle;
206 typedef struct __TEE_SEChannelHandle *TEE_SEChannelHandle;
207
208 typedef struct {
209     bool sePresent;
210     bool teeOnly;
211     bool selectResponseEnable;
212 } TEE_SEReaderProperties;
213
214 typedef struct {
215     uint8_t *buffer;
216     size_t bufferLen;
217 } TEE_SEAID;
218
219 /* Other definitions */
220 typedef uint32_t TEE_ErrorOrigin;
221 typedef void *TEE_Session;
222
223 #ifndef DOXYGEN_SHOULD_SKIP_THIS
224 #define TEE_MEM_INPUT   0x00000001
225 #define TEE_MEM_OUTPUT  0x00000002
226
227 #define TEE_MEMREF_0_USED  0x00000001
228 #define TEE_MEMREF_1_USED  0x00000002
229 #define TEE_MEMREF_2_USED  0x00000004
230 #define TEE_MEMREF_3_USED  0x00000008
231
232 #define TEE_SE_READER_NAME_MAX  20
233 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
234
235 #ifndef PLAT_KEYSTONE
236 // TODO: ???
237
238 typedef unsigned long int nfds_t;
239
240 struct pollfd
241 {
242         int fd;                     /* File descriptor to poll.  */
243     short int events;           /* Types of events poller cares about.  */
244     short int revents;          /* Types of events that actually occurred.  */
245 };
246
247 typedef uint32_t socklen_t;
248
249 struct addrinfo {
250     int              ai_flags;
251     int              ai_family;
```

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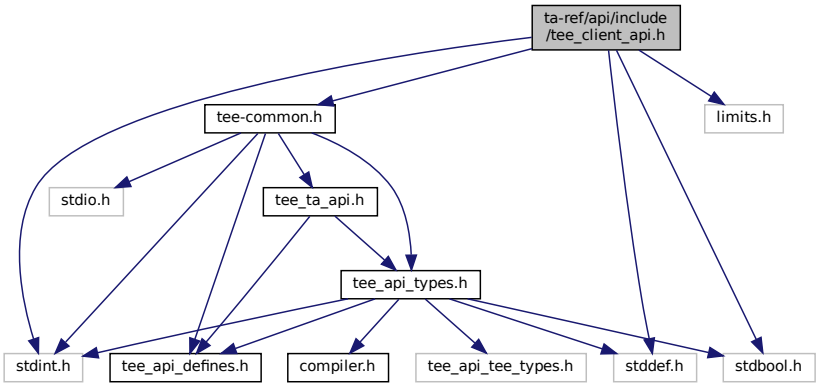
```
252     int              ai_socktype;
253     int              ai_protocol;
254     socklen_t        ai_addrlen;
255     struct sockaddr *ai_addr;
256     char            *ai_canonname;
257     struct addrinfo *ai_next;
258 };
259
260 #endif /* !PLAT_KEYSTONE */
261
262 #endif /* TEE_API_TYPES_H */
```

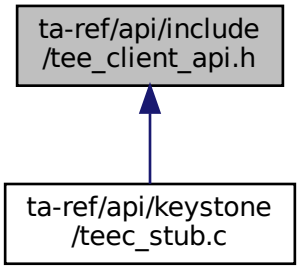
13.17 ta-ref/api/include/tee_client_api.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include <stdbool.h>
#include <limits.h>
#include "tee-common.h"
```

Include dependency graph for tee_client_api.h:



This graph shows which files directly or indirectly include this file:



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Classes

- struct TEEC_Context
- struct TEEC_UUID
- struct TEEC_SharedMemory
- struct TEEC_TempMemoryReference
- struct TEEC_RegisteredMemoryReference
- struct TEEC_Value
- union TEEC_Parameter
- struct TEEC_Session
- struct TEEC_Operation

Typedefs

- typedef uint32_t TEEC_Result

Functions

- TEEC_Result TEEC_InitializeContext (const char *name, TEEC_Context *context)
- void TEEC_FinalizeContext (TEEC_Context *context)
- TEEC_Result TEEC_OpenSession (TEEC_Context *context, TEEC_Session *session, const TEEC_UUID *destination, uint32_t connectionMethod, const void *connectionData, TEEC_Operation *operation, uint32_t *returnOrigin)
- void TEEC_CloseSession (TEEC_Session *session)
- TEEC_Result TEEC_InvokeCommand (TEEC_Session *session, uint32_t commandID, TEEC_Operation *operation, uint32_t *returnOrigin)
- TEEC_Result TEEC_RegisterSharedMemory (TEEC_Context *context, TEEC_SharedMemory *sharedMem)
- TEEC_Result TEEC_AllocateSharedMemory (TEEC_Context *context, TEEC_SharedMemory *sharedMem)
- void TEEC_ReleaseSharedMemory (TEEC_SharedMemory *sharedMemory)
- void TEEC_RequestCancellation (TEEC_Operation *operation)

13.17.1 Typedef Documentation

13.17.1.1 TEEC_Result

```
typedef uint32_t TEEC_Result
```

13.17.2 Function Documentation

13.17.2.1 TEEC_AllocateSharedMemory()

```
TEEC_Result TEEC_AllocateSharedMemory (
    TEEC_Context * context,
    TEEC_SharedMemory * sharedMem )
```

TEEC_AllocateSharedMemory() - Allocate shared memory for TEE.

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Parameters

context	The initialized TEE context structure in which scope to open the session.
sharedMem	Pointer to the allocated shared memory.

Returns

TEEC_SUCCESS The registration was successful.

TEEC_ERROR_OUT_OF_MEMORY Memory exhaustion.

TEEC_Result Something failed.

13.17.2.2 TEEC_CloseSession() `void TEEC_CloseSession (`

`TEEC_Session * session )`

TEEC_CloseSession() - Closes the session which has been opened with the specific trusted application.

Parameters

session	The opened session to close.

13.17.2.3 TEEC_FinalizeContext() `void TEEC_FinalizeContext (`

`TEEC_Context * context )`

TEEC_FinalizeContext() - Destroys a context holding connection information on the specific TEE.

This function destroys an initialized TEE context, closing the connection between the client application and the TEE. This function must only be called when all sessions related to this TEE context have been closed and all shared memory blocks have been released.

Parameters

context	The context to be destroyed.

TEEC_FinalizeContext() - Destroys a context holding connection information on the specific TEE.

This function finalizes an initialized TEE context, closing the connection between the client application and the TEE. This function must only be called when all sessions related to this TEE context have been closed and all shared memory blocks have been released.

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Parameters

context	The context to be finalized.

13.17.2.4 TEEC_InitializeContext()

```
TEEC_Result TEEC_InitializeContext (
    const char * name,
    TEEC_Context * context )
```

TEEC_InitializeContext() - Initializes a context holding connection information on the specific TEE, designated by the name string.

Parameters

name	A zero-terminated string identifying the TEE to connect to. If name is set to NULL, the default TEE is connected to. NULL is the only supported value in this version of the API implementation.
context	The context structure which is to be initialized.

Returns

TEEC_SUCCESS The initialization was successful.

TEEC_Result Something failed.

13.17.2.5 TEEC_InvokeCommand()

```
TEEC_Result TEEC_InvokeCommand (
    TEEC_Session * session,
    uint32_t commandID,
    TEEC_Operation * operation,
    uint32_t * returnOrigin )
```

TEEC_InvokeCommand() - Executes a command in the specified trusted application.

Parameters

session	A handle to an open connection to the trusted application.
commandID	Identifier of the command in the trusted application to invoke.
operation	An operation structure to use in the invoke command. May be set to NULL to signify no operation structure needed.
returnOrigin	A parameter which will hold the error origin if this function returns any value other than TEEC_SUCCESS.

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Returns

TEEC_SUCCESS OpenSession successfully opened a new session.

TEEC_Result Something failed.

13.17.2.6 TEEC_OpenSession()

```
TEEC_Result TEEC_OpenSession (
    TEEC_Context * context,
    TEEC_Session * session,
    const TEEC_UUID * destination,
    uint32_t connectionMethod,
    const void * connectionData,
    TEEC_Operation * operation,
    uint32_t * returnOrigin )
```

TEEC_OpenSession() - Opens a new session with the specified trusted application.

Parameters

context	The initialized TEE context structure in which scope to open the session.
session	The session to initialize.
destination	A structure identifying the trusted application with which to open a session.
connectionMethod	The connection method to use.
connectionData	Any data necessary to connect with the chosen connection method. Not supported, should be set to NULL.
operation	An operation structure to use in the session. May be set to NULL to signify no operation structure needed.
returnOrigin	A parameter which will hold the error origin if this function returns any value other than TEEC_SUCCESS.

Returns

TEEC_SUCCESS OpenSession successfully opened a new session.

TEEC_Result Something failed.

13.17.2.7 TEEC_RegisterSharedMemory()

```
TEEC_Result TEEC_RegisterSharedMemory (
    TEEC_Context * context,
    TEEC_SharedMemory * sharedMem )
```

TEEC_RegisterSharedMemory() - Register a block of existing memory as a shared block within the scope of the specified context.

Parameters

context	The initialized TEE context structure in which scope to open the session.
sharedMem	pointer to the shared memory structure to register.

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Returns

TEEC_SUCCESS The registration was successful.

TEEC_ERROR_OUT_OF_MEMORY Memory exhaustion.

TEEC_Result Something failed.

13.17.2.8 TEEC_ReleaseSharedMemory() `void TEEC_ReleaseSharedMemory ( TEEC_SharedMemory * sharedMemory )`

TEEC_ReleaseSharedMemory() - Free or deregister the shared memory.

Parameters

sharedMem	Pointer to the shared memory to be freed.

13.17.2.9 TEEC_RequestCancellation() `void TEEC_RequestCancellation ( TEEC_Operation * operation )`

TEEC_RequestCancellation() - Request the cancellation of a pending open session or command invocation.

Parameters

operation	Pointer to an operation previously passed to open session or invoke.

13.18 tee_client_api.h

Go to the documentation of this file.

```
1 /*
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3  * All rights reserved.
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6  *
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9  *
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21  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
22  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
23  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
```

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```
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 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
 * POSSIBILITY OF SUCH DAMAGE.
 */
#ifndef TEE_CLIENT_API_H
#define TEE_CLIENT_API_H

#ifdef __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <stddef.h>
#include <stdbool.h>
#include <limits.h>
#include "tee-common.h"

#ifndef DOXYGEN_SHOULD_SKIP_THIS
/*
 * Defines the number of available memory references in an open session or
 * invoke command operation payload.
 */
#define TEEC_CONFIG_PAYLOAD_REF_COUNT 4

#define TEEC_CONFIG_SHAREDMEM_MAX_SIZE ULONG_MAX

#define TEEC_NONE                   0x00000000
#define TEEC_VALUE_INPUT            0x00000001
#define TEEC_VALUE_OUTPUT           0x00000002
#define TEEC_VALUE_INOUT            0x00000003
#define TEEC_MEMREF_TEMP_INPUT      0x00000005
#define TEEC_MEMREF_TEMP_OUTPUT     0x00000006
#define TEEC_MEMREF_TEMP_INOUT      0x00000007
#define TEEC_MEMREF_WHOLE           0x0000000C
#define TEEC_MEMREF_PARTIAL_INPUT   0x0000000D
#define TEEC_MEMREF_PARTIAL_OUTPUT  0x0000000E
#define TEEC_MEMREF_PARTIAL_INOUT   0x0000000F

#define TEEC_MEM_INPUT   0x00000001
#define TEEC_MEM_OUTPUT  0x00000002

#define TEEC_SUCCESS                0x00000000
#define TEEC_ERROR_GENERIC          0xFFFF0000
#define TEEC_ERROR_ACCESS_DENIED    0xFFFF0001
#define TEEC_ERROR_CANCEL           0xFFFF0002
#define TEEC_ERROR_ACCESS_CONFLICT  0xFFFF0003
#define TEEC_ERROR_EXCESS_DATA      0xFFFF0004
#define TEEC_ERROR_BAD_FORMAT       0xFFFF0005
#define TEEC_ERROR_BAD_PARAMETERS   0xFFFF0006
#define TEEC_ERROR_BAD_STATE        0xFFFF0007
#define TEEC_ERROR_ITEM_NOT_FOUND   0xFFFF0008
#define TEEC_ERROR_NOT_IMPLEMENTED  0xFFFF0009
#define TEEC_ERROR_NOT_SUPPORTED    0xFFFF000A
#define TEEC_ERROR_NO_DATA          0xFFFF000B
#define TEEC_ERROR_OUT_OF_MEMORY    0xFFFF000C
#define TEEC_ERROR_BUSY             0xFFFF000D
#define TEEC_ERROR_COMMUNICATION    0xFFFF000E
#define TEEC_ERROR_SECURITY         0xFFFF000F
#define TEEC_ERROR_SHORT_BUFFER     0xFFFF0010
#define TEEC_ERROR_EXTERNAL_CANCEL  0xFFFF0011
#define TEEC_ERROR_TARGET_DEAD      0xFFFF3024

#define TEEC_ORIGIN_API          0x00000001
#define TEEC_ORIGIN_COMMS        0x00000002
#define TEEC_ORIGIN_TEE          0x00000003
#define TEEC_ORIGIN_TRUSTED_APP  0x00000004

#define TEEC_LOGIN_PUBLIC       0x00000000
#define TEEC_LOGIN_USER         0x00000001
#define TEEC_LOGIN_GROUP        0x00000002
#define TEEC_LOGIN_APPLICATION  0x00000004
#define TEEC_LOGIN_USER_APPLICATION  0x00000005
#define TEEC_LOGIN_GROUP_APPLICATION  0x00000006

#define TEEC_PARAM_TYPES(p0, p1, p2, p3) \
    ((p0) | ((p1) << 4) | ((p2) << 8) | ((p3) << 12))

#define TEEC_PARAM_TYPE_GET(p, i) (((p) >> (i * 4)) & 0xF)
#endif /*DOXYGEN_SHOULD_SKIP_THIS*/

typedef uint32_t TEEC_Result;

typedef struct {
    /* Implementation defined */
```

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```
259     int fd;
260     bool reg_mem;
261 } TEEC_Context;
262
268 typedef struct {
269     uint32_t timeLow;
270     uint16_t timeMid;
271     uint16_t timeHiAndVersion;
272     uint8_t clockSeqAndNode[8];
273 } TEEC_UUID;
274
291 typedef struct {
292     void *buffer;
293     size_t size;
294     uint32_t flags;
295     /*
296      * Implementation-Defined
297      */
298     int id;
299     size_t alloced_size;
300     void *shadow_buffer;
301     int registered_fd;
302     bool buffer_allocated;
303 } TEEC_SharedMemory;
304
317 typedef struct {
318     void *buffer;
319     size_t size;
320 } TEEC_TempMemoryReference;
321
337 typedef struct {
338     TEEC_SharedMemory *parent;
339     size_t size;
340     size_t offset;
341 } TEEC_RegisteredMemoryReference;
342
353 typedef struct {
354     uint32_t a;
355     uint32_t b;
356 } TEEC_Value;
357
372 typedef union {
373     TEEC_TempMemoryReference tmpref;
374     TEEC_RegisteredMemoryReference memref;
375     TEEC_Value value;
376 } TEEC_Parameter;
377
382 typedef struct {
383     /* Implementation defined */
384     TEEC_Context *ctx;
385     uint32_t session_id;
386 } TEEC_Session;
387
402 typedef struct {
403     uint32_t started;
404     uint32_t paramTypes;
405     TEEC_Parameter params[TEEC_CONFIG_PAYLOAD_REF_COUNT];
406     /* Implementation-Defined */
407     TEEC_Session *session;
408 } TEEC_Operation;
409
424 TEEC_Result TEEC_InitializeContext(const char *name, TEEC_Context *context);
425
437 void TEEC_FinalizeContext(TEEC_Context *context);
438
465 TEEC_Result TEEC_OpenSession(TEEC_Context *context,
466                 TEEC_Session *session,
467                 const TEEC_UUID *destination,
468                 uint32_t connectionMethod,
469                 const void *connectionData,
470                 TEEC_Operation *operation,
471                 uint32_t *returnOrigin);
472
479 void TEEC_CloseSession(TEEC_Session *session);
480
498 TEEC_Result TEEC_InvokeCommand(TEEC_Session *session,
499                   uint32_t commandID,
500                   TEEC_Operation *operation,
501                   uint32_t *returnOrigin);
502
515 TEEC_Result TEEC_RegisterSharedMemory(TEEC_Context *context,
516                       TEEC_SharedMemory *sharedMem);
517
529 TEEC_Result TEEC_AllocateSharedMemory(TEEC_Context *context,
530                       TEEC_SharedMemory *sharedMem);
```

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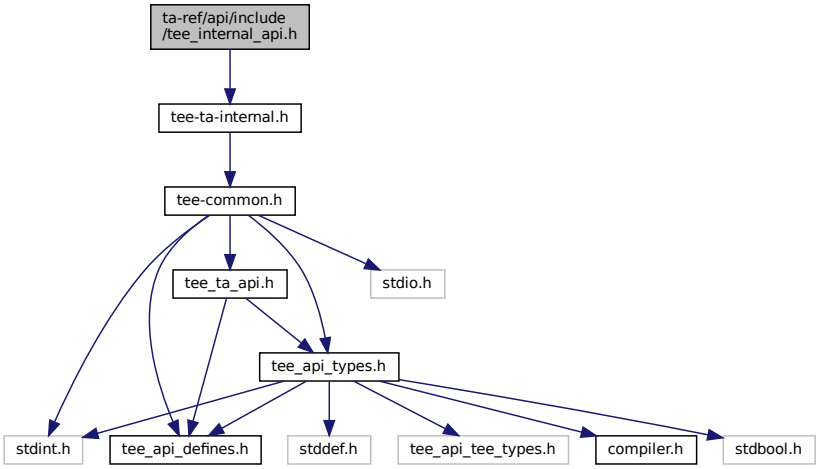
```
531
537 void TEEC_ReleaseSharedMemory(TEEC_SharedMemory *sharedMemory);
538
546 void TEEC_RequestCancellation(TEEC_Operation *operation);
547
548 #ifdef __cplusplus
549 }
550 #endif
551
552 #endif
```

13.19 ta-ref/api/include/tee_internal_api.h File Reference

`#include "tee-ta-internal.h"`
Include dependency graph for tee_internal_api.h:



13.20 tee_internal_api.h

Go to the documentation of this file.

```
1 #include "tee-ta-internal.h"
```

13.21 ta-ref/api/include/tee_internal_api_extensions.h File Reference

```
#include <trace.h>
#include <stdio.h>
#include <tee_api_defines_extensions.h>
```

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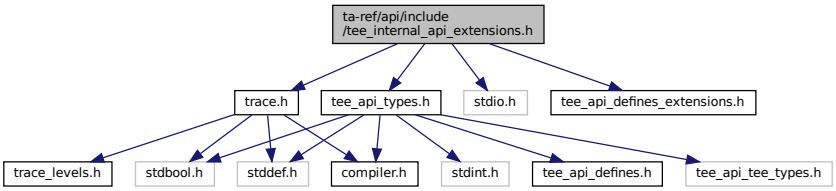
```
#include <tee_api_types.h>
```

Include dependency graph for tee_internal_api_extensions.h:



Functions

- void tee_user_mem_mark_heap (void)
- size_t tee_user_mem_check_heap (void)
- TEE_Result TEE_CacheClean (char ∗buf, size_t len)
- TEE_Result TEE_CacheFlush (char ∗buf, size_t len)
- TEE_Result TEE_CacheInvalidate (char ∗buf, size_t len)
- void ∗ tee_map_zi (size_t len, uint32_t flags)
- TEE_Result tee_unmap (void ∗buf, size_t len)
- TEE_Result tee_uuid_from_str (TEE_UUID ∗uuid, const char ∗s)

13.21.1 Function Documentation

13.21.1.1 TEE_CacheClean()

```
TEE_Result TEE_CacheClean (
    char * buf,
    size_t len )
```

13.21.1.2 TEE_CacheFlush()

```
TEE_Result TEE_CacheFlush (
    char * buf,
    size_t len )
```

13.21.1.3 TEE_CacheInvalidate()

```
TEE_Result TEE_CacheInvalidate (
    char * buf,
    size_t len )
```

13.21.1.4 tee_map_zi()

```
void * tee_map_zi (
    size_t len,
    uint32_t flags )
```

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13.21.1.5 tee_unmap()

```
TEE_Result tee_unmap (
    void * buf,
    size_t len )
```

13.21.1.6 tee_user_mem_check_heap()

```
size_t tee_user_mem_check_heap (
    void  )
```

13.21.1.7 tee_user_mem_mark_heap()

```
void tee_user_mem_mark_heap (
    void  )
```

13.21.1.8 tee_uuid_from_str()

```
TEE_Result tee_uuid_from_str (
    TEE_UUID * uuid,
    const char * s )
```

13.22 tee_internal_api_extensions.h

Go to the documentation of this file.

```
1  /* SPDX-License-Identifier: BSD-2-Clause */
2  /*
3   * Copyright (c) 2014, STMicroelectronics International N.V.
4   */
5
6  #ifndef TEE_INTERNAL_API_EXTENSIONS_H
7  #define TEE_INTERNAL_API_EXTENSIONS_H
8
9  /* trace support */
10 #include <trace.h>
11 #include <stdio.h>
12 #include <tee_api_defines_extensions.h>
13 #include <tee_api_types.h>
14
15 void tee_user_mem_mark_heap(void);
16 size_t tee_user_mem_check_heap(void);
17 /* Hint implementation defines */
18
19 #ifndef DOXYGEN_SHOULD_SKIP_THIS
20 #define TEE_USER_MEM_HINT_NO_FILL_ZERO       0x80000000
21 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
22
23 /*
24  * Cache maintenance support (TA requires the CACHE_MAINTENANCE property)
25  *
26  * TEE_CacheClean() Write back to memory any dirty data cache lines. The line
27  *                  is marked as not dirty. The valid bit is unchanged.
28  *
29  * TEE_CacheFlush() Purges any valid data cache lines. Any dirty cache lines
30  *                  are first written back to memory, then the cache line is
31  *                  invalidated.
32  *
33  * TEE_CacheInvalidate() Invalidate any valid data cache lines. Any dirty line
34  *                       are not written back to memory.
35  */
36 TEE_Result TEE_CacheClean(char *buf, size_t len);
37 TEE_Result TEE_CacheFlush(char *buf, size_t len);
38 TEE_Result TEE_CacheInvalidate(char *buf, size_t len);
39
40 /*
41  * tee_map_zi() - Map zero initialized memory
42  * @len:    Number of bytes
```

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```
 * @flags:  0 or TEE_MEMORY_ACCESS_ANY_OWNER to allow sharing with other TAs
 *
 * Returns valid pointer on success or NULL on error.
 */
void *tee_map_zi(size_t len, uint32_t flags);

/*
 * tee_unmap() - Unmap previously mapped memory
 * @buf:    Buffer
 * @len:    Number of bytes
 *
 * Note that supplied @buf and @len has to match exactly what has
 * previously been returned by tee_map_zi().
 *
 * Return TEE_SUCCESS on success or TEE_ERRROR_* on failure.
 */
TEE_Result tee_unmap(void *buf, size_t len);

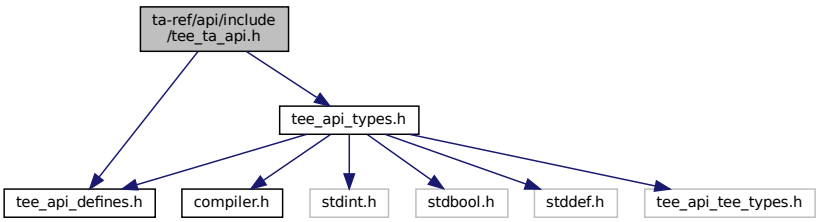
/*
 * Convert a UUID string @s into a TEE_UUID @uuid
 * Expected format for @s is: xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx
 * 'x' being any hexadecimal digit (0-9a-fA-F)
 */
TEE_Result tee_uuid_from_str(TEE_UUID *uuid, const char *s);

#endif
```

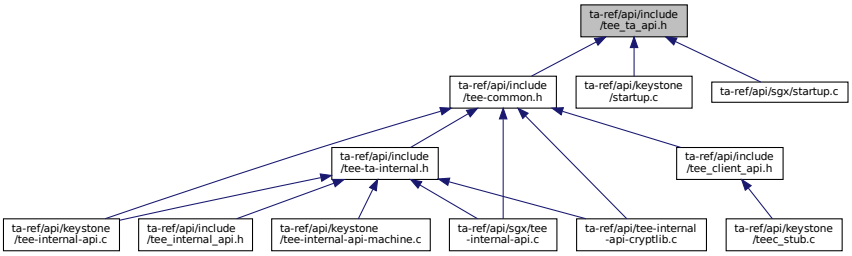
13.23 ta-ref/api/include/tee_ta_api.h File Reference

```
#include <tee_api_defines.h>
#include <tee_api_types.h>
```

Include dependency graph for tee_ta_api.h:



This graph shows which files directly or indirectly include this file:



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Functions

- TEE_Result TA_EXPORT TA_CreateEntryPoint (void)
- void TA_EXPORT TA_DestroyEntryPoint (void)
- TEE_Result TA_EXPORT TA_OpenSessionEntryPoint (uint32_t paramTypes, TEE_Param params[TEE_↩ NUM_PARAMS], void ∗∗sessionContext)
- void TA_EXPORT TA_CloseSessionEntryPoint (void ∗sessionContext)
- TEE_Result TA_EXPORT TA_InvokeCommandEntryPoint (void ∗sessionContext, uint32_t commandID, uint32_t paramTypes, TEE_Param params[TEE_NUM_PARAMS])

13.23.1 Function Documentation

13.23.1.1 TA_CloseSessionEntryPoint()

```
void TA_EXPORT TA_CloseSessionEntryPoint (
    void * sessionContext )
```

13.23.1.2 TA_CreateEntryPoint()

```
TEE_Result TA_EXPORT TA_CreateEntryPoint (
    void  )
```

13.23.1.3 TA_DestroyEntryPoint()

```
void TA_EXPORT TA_DestroyEntryPoint (
    void  )
```

13.23.1.4 TA_InvokeCommandEntryPoint()

```
TEE_Result TA_EXPORT TA_InvokeCommandEntryPoint (
    void * sessionContext,
    uint32_t commandID,
    uint32_t paramTypes,
    TEE_Param params[TEE_NUM_PARAMS] )
```

13.23.1.5 TA_OpenSessionEntryPoint()

```
TEE_Result TA_EXPORT TA_OpenSessionEntryPoint (
    uint32_t paramTypes,
    TEE_Param params[TEE_NUM_PARAMS],
    void ** sessionContext )
```

13.24 tee_ta_api.h

Go to the documentation of this file.

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```c
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 *
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 *
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 * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
 * POSSIBILITY OF SUCH DAMAGE.
 */

/* Based on GP TEE Internal API Specification Version 0.22 */
#ifndef TEE_TA_API_H
#define TEE_TA_API_H

#include <tee_api_defines.h>
#include <tee_api_types.h>

#ifndef DOXYGEN_SHOULD_SKIP_THIS
/* This is a null define in STE TEE environment */
#define TA_EXPORT
#endif /*DOXYGEN_SHOULD_SKIP_THIS*/

/*
 * TA Interface
 *
 * Each Trusted Application must provide the Implementation with a number
 * of functions, collectively called the "TA interface". These functions
 * are the entry points called by the Trusted Core Framework to create the
 * instance, notify the instance that a new client is connecting, notify
 * the instance when the client invokes a command, etc.
 *
 * Trusted Application Entry Points:
 */

/*
 * The function TA_CreateEntryPoint is the Trusted Application's
 * constructor, which the Framework calls when it creates a new instance of
 * the Trusted Application. To register instance data, the implementation
 * of this constructor can use either global variables or the function
 * TEE_InstanceSetData.
 *
 * Return Value:
 * - TEE_SUCCESS: if the instance is successfully created, the function
 *   must return TEE_SUCCESS.
 * - Any other value: if any other code is returned the instance is not
 *   created, and no other entry points of this instance will be called.
 *   The Framework MUST reclaim all resources and dereference all objects
 *   related to the creation of the instance.
 *
 *   If this entry point was called as a result of a client opening a
 *   session, the error code is returned to the client and the session is
 *   not opened.
 */
TEE_Result TA_EXPORT TA_CreateEntryPoint(void);

/*
 * The function TA_DestroyEntryPoint is the Trusted Applications
 * destructor, which the Framework calls when the instance is being
 * destroyed.
 *
 * When the function TA_DestroyEntryPoint is called, the Framework
 * guarantees that no client session is currently open. Once the call to
 * TA_DestroyEntryPoint has been completed, no other entry point of this
 * instance will ever be called.
 *
 * Note that when this function is called, all resources opened by the
 * instance are still available. It is only after the function returns that
 * the Implementation MUST start automatically reclaiming resources left
```

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```
 * opened.
 *
 * Return Value:
 * This function can return no success or error code. After this function
 * returns the Implementation MUST consider the instance destroyed and
 * reclaims all resources left open by the instance.
 */
void TA_EXPORT TA_DestroyEntryPoint(void);

/*
 * The Framework calls the function TA_OpenSessionEntryPoint when a client
 * requests to open a session with the Trusted Application. The open
 * session request may result in a new Trusted Application instance being
 * created as defined in section 4.5.
 *
 * The client can specify parameters in an open operation which are passed
 * to the Trusted Application instance in the arguments paramTypes and
 * params. These arguments can also be used by the Trusted Application
 * instance to transfer response data back to the client. See section 4.3.6
 * for a specification of how to handle the operation parameters.
 *
 * If this function returns TEE_SUCCESS, the client is connected to a
 * Trusted Application instance and can invoke Trusted Application
 * commands. When the client disconnects, the Framework will eventually
 * call the TA_CloseSessionEntryPoint entry point.
 *
 * If the function returns any error, the Framework rejects the connection
 * and returns the error code and the current content of the parameters the
 * client. The return origin is then set to TEE_ORIGIN_TRUSTED_APP.
 *
 * The Trusted Application instance can register a session data pointer by
 * setting *psessionContext. The value of this pointer is not interpreted
 * by the Framework, and is simply passed back to other TA_ functions
 * within this session. Note that *sessionContext may be set with a pointer
 * to a memory allocated by the Trusted Application instance or with
 * anything else, like an integer, a handle etc. The Framework will not
 * automatically free *sessionContext when the session is closed; the
 * Trusted Application instance is responsible for freeing memory if
 * required.
 *
 * During the call to TA_OpenSessionEntryPoint the client may request to
 * cancel the operation. See section 4.10 for more details on
 * cancellations. If the call to TA_OpenSessionEntryPoint returns
 * TEE_SUCCESS, the client must consider the session as successfully opened
 * and explicitly close it if necessary.
 *
 * Parameters:
 * - paramTypes: the types of the four parameters.
 * - params: a pointer to an array of four parameters.
 * - sessionContext: A pointer to a variable that can be filled by the
 *   Trusted Application instance with an opaque void* data pointer
 *
 * Return Value:
 * - TEE_SUCCESS if the session is successfully opened.
 * - Any other value if the session could not be open.
 *   o The error code may be one of the pre-defined codes, or may be a new
 *     error code defined by the Trusted Application implementation itself.
 */
TEE_Result TA_EXPORT TA_OpenSessionEntryPoint(uint32_t paramTypes,
                TEE_Param params[TEE_NUM_PARAMS],
                void **sessionContext);

/*
 * The Framework calls this function to close a client session. During the
 * call to this function the implementation can use any session functions.
 *
 * The Trusted Application implementation is responsible for freeing any
 * resources consumed by the session being closed. Note that the Trusted
 * Application cannot refuse to close a session, but can hold the closing
 * until it returns from TA_CloseSessionEntryPoint. This is why this
 * function cannot return an error code.
 *
 * Parameters:
 * - sessionContext: The value of the void* opaque data pointer set by the
 *   Trusted Application in the function TA_OpenSessionEntryPoint for this
 *   session.
 */
void TA_EXPORT TA_CloseSessionEntryPoint(void *sessionContext);

/*
 * The Framework calls this function when the client invokes a command
 * within the given session.
 *
 * The Trusted Application can access the parameters sent by the client
 * through the paramTypes and params arguments. It can also use these
```

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```
171  * arguments to transfer response data back to the client.
172  *
173  * During the call to TA_InvokeCommandEntryPoint the client may request to
174  * cancel the operation.
175  *
176  * A command is always invoked within the context of a client session.
177  * Thus, any session function  can be called by the command implementation.
178  *
179  * Parameter:
180  * - sessionContext: The value of the void* opaque data pointer set by the
181  *   Trusted Application in the function TA_OpenSessionEntryPoint.
182  * - commandID: A Trusted Application-specific code that identifies the
183  *   command to be invoked.
184  * - paramTypes: the types of the four parameters.
185  * - params: a pointer to an array of four parameters.
186  *
187  * Return Value:
188  * - TEE_SUCCESS: if the command is successfully executed, the function
189  *   must return this value.
190  * - Any other value: if the invocation of the command fails for any
191  *   reason.
192  *   o The error code may be one of the pre-defined codes, or may be a new
193  *     error code defined by the Trusted Application implementation itself.
194  */
195
196 TEE_Result TA_EXPORT TA_InvokeCommandEntryPoint(void *sessionContext,
197             uint32_t commandID,
198             uint32_t paramTypes,
199             TEE_Param params[TEE_NUM_PARAMS]);
200
201 /*
202  * Correspondance Client Functions <--> TA Functions
203  *
204  * TEE_OpenSession or TEE_OpenTASession:
205  * If a new Trusted Application instance is needed to handle the session,
206  * TA_CreateEntryPoint is called.
207  * Then, TA_OpenSessionEntryPoint is called.
208  *
209  *
210  * TEE_InvokeCommand or TEE_InvokeTACommand:
211  * TA_InvokeCommandEntryPoint is called.
212  *
213  *
214  * TEE_CloseSession or TEE_CloseTASession:
215  * TA_CloseSessionEntryPoint is called.
216  * For a multi-instance TA or for a single-instance, non keep-alive TA, if
217  * the session closed was the last session on the instance, then
218  * TA_DestroyEntryPoint is called. Otherwise, the instance is kept until
219  * the TEE shuts down.
220  *
221  */
222
223 #endif
```

13.25 ta-ref/api/include/test_dev_key.h File Reference

Variables

- static const unsigned char _sanctum_dev_secret_key [ ]
- static const size_t _sanctum_dev_secret_key_len = 64
- static const unsigned char _sanctum_dev_public_key [ ]
- static const size_t _sanctum_dev_public_key_len = 32

13.25.1 Variable Documentation

13.25.1.1 _sanctum_dev_public_key `const unsigned char _sanctum_dev_public_key[ ] [static]`

Initial value:

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```
= {
  0x0f, 0xaa, 0xd4, 0xff, 0x01, 0x17, 0x85, 0x83, 0xba, 0xa5, 0x88, 0x96,
  0x6f, 0x7c, 0x1f, 0xf3, 0x25, 0x64, 0xdd, 0x17, 0xd7, 0xdc, 0x2b, 0x46,
  0xcb, 0x50, 0xa8, 0x4a, 0x69, 0x27, 0x0b, 0x4c
}
```

13.25.1.2 _sanctum_dev_public_key_len const size_t _sanctum_dev_public_key_len = 32 [static]

13.25.1.3 _sanctum_dev_secret_key const unsigned char _sanctum_dev_secret_key[] [static]

Initial value:

```
= {
  0x40, 0xa0, 0x99, 0x47, 0x8c, 0xce, 0xfa, 0x3a, 0x06, 0x63, 0xab, 0xc9,
  0x5e, 0x7a, 0x1e, 0xc9, 0x54, 0xb4, 0xf5, 0xf6, 0x45, 0xba, 0xd8, 0x04,
  0xdb, 0x13, 0xe7, 0xd7, 0x82, 0x6c, 0x70, 0x73, 0x57, 0x6a, 0x9a, 0xb6,
  0x21, 0x60, 0xd9, 0xd1, 0xc6, 0xae, 0xdc, 0x29, 0x85, 0x2f, 0xb9, 0x60,
  0xee, 0x51, 0x32, 0x83, 0x5a, 0x16, 0x89, 0xec, 0x06, 0xa8, 0x72, 0x34,
  0x51, 0xaa, 0x0e, 0x4a
}
```

13.25.1.4 _sanctum_dev_secret_key_len const size_t _sanctum_dev_secret_key_len = 64 [static]

13.26 test_dev_key.h

Go to the documentation of this file.

```
1 /* These are known device TESTING keys, use them for testing on platforms/qemu */
2
3 #warning Using TEST device root key. No integrity guarantee.
4 static const unsigned char _sanctum_dev_secret_key[] = {
5   0x40, 0xa0, 0x99, 0x47, 0x8c, 0xce, 0xfa, 0x3a, 0x06, 0x63, 0xab, 0xc9,
6   0x5e, 0x7a, 0x1e, 0xc9, 0x54, 0xb4, 0xf5, 0xf6, 0x45, 0xba, 0xd8, 0x04,
7   0xdb, 0x13, 0xe7, 0xd7, 0x82, 0x6c, 0x70, 0x73, 0x57, 0x6a, 0x9a, 0xb6,
8   0x21, 0x60, 0xd9, 0xd1, 0xc6, 0xae, 0xdc, 0x29, 0x85, 0x2f, 0xb9, 0x60,
9   0xee, 0x51, 0x32, 0x83, 0x5a, 0x16, 0x89, 0xec, 0x06, 0xa8, 0x72, 0x34,
10   0x51, 0xaa, 0x0e, 0x4a
11 };
12 static const size_t _sanctum_dev_secret_key_len = 64;
13
14 static const unsigned char _sanctum_dev_public_key[] = {
15   0x0f, 0xaa, 0xd4, 0xff, 0x01, 0x17, 0x85, 0x83, 0xba, 0xa5, 0x88, 0x96,
16   0x6f, 0x7c, 0x1f, 0xf3, 0x25, 0x64, 0xdd, 0x17, 0xd7, 0xdc, 0x2b, 0x46,
17   0xcb, 0x50, 0xa8, 0x4a, 0x69, 0x27, 0x0b, 0x4c
18 };
19 static const size_t _sanctum_dev_public_key_len = 32;
```

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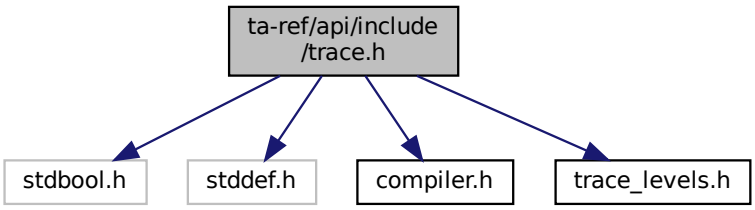
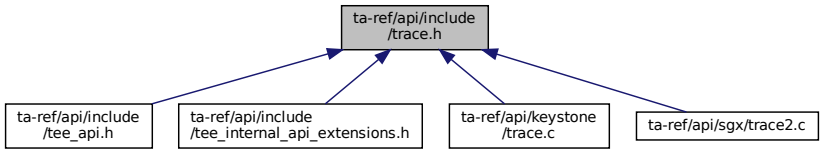
13.27 ta-ref/api/include/trace.h File Reference

```
#include <stdbool.h>
#include <stddef.h>
#include <compiler.h>
#include <trace_levels.h>
```

Include dependency graph for trace.h:



This graph shows which files directly or indirectly include this file:



Functions

- void trace_ext_puts (const char ∗str)
- int trace_ext_get_thread_id (void)
- void trace_set_level (int level)
- int trace_get_level (void)
- void trace_printf (const char ∗func, int line, int level, bool level_ok, const char ∗fmt,...) __printf(5
- void void dhex_dump (const char ∗function, int line, int level, const void ∗buf, int len)

Variables

- int trace_level
- const char trace_ext_prefix [ ]

13.27.1 Function Documentation

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13.27.1.1 dhex_dump() void void dhex_dump (

```
const char * function,
int line,
int level,
const void * buf,
int len )
```

13.27.1.2 trace_ext_get_thread_id() int trace_ext_get_thread_id (

```
void  )
```

13.27.1.3 trace_ext_puts() void trace_ext_puts (

```
const char * str )
```

13.27.1.4 trace_get_level() int trace_get_level (

```
void  )
```

13.27.1.5 trace_printf() void trace_printf (

```
const char * func,
int line,
int level,
bool level_ok,
const char * fmt,
 ...  )
```

13.27.1.6 trace_set_level() void trace_set_level (

```
int level )
```

13.27.2 Variable Documentation

13.27.2.1 trace_ext_prefix const char trace_ext_prefix[] [extern]

13.27.2.2 trace_level int trace_level [extern]

13.28 trace.h

Go to the documentation of this file.

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```
/*
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 *
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 * modification, are permitted provided that the following conditions are met:
 *
 * 1. Redistributions of source code must retain the above copyright notice,
 * this list of conditions and the following disclaimer.
 *
 * 2. Redistributions in binary form must reproduce the above copyright notice,
 * this list of conditions and the following disclaimer in the documentation
 * and/or other materials provided with the distribution.
 *
 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
 * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
 * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
 * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
 * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
 * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
 * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
 * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
 * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
 * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
 * POSSIBILITY OF SUCH DAMAGE.
 */
#ifndef TRACE_H
#define TRACE_H

#include <stdbool.h>
#include <stddef.h>
#include <compiler.h>
#include <trace_levels.h>

#ifndef DOXYGEN_SHOULD_SKIP_THIS
#define MAX_PRINT_SIZE      256
#define MAX_FUNC_PRINT_SIZE 32

#ifndef TRACE_LEVEL
#define TRACE_LEVEL TRACE_MAX
#endif
#endif /*DOXYGEN_SHOULD_SKIP_THIS*/

/*
 * Symbols provided by the entity that uses this API.
 */
extern int trace_level;
extern const char trace_ext_prefix[];
void trace_ext_puts(const char *str);
int trace_ext_get_thread_id(void);
void trace_set_level(int level);
int trace_get_level(void);

/* Internal functions used by the macros below */
void trace_printf(const char *func, int line, int level, bool level_ok,
          const char *fmt, ...) __printf(5, 6);

#ifndef DOXYGEN_SHOULD_SKIP_THIS
#define trace_printf_helper(level, level_ok, ...) \
    trace_printf(__func__, __LINE__, (level), (level_ok), \
             __VA_ARGS__)

/* Formatted trace tagged with level independent */
#if (TRACE_LEVEL <= 0)
#define MSG(...)    (void)0
#else
#define MSG(...)    trace_printf_helper(0, false, __VA_ARGS__)
#endif

/* Formatted trace tagged with TRACE_ERROR level */
#if (TRACE_LEVEL < TRACE_ERROR)
#define EMSG(...)    (void)0
#else
#define EMSG(...)    trace_printf_helper(TRACE_ERROR, true, __VA_ARGS__)
#endif

/* Formatted trace tagged with TRACE_INFO level */
#if (TRACE_LEVEL < TRACE_INFO)
#define IMSG(...)    (void)0
#else
#define IMSG(...)    trace_printf_helper(TRACE_INFO, true, __VA_ARGS__)
#endif

/* Formatted trace tagged with TRACE_DEBUG level */
#if (TRACE_LEVEL < TRACE_DEBUG)
```

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```
86 #define DMSG(...)    (void)0
87 #else
88 #define DMSG(...)    trace_printf_helper(TRACE_DEBUG, true, __VA_ARGS__)
89 #endif
90
91 /* Formatted trace tagged with TRACE_FLOW level */
92 #if (TRACE_LEVEL < TRACE_FLOW)
93 #define FMSG(...)    (void)0
94 #else
95 #define FMSG(...)    trace_printf_helper(TRACE_FLOW, true, __VA_ARGS__)
96 #endif
97
98 /* Formatted trace tagged with TRACE_FLOW level and prefix with '> ' */
99 #define INMSG(...)     FMSG("> " __VA_ARGS__)
100 /* Formatted trace tagged with TRACE_FLOW level and prefix with '< ' */
101 #define OUTMSG(...)    FMSG("< " __VA_ARGS__)
102 /* Formatted trace tagged with TRACE_FLOW level and prefix with '< ' and print
103  * an error message if r != 0 */
104 #define OUTRMSG(r)          \
105     do {                \
106         OUTMSG("r=[%x]", r);    \
107         return r;       \
108     } while (0)
109
110 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
111
112 void dhex_dump(const char *function, int line, int level,
113            const void *buf, int len);
114
115
116 #ifndef DOXYGEN_SHOULD_SKIP_THIS
117 #if (TRACE_LEVEL < TRACE_DEBUG)
118 #define DHEXDUMP(buf, len) (void)0
119 #else
120 #define DHEXDUMP(buf, len) dhex_dump(__func__, __LINE__, TRACE_DEBUG, \
121                      buf, len)
122 #endif
123
124
125 /* Trace api without trace formatting */
126
127 #define trace_printf_helper_raw(level, level_ok, ...) \
128     trace_printf(NULL, 0, (level), (level_ok), __VA_ARGS__)
129
130 /* No formatted trace tagged with level independent */
131 #if (TRACE_LEVEL <= 0)
132 #define MSG_RAW(...)    (void)0
133 #else
134 #define MSG_RAW(...)    trace_printf_helper_raw(0, false, __VA_ARGS__)
135 #endif
136
137 /* No formatted trace tagged with TRACE_ERROR level */
138 #if (TRACE_LEVEL < TRACE_ERROR)
139 #define EMSG_RAW(...)    (void)0
140 #else
141 #define EMSG_RAW(...)    trace_printf_helper_raw(TRACE_ERROR, true, __VA_ARGS__)
142 #endif
143
144 /* No formatted trace tagged with TRACE_INFO level */
145 #if (TRACE_LEVEL < TRACE_INFO)
146 #define IMSG_RAW(...)    (void)0
147 #else
148 #define IMSG_RAW(...)    trace_printf_helper_raw(TRACE_INFO, true, __VA_ARGS__)
149 #endif
150
151 /* No formatted trace tagged with TRACE_DEBUG level */
152 #if (TRACE_LEVEL < TRACE_DEBUG)
153 #define DMSG_RAW(...)    (void)0
154 #else
155 #define DMSG_RAW(...)    trace_printf_helper_raw(TRACE_DEBUG, true, __VA_ARGS__)
156 #endif
157
158 /* No formatted trace tagged with TRACE_FLOW level */
159 #if (TRACE_LEVEL < TRACE_FLOW)
160 #define FMSG_RAW(...)    (void)0
161 #else
162 #define FMSG_RAW(...)    trace_printf_helper_raw(TRACE_FLOW, true, __VA_ARGS__)
163 #endif
164
165 #if (TRACE_LEVEL <= 0)
166 #define SMSG(...)    (void)0
167 #else
168 /*
169  * Synchronised flushed trace, an Always message straight to HW trace IP.
170  * Current only supported inside OP-TEE kernel, will be just like an EMSG()
```

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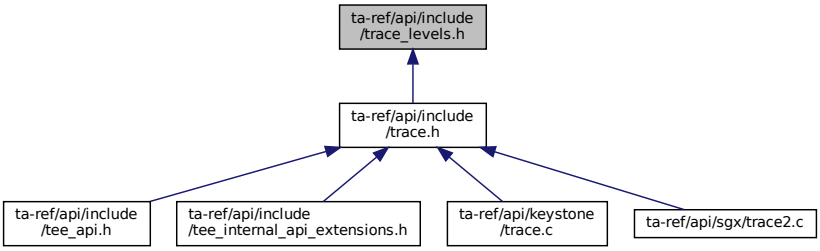
```
171  * in another context.
172  */
173 #define SMSG(...)   \
174     trace_printf(__func__, __LINE__, TRACE_ERROR, true, __VA_ARGS__)
175
176 #endif /* TRACE_LEVEL */
177
178 #if defined(__KERNEL__) && defined(CFG_UNWIND)
179 #include <kernel/unwind.h>
180 #define _PRINT_STACK
181 #endif
182
183 #if defined(_PRINT_STACK) && (TRACE_LEVEL >= TRACE_ERROR)
184 #define EPRINT_STACK() print_kernel_stack(TRACE_ERROR)
185 #else
186 #define EPRINT_STACK() (void)0
187 #endif
188
189 #if defined(_PRINT_STACK) && (TRACE_LEVEL >= TRACE_INFO)
190 #define IPRINT_STACK() print_kernel_stack(TRACE_INFO)
191 #else
192 #define IPRINT_STACK() (void)0
193 #endif
194
195 #if defined(_PRINT_STACK) && (TRACE_LEVEL >= TRACE_DEBUG)
196 #define DPRINT_STACK() print_kernel_stack(TRACE_DEBUG)
197 #else
198 #define DPRINT_STACK() (void)0
199 #endif
200
201 #if defined(_PRINT_STACK) && (TRACE_LEVEL >= TRACE_FLOW)
202 #define FPRINT_STACK() print_kernel_stack(TRACE_FLOW)
203 #else
204 #define FPRINT_STACK() (void)0
205 #endif
206
207 #if defined(__KERNEL__) && defined(CFG_UNWIND)
208 #undef _PRINT_STACK
209 #endif
210
211 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
212 #endif /* TRACE_H */
```

13.29 ta-ref/api/include/trace_levels.h File Reference

This graph shows which files directly or indirectly include this file:



13.30 trace_levels.h

Go to the documentation of this file.

```
1 /*
2  * Copyright (c) 2014, STMicroelectronics International N.V.
3  * All rights reserved.
```

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```
 4  *
 5  * Redistribution and use in source and binary forms, with or without
 6  * modification, are permitted provided that the following conditions are met:
 7  *
 8  * 1. Redistributions of source code must retain the above copyright notice,
 9  * this list of conditions and the following disclaimer.
10  *
11  * 2. Redistributions in binary form must reproduce the above copyright notice,
12  * this list of conditions and the following disclaimer in the documentation
13  * and/or other materials provided with the distribution.
14  *
15  * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
16  * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
17  * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
18  * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
19  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
20  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
21  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
22  * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
23  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
24  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
25  * POSSIBILITY OF SUCH DAMAGE.
26  */
27 #ifndef TRACE_LEVELS_H
28 #define TRACE_LEVELS_H
29
30 /*
31  * Trace levels.
32  *
33  * ALWAYS is used when you always want a print to be seen, but it is not always
34  * an error.
35  *
36  * ERROR is used when some kind of error has happened, this is most likely the
37  * print you will use most of the time when you report some kind of error.
38  *
39  * INFO is used when you want to print some 'normal' text to the user.
40  * This is the default level.
41  *
42  * DEBUG is used to print extra information to enter deeply in the module.
43  *
44  * FLOW is used to print the execution flox, typically the in/out of functions.
45  *
46  */
47
48 #ifndef DOXYGEN_SHOULD_SKIP_THIS
49 #define TRACE_MIN       1
50 #define TRACE_ERROR     TRACE_MIN
51 #define TRACE_INFO      2
52 #define TRACE_DEBUG     3
53 #define TRACE_FLOW      4
54 #define TRACE_MAX       TRACE_FLOW
55
56 /* Trace level of the casual printf */
57 #define TRACE_PRINTF_LEVEL TRACE_ERROR
58
59 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
60 #endif /*TRACE_LEVELS_H*/
61
```

13.31 ta-ref/api/include/types.h File Reference

```
#include <stddef.h>
#include "sgx_error.h"
#include "sgx_eid.h"
```

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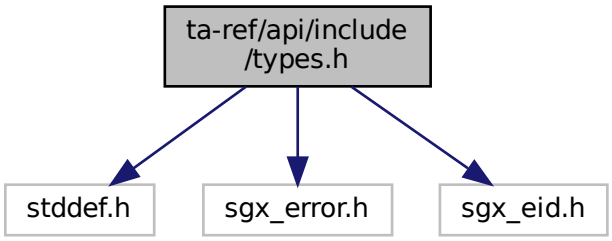
Include dependency graph for types.h:



Classes

- struct _sgx_errlist_t

Typedefs

- typedef struct _sgx_errlist_t sgx_errlist_t

Variables

- sgx_enclave_id_t global_eid = 0
- static sgx_errlist_t sgx_errlist [ ]

13.31.1 Typedef Documentation

13.31.1.1 sgx_errlist_t `typedef struct _sgx_errlist_t sgx_errlist_t`

13.31.2 Variable Documentation

13.31.2.1 global_eid `sgx_enclave_id_t global_eid = 0`

13.31.2.2 sgx_errlist `sgx_errlist_t sgx_errlist[ ] [static]`

13.32 types.h

Go to the documentation of this file.

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```
#pragma once
#include <stddef.h>
#include "sgx_error.h"       /* sgx_status_t */
#include "sgx_eid.h"     /* sgx_enclave_id_t */

/* Global EID shared by multiple threads */
sgx_enclave_id_t global_eid = 0;

typedef struct _sgx_errlist_t {
    sgx_status_t err;
    const char *msg;
    const char *sug; /* Suggestion */
} sgx_errlist_t;

/* Error code returned by sgx_create_enclave */
static sgx_errlist_t sgx_errlist[] = {
    {
        SGX_ERROR_UNEXPECTED,
        "Unexpected error occurred.",
        NULL
    },
    {
        SGX_ERROR_INVALID_PARAMETER,
        "Invalid parameter.",
        NULL
    },
    {
        SGX_ERROR_OUT_OF_MEMORY,
        "Out of memory.",
        NULL
    },
    {
        SGX_ERROR_ENCLAVE_LOST,
        "Power transition occurred.",
        "Please refer to the sample \"PowerTransition\" for details."
    },
    {
        SGX_ERROR_INVALID_ENCLAVE,
        "Invalid enclave image.",
        NULL
    },
    {
        SGX_ERROR_INVALID_ENCLAVE_ID,
        "Invalid enclave identification.",
        NULL
    },
    {
        SGX_ERROR_INVALID_SIGNATURE,
        "Invalid enclave signature.",
        NULL
    },
    {
        SGX_ERROR_OUT_OF_EPC,
        "Out of EPC memory.",
        NULL
    },
    {
        SGX_ERROR_NO_DEVICE,
        "Invalid SGX device.",
        "Please make sure SGX module is enabled in the BIOS, and install SGX driver afterwards."
    },
    {
        SGX_ERROR_MEMORY_MAP_CONFLICT,
        "Memory map conflicted.",
        NULL
    },
    {
        SGX_ERROR_INVALID_METADATA,
        "Invalid enclave metadata.",
        NULL
    },
    {
        SGX_ERROR_DEVICE_BUSY,
        "SGX device was busy.",
        NULL
    },
    {
        SGX_ERROR_INVALID_VERSION,
        "Enclave version was invalid.",
        NULL
    },
    {
        SGX_ERROR_INVALID_ATTRIBUTE,
        "Enclave was not authorized.",
        NULL
```

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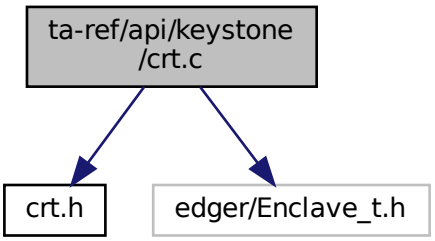
```
86     },
87     {
88         SGX_ERROR_ENCLAVE_FILE_ACCESS,
89         "Can't open enclave file.",
90         NULL
91     },
92 };
```

13.33 ta-ref/api/keystone/crt.c File Reference

```
#include "crt.h"
#include "edger/Enclave_t.h"
```

Include dependency graph for crt.c:



Functions

- void crt_end (void)

Variables

- static void(∗const init_array [ ])() __attribute__((section(".init_array")
- static void(∗const aligned [ ])(sizeof(void ∗)))
- static void(∗const fini_array [ ])() __attribute__((section(".fini_array")
- void(∗ __init_array_start [ ])(void)

13.33.1 Function Documentation

13.33.1.1 crt_end() `void crt_end (`

```
    void  )
```

crt_end() - Ends the certification.

It compares __fini_array_start and __fini_array_end; and then it the loops through the file pointer.

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13.33.2 Variable Documentation

13.33.2.1 __init_array_start `void(* __init_array_start[])(void) ( void ) [extern]`

crt_begin() - Commences the certification.

It compares __init_array_start and __init_array_end; and then it the loops through the file pointer.

13.33.2.2 aligned `void(*const aligned[])(sizeof(void *))) ( sizeof(void *) )`

Initial value:

```
= {
  }
```

13.33.2.3 fini_array `void(*const fini_array[])() __attribute__((section(".fini_array") ( ) [static]`

Termination array for the executable.

This section holds an array of function pointers that contributes to a single termination array for the executable or shared object containing the section and if defined is PERF_ENABLE then unmapping the profiler information.

Parameters

fini_array[ ]	constant array.

13.33.2.4 init_array `void(*const init_array[])() __attribute__((section(".init_array") ( ) [static]`

Initialization array for the executable.

This section holds an array of function pointers that contributes to a single initialization array for the executable or shared object containing the section if defined is PERF_ENABLE then mapping the profiler information.

Parameters

init_array[ ]	constant array.

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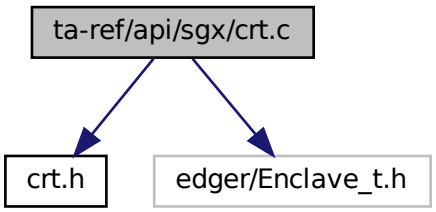
13.34 ta-ref/api/sgx/crt.c File Reference

```
#include "crt.h"
#include "edger/Enclave_t.h"
```

Include dependency graph for crt.c:



Functions

- void crt_end (void)

Variables

- static void(∗const init_array [])() __attribute__((section(".init_array")
- static void(∗const aligned [])(sizeof(void ∗))))
- static void(∗const fini_array [])() __attribute__((section(".fini_array")
- void(∗ __init_array_start [])(void)

13.34.1 Function Documentation

13.34.1.1 crt_end() `void crt_end ( void )`

crt_end() - Ends the certification.

It compares __fini_array_start and __fini_array_end; and then it the loops through the file pointer.

13.34.2 Variable Documentation

13.34.2.1 __init_array_start `void(* __init_array_start[])(void) ( void ) [extern]`

crt_begin() - Commences the certification.

It compares __init_array_start and __init_array_end; and then it the loops through the file pointer.

13.34.2.2 aligned `void(*const aligned[])(sizeof(void *))) ( sizeof(void *) )`

Initial value:

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```
= {
  }
```

13.34.2.3 fini_array `void(*const fini_array[])() __attribute__((section(".fini_array")) ( ) [static]`

Termination array for the executable.

This section holds an array of function pointers that contributes to a single termination array for the executable or shared object containing the section and if defined is PERF_ENABLE then unmapping the profiler information.

Parameters

fini_array[ ]	constant array.

13.34.2.4 init_array `void(*const init_array[])() __attribute__((section(".init_array")) ( ) [static]`

Initialization array for the executable.

This section holds an array of function pointers that contributes to a single initialization array for the executable or shared object containing the section if defined is PERF_ENABLE then mapping the profiler information.

Parameters

init_array[ ]	constant array.

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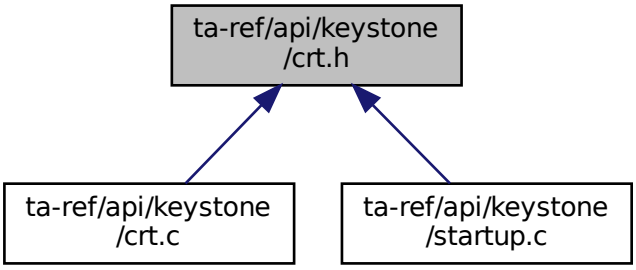
13.35 ta-ref/api/keystone/crt.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- void crt_begin (void)
- void crt_end (void)
- int main (void)

13.35.1 Function Documentation

13.35.1.1 crt_begin() `void crt_begin (`

```
    void  )
```

13.35.1.2 crt_end() `void crt_end (`

```
    void  )
```

crt_end() - Ends the certification.

It compares __fini_array_start and __fini_array_end; and then it the loops through the file pointer.

13.35.1.3 main() `int main (`

```
    void  )
```

13.36 crt.h

Go to the documentation of this file.

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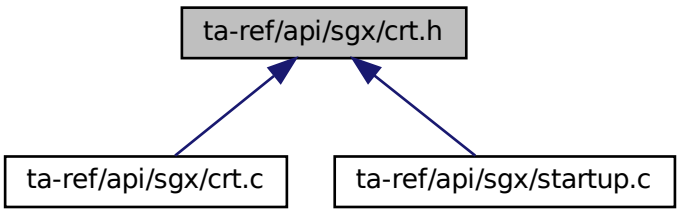
```
1 void crt_begin(void);
2 void crt_end(void);
3 int main(void);
```

13.37 ta-ref/api/sgx/crt.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- void crt_begin (void)
- void crt_end (void)
- int main (void)

13.37.1 Function Documentation

13.37.1.1 crt_begin() `void crt_begin ( void )`

13.37.1.2 crt_end() `void crt_end ( void )`

crt_end() - Ends the certification.

It compares __fini_array_start and __fini_array_end; and then it the loops through the file pointer.

13.37.1.3 main() `int main ( void )`

13.38 crt.h

Go to the documentation of this file.

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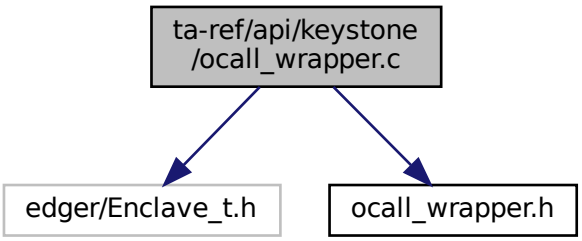
```
1 void crt_begin(void);
2 void crt_end(void);
3 int main(void);
```

13.39 ta-ref/api/keystone/ocall_wrapper.c File Reference

```
#include "edger/Enclave_t.h"
#include "ocall_wrapper.h"
```

Include dependency graph for ocall_wrapper.c:



Functions

- unsigned int ocall_print_string_wrapper (const char *str)

13.39.1 Function Documentation

13.39.1.1 ocall_print_string_wrapper() `unsigned int ocall_print_string_wrapper ( const char * str )`

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

Parameters

str	The string value for print.

Returns

string It prints the value of str by calling ocall_print_string().

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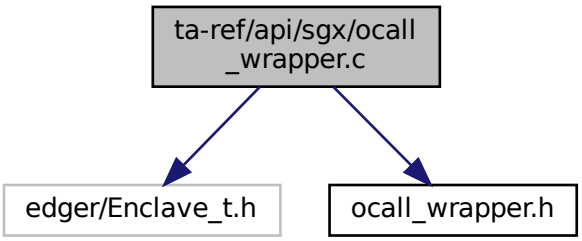
13.40 ta-ref/api/sgx/ocall_wrapper.c File Reference

```
#include "edger/Enclave_t.h"
#include "ocall_wrapper.h"
```

Include dependency graph for ocall_wrapper.c:



Functions

- unsigned int ocall_print_string_wrapper (const char *str)

13.40.1 Function Documentation

13.40.1.1 ocall_print_string_wrapper() `unsigned int ocall_print_string_wrapper ( const char * str )`

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

Parameters

str	The string value for print.

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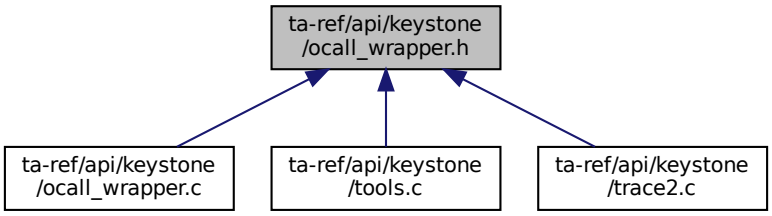
Returns

retval Its prints the value of str by calling ocall_print_string().

13.41 ta-ref/api/keystone/ocall_wrapper.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- unsigned int ocall_print_string_wrapper (const char ∗str)

13.41.1 Function Documentation

13.41.1.1 ocall_print_string_wrapper() `unsigned int ocall_print_string_wrapper ( const char * str )`

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

Parameters

str	The string value for print.

Returns

string It prints the value of str by calling ocall_print_string().

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

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Parameters

str	The string value for print.

Returns

retval Its prints the value of str by calling ocall_print_string().

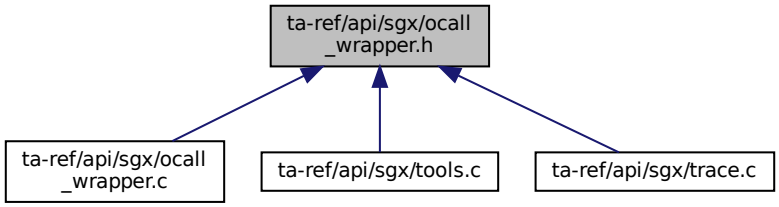
13.42 ocall_wrapper.h

Go to the documentation of this file.

```
1 #pragma once
2 unsigned int ocall_print_string_wrapper(const char* str);
```

13.43 ta-ref/api/sgx/ocall_wrapper.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- unsigned int ocall_print_string_wrapper (const char ∗str)

13.43.1 Function Documentation

13.43.1.1 ocall_print_string_wrapper() `unsigned int ocall_print_string_wrapper ( const char * str )`

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

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Parameters

str	The string value for print.

Returns

string It prints the value of str by calling ocall_print_string().

ocall_print_string_wrapper() - To print the argument string

This function invokes ocall_print_string() to print the string.

Parameters

str	The string value for print.

Returns

retval Its prints the value of str by calling ocall_print_string().

13.44 ocall_wrapper.h

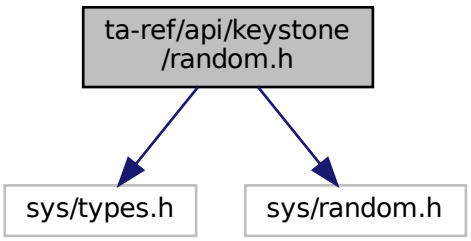
Go to the documentation of this file.

```
1 #pragma once
2 unsigned int ocall_print_string_wrapper(const char* str);
```

13.45 ta-ref/api/keystone/random.h File Reference

```
#include <sys/types.h>
#include <sys/random.h>
```

Include dependency graph for random.h:



13.46 random.h

Go to the documentation of this file.

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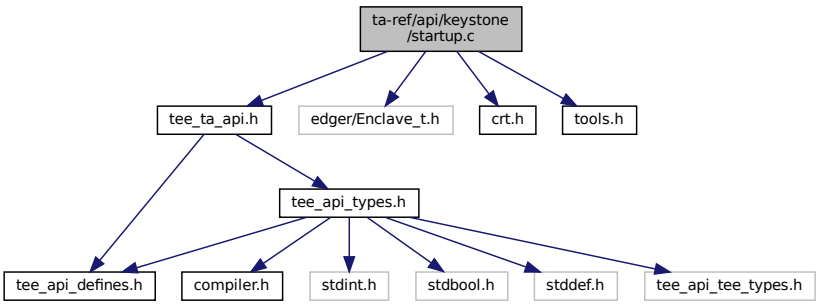
```c
#include <sys/types.h>
// for keystone-enclave v0.4 we saw the getrandom(2) function freeze, so we use srandom/random
    instead when we set 'SEED' value.
#ifdef SEED
#include <stdlib.h>
#define getrandom seed_random
static ssize_t seed_random(void *buf, size_t buflen, unsigned int flags) {
    (flags); // not used
    const ssize_t ss = sizeof(unsigned int);
    unsigned int retval;
     unsigned int *b = (unsigned int*)buf;
     ssize_t idx = 0;
     srandom((unsigned int)SEED);
     while(buflen) {
         retval = random();
         buflen -= ss;
         b[idx++] = retval;
     }
     return idx*ss;
}
#else
#include <sys/random.h>
#endif
```

13.47 ta-ref/api/keystone/startup.c File Reference

```c
#include "tee_ta_api.h"
#include "edger/Enclave_t.h"
#include "crt.h"
#include "tools.h"
```

Include dependency graph for startup.c:



Functions

- TEE_Result TA_InvokeCommandEntryPoint (void *sess_ctx, uint32_t cmd_id, uint32_t param_types, TEE_Param params[4])
- void EAPP_ENTRY eapp_entry ()

13.47.1 Function Documentation

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13.47.1.1 eapp_entry() `void EAPP_ENTRY eapp_entry ( )`

The eapp_entry() - It contains enclave verbose and invokes main function.

This function invokes crt_begin() if defined macro is ENCLAVE_VERBOSE then prints the main start and invokes main(). Once main() is completed prints the main end and invokes the crt_end().

Returns

It will return EAPP_RETURN(0).

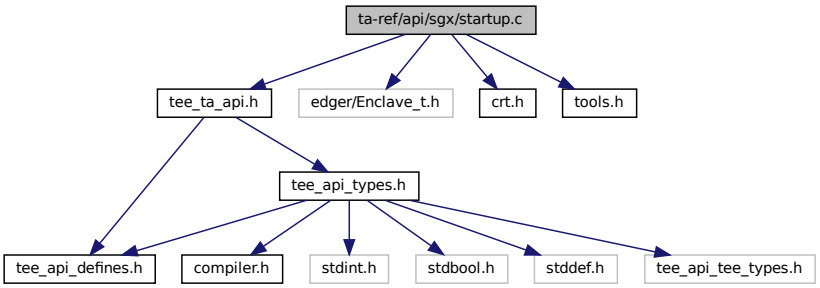
13.47.1.2 TA_InvokeCommandEntryPoint()

```
TEE_Result TA_InvokeCommandEntryPoint (
    void * sess_ctx,
    uint32_t cmd_id,
    uint32_t param_types,
    TEE_Param params[4] )
```

13.48 ta-ref/api/sgx/startup.c File Reference

```
#include "tee_ta_api.h"
#include "edger/Enclave_t.h"
#include "crt.h"
#include "tools.h"
```

Include dependency graph for startup.c:



Functions

- TEE_Result TA_InvokeCommandEntryPoint (void *sess_ctx, uint32_t cmd_id, uint32_t param_types, TEE_Param params[4])
- void ecall_ta_main (uint32_t command)

13.48.1 Function Documentation

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13.48.1.1 ecall_ta_main()

```
void ecall_ta_main (
    uint32_t command )
```

The eapp_entry() - It contains enclave verbose and invokes the main function.

This function invokes crt_begin() if defined macro is ENCLAVE_VERBOSE then prints the main start and invokes main(). Once main() is completed, it prints the main end and invokes the crt_end().

Returns

It will return EAPP_RETURN(0).

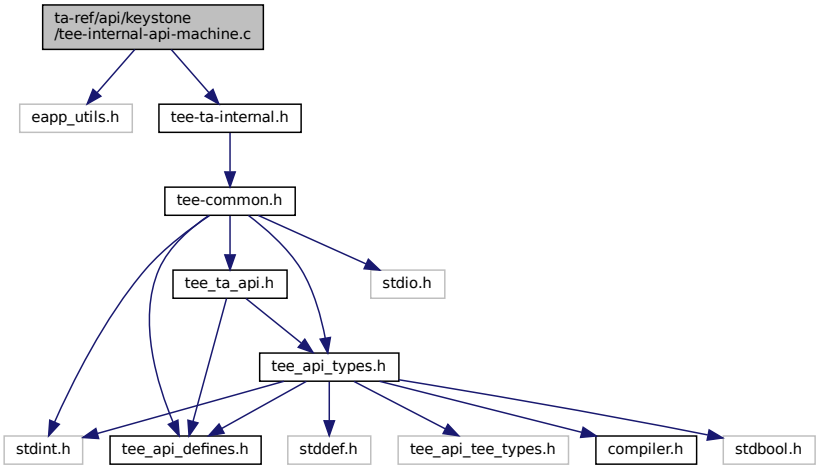
13.48.1.2 TA_InvokeCommandEntryPoint()

```
TEE_Result TA_InvokeCommandEntryPoint (
    void * sess_ctx,
    uint32_t cmd_id,
    uint32_t param_types,
    TEE_Param params[4] )
```

13.49 ta-ref/api/keystone/tee-internal-api-machine.c File Reference

```
#include "eapp_utils.h"
#include "tee-ta-internal.h"
```

Include dependency graph for tee-internal-api-machine.c:



Functions

- void __attribute__ ((noreturn))

13.49.1 Function Documentation

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13.49.1.1 __attribute__() `void __attribute__ ( (noreturn) )`

TEE_Panic() - Raises a panic in the Trusted Application instance.

When a Trusted Application calls the TEE_Panic function, the current instance shall be destroyed and all the resources opened by the instance shall be reclaimed. All sessions opened from the panicking instance on another TA shall be gracefully closed and all cryptographic objects and operations shall be closed properly.

Parameters

code	An informative panic code defined by the TA.

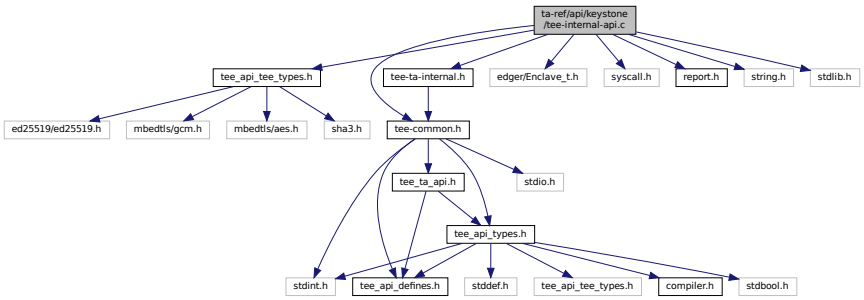
Returns

panic code will be returned.

13.50 ta-ref/api/keystone/tee-internal-api.c File Reference

```
#include "tee_api_tee_types.h"
#include "tee-common.h"
#include "tee-ta-internal.h"
#include "edger/Enclave_t.h"
#include "syscall.h"
#include "report.h"
#include <string.h>
#include <stdlib.h>
```

Include dependency graph for tee-internal-api.c:



Functions

- void * TEE_Malloc (uint32_t size, uint32_t hint)
- void * TEE_Realloc (void *buffer, uint32_t newSize)
- void TEE_Free (void *buffer)
- void TEE_GetREETime (TEE_Time *time)

  Core Functions, Time Functions.
- void TEE_GetSystemTime (TEE_Time *time)

  Core Functions, Time Functions.

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- TEE_Result GetRelTimeStart (uint64_t start)

  Core Functions, Time Functions.
- TEE_Result GetRelTimeEnd (uint64_t end)

  Core Functions, Time Functions.
- static int flags2flags (int flags)
- static int set_object_key (void *id, unsigned int idlen, TEE_ObjectHandle object)
- static TEE_Result OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object, int ocreat)
- TEE_Result TEE_CreatePersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle attributes, const void *initialData, uint32_t initialDataLen, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_GetObjectInfo1 (TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_WriteObjectData (TEE_ObjectHandle object, const void *buffer, uint32_t size)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_ReadObjectData (TEE_ObjectHandle object, void *buffer, uint32_t size, uint32_t *count)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_CloseObject (TEE_ObjectHandle object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- WC_RNG * get_wc_rng (void)
- int wc_ocall_genseed (void *nonce, uint32_t len)
- void TEE_GenerateRandom (void *randomBuffer, uint32_t randomBufferLen)

  Crypto, common.

Variables

- static int wc_rng_init = 0
- static WC_RNG rngstr

13.50.1 Function Documentation

13.50.1.1 flags2flags() `static int flags2flags ( int flags ) [inline], [static]`

flags2flags() - Checks the status for reading or writing of the file operational.

This function is used to check the status for reading or writing of the file operational.

Parameters

flags	Flags of the referencing node.

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Returns

ret if success.

13.50.1.2 get_wc_rng() `WC_RNG * get_wc_rng ( void )`

get_wc_rng() - Gets the seed (from OS) and key cipher for rng (random number genertor).

This function returns the random number or unique number of "rngstr".

Returns

random number if success else error occured.

13.50.1.3 GetRelTimeEnd() `TEE_Result GetRelTimeEnd ( uint64_t end )`

Core Functions, Time Functions.

GetRelTimeEnd() - finds the real time of the end timing.

This function prints the ending time.

Parameters

end	End timing

Returns

0 If success

13.50.1.4 GetRelTimeStart() `TEE_Result GetRelTimeStart ( uint64_t start )`

Core Functions, Time Functions.

GetRelTimeStart() - Gets the real time of the start timing.

This function prints the starting time.

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Parameters

start	Start timing

Returns

0 on success

13.50.1.5 OpenPersistentObject()

```
static TEE_Result OpenPersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle * object,
    int ocreat )  [static]
```

OpenPersistentObject() - Opens a handle on an existing persistent object.

The flags parameter is a set of flags that controls the access rights and sharing permissions with which the object handle is opened. The value of the flags parameter is constructed by a bitwise-inclusive OR of flags TEE_DATA↩ _FLAG_ACCESS_READ, the object is opened with the read access right. This allows the Trusted Application to call the function TEE_ReadObjectData. TEE_DATA_FLAG_ACCESS_WRITE, the object is opened with the write access right. TEE_DATA_FLAG_ACCESS_WRITE_META, the object is opened with the write-meta access right.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	length of the identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion.

Returns

0 if success else error occured.

13.50.1.6 set_object_key()

```
static int set_object_key (
    void * id,
    unsigned int idlen,
    TEE_ObjectHandle object )  [static]
```

set_object_key() - Initialize report and then attest enclave with file.

This function describes the intialization of report, attest the enclave with file id and its length then assigned to ret. Based on "mbedtls" key encryption and decryption position of the object will be copied. Finally ret value returns on success else signature too short error will appear on failure.

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Parameters

id	id of the object.
idlen	length of the id.
object	TEE_ObjectHandle type handle.

Returns

ret if success.

13.50.1.7 TEE_CloseObject() `void TEE_CloseObject (`

```
TEE_ObjectHandle object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CloseObject() - Closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

Parameters

object	Handle of the object.

Returns

TEE_SUCCESS if success else error occured.

13.50.1.8 TEE_CreatePersistentObject() `TEE_Result TEE_CreatePersistentObject (`

```
uint32_t storageID,
const void * objectID,
uint32_t objectIDLen,
uint32_t flags,
TEE_ObjectHandle attributes,
const void * initialData,
uint32_t initialDataLen,
TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

In this function an initial data stream content returns either a handle on the created object or TEE_HANDLE_NULL upon failure.

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Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle which contains the opened handle upon successful completion

Returns

0 if success else error occured.

13.50.1.9 TEE_Free() `void TEE_Free (`

```
void * buffer )
```

TEE_Free() - causes the space pointed to by buffer to be deallocated;that is made available for further allocation.

This function describes if buffer is a NULL pointer, TEE_Free does nothing. Otherwise, it is a Programmer Error if the argument does not match a pointer previously returned by the TEE_Malloc or TEE_Realloc if the space has been deallocated by a call to TEE_Free or TEE_Realloc.

Parameters

buffer	The pointer to the memory block to be freed.

13.50.1.10 TEE_GenerateRandom() `void TEE_GenerateRandom (`

```
void * randomBuffer,
uint32_t randomBufferLen )
```

Crypto, common.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random buffer length and is stored in to random Buffer by calling wc_↩ RNG_GenerateBlock().If ret is not equal
to 0 then TEE_Panic is called.

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Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

Returns

random data random data will be returned.

13.50.1.11 TEE_GetObjectInfo1() `TEE_Result TEE_GetObjectInfo1 ( TEE_ObjectHandle object, TEE_ObjectInfo * objectInfo )`

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_GetObjectInfo1() - Returns the characteristics of an object.

This function returns a handle which can be used to access the object's attributes and data stream.

Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

13.50.1.12 TEE_GetREETime() `void TEE_GetREETime ( TEE_Time * time )`

Core Functions, Time Functions.

TEE_GetREETime() - Retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of the REE.

Parameters

time	Filled with the number of seconds and milliseconds

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13.50.1.13 TEE_GetSystemTime() `void TEE_GetSystemTime (`

```
TEE_Time * time )
```

Core Functions, Time Functions.

TEE_GetSystemTime() - Retrieves the current system time.

This function describes the system time has an arbitrary implementation
defined origin that can vary across TA instances. The minimum guarantee
is that the system time shall be monotonic for a given TA instance.

Parameters

time	Filled with the number of seconds and milliseconds

13.50.1.14 TEE_Malloc() `void * TEE_Malloc (`

```
uint32_t size,
uint32_t hint )
```

TEE_Malloc() - Allocates space for an object whose size in bytes is specified in the parameter size.

This function describes the pointer returned is guaranteed to be aligned
such that it may be assigned as a pointer to any basic C type.The valid hint values are a bitmask and can be independently set. This parameter allows Trusted Applications to refer to various pools of memory or to
request special characteristics for the allocated memory by using an
implementation-defined hint. Future versions of this specification may introduce additional standard hints.

Parameters

size	The size of the buffer to be allocated.
hint	A hint to the allocator.

Returns

Upon successful completion, with size not equal to zero, the function returns a pointer to the allocated space.

13.50.1.15 TEE_OpenPersistentObject() `TEE_Result TEE_OpenPersistentObject (`

```
uint32_t storageID,
const void * objectID,
uint32_t objectIDLen,
uint32_t flags,
TEE_ObjectHandle * object )
```

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Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle which can be used to access the object's attributes and data stream.

Parameters

storageID	The storage to use
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

Returns

0 if success else error occured.

13.50.1.16 TEE_ReadObjectData()

```
TEE_Result TEE_ReadObjectData (
    TEE_ObjectHandle object,
    void * buffer,
    uint32_t size,
    uint32_t * count )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion of TEE_ReadObjectData sets the number of bytes actually read in the "uint32_t" pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

Returns

TEE_SUCCESS if success else error occured.

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13.50.1.17 TEE_Realloc()

```
void * TEE_Realloc (
    void * buffer,
    uint32_t newSize )
```

TEE_Realloc() - Changes the size of the memory object pointed to by buffer to the size specified by new size.

This function describes the content of the object remains unchanged up to the lesser of the new and old sizes. Space in excess of the old size contains unspecified content. If the new size of the memory object requires movement of the object, the space for the previous instantiation of the object is deallocated. If the space cannot be allocated, the original object remains allocated, and this function returns a NULL pointer.

Parameters

buffer	The pointer to the object to be reallocated.
newSize	The new size required for the object

Returns

Upon successful completion, TEE_Realloc returns a pointer to the (possibly moved) allocated space. If there is not enough available memory, TEE_Realloc returns a NULL pointer and the original buffer is still allocated and unchanged.

13.50.1.18 TEE_WriteObjectData()

```
TEE_Result TEE_WriteObjectData (
    TEE_ObjectHandle object,
    const void * buffer,
    uint32_t size )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_WriteObjectData() - Writes the buffer data in to persistent objects.

In this function it checks if object is present or not, the encryption/ decryption buffer is taken by calling mbedtls_aes↩ _crypt_cbc() then that buffer data is encrypted and mapped to object.On the base of object creation TEE_SUCCESS appears else TEE_ERROR_GENERIC appears.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

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13.50.1.19 wc_ocall_genseed() int wc_ocall_genseed (

```
void * nonce,
uint32_t len )
```

wc_ocall_genseed() To generate random data.

This function describes the return value of random generated data. if generated random value is not equal to length of buffer then panic
reason occurs.

Parameters

nonce	pointer of buffer
len	length of the buffer.

Returns

0 on success else error will occur based on panic raised inside trusted application.

13.50.2 Variable Documentation

13.50.2.1 rngstr WC_RNG rngstr [static]

13.50.2.2 wc_rng_init int wc_rng_init = 0 [static]

ocall_getrandom() - For getting random data.

This function describes that the retval is returned based on the size of buffer by calling the functions ocall_↩ getrandom196 and ocall_getrandom16

Parameters

buf	character type buffer
len	size of the buffer
flags	unassigned integer flag

Returns

retval value will be returned based on length of buffer.

13.51 ta-ref/api/sgx/tee-internal-api.c File Reference

```
#include "tee_api_tee_types.h"
#include "tee-common.h"
```

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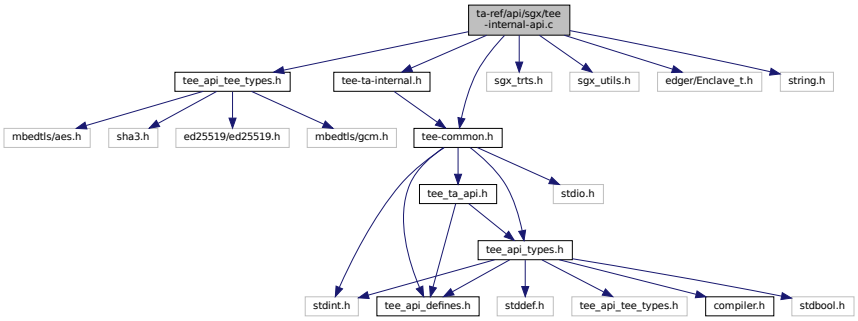
```
#include "tee-ta-internal.h"
#include "sgx_trts.h"
#include "sgx_utils.h"
#include "edger/Enclave_t.h"
#include <string.h>
```

Include dependency graph for tee-internal-api.c:



Functions

- void __attribute__ ((noreturn))
- void TEE_GetREETime (TEE_Time *time)

  Core Functions, Time Functions.
- void TEE_GetSystemTime (TEE_Time *time)

  Core Functions, Time Functions.
- TEE_Result GetRelTimeStart (uint64_t start)

  Core Functions, Time Functions.
- TEE_Result GetRelTimeEnd (uint64_t end)

  Core Functions, Time Functions.
- static int flags2flags (int flags)
- static int set_object_key (const void *id, unsigned int idlen, TEE_ObjectHandle object)
- static TEE_Result OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object, int ocreat)
- TEE_Result TEE_CreatePersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle attributes, const void *initialData, uint32_t initialDataLen, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_OpenPersistentObject (uint32_t storageID, const void *objectID, uint32_t objectIDLen, uint32_t flags, TEE_ObjectHandle *object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_GetObjectInfo1 (TEE_ObjectHandle object, TEE_ObjectInfo *objectInfo)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_WriteObjectData (TEE_ObjectHandle object, const void *buffer, uint32_t size)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- TEE_Result TEE_ReadObjectData (TEE_ObjectHandle object, void *buffer, uint32_t size, uint32_t *count)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_CloseObject (TEE_ObjectHandle object)

  Core Functions, Secure Storage Functions (data is isolated for each TA)
- void TEE_GenerateRandom (void *randomBuffer, uint32_t randomBufferLen)

  Crypto, common.
- static WC_RNG * get_wc_rng (void)

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Variables

- static int wc_rng_init = 0
- static WC_RNG rngstr

13.51.1 Function Documentation

13.51.1.1 __attribute__() `void __attribute__ ( (noreturn) )`

TEE_Panic() - Raises a Panic in the Trusted Application instance

When a Trusted Application calls the TEE_Panic function, the current instance shall be destroyed and all the resources opened by the instance shall be reclaimed.

Parameters

ec	An informative panic code defined by the TA. May be displayed in traces if traces are available.

13.51.1.2 flags2flags() `static int flags2flags ( int flags ) [inline], [static]`

flags2flags() - Checks the status for reading or writing of the file operational.

This function is to check the status for reading or writing of the file operational.

Parameters

flags	Flags of the referencing node.

Returns

0 if success else error occured.

13.51.1.3 get_wc_rng() `static WC_RNG * get_wc_rng ( void ) [static]`

get_wc_rng() - Gets the seed (from OS) and key cipher for rng(random number genertor).

This function returns the random number or unique number of "rngstr".

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Returns

random number if success else error occured.

13.51.1.4 GetRelTimeEnd() `TEE_Result GetRelTimeEnd (`

```
uint64_t end )
```

Core Functions, Time Functions.

GetRelTimeStart() - find the real time of the end timing.

This function prints the End timing.

Parameters

end	End timing

Returns

0 if success else error occured

13.51.1.5 GetRelTimeStart() `TEE_Result GetRelTimeStart (`

```
uint64_t start )
```

Core Functions, Time Functions.

GetRelTimeStart() - Gets the real time of the start timing.

Ths function prints the start timing.

Parameters

start	start timing

Returns

0 if success else error occured.

13.51.1.6 OpenPersistentObject() `static TEE_Result OpenPersistentObject (`

```
uint32_t storageID,
const void * objectID,
```

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```
uint32_t objectIDLen,
uint32_t flags,
TEE_ObjectHandle * object,
int ocreat )  [static]
```

OpenPersistentObject() - Opens a handle on an existing persistent object.

The flags parameter is a set of flags that controls the access rights and sharing permissions with which the object handle is opened. The value of the flags parameter is constructed by a bitwise-inclusive OR of flags TEE_DATA↩ _FLAG_ACCESS_READ, the object is opened with the read access right. This allows the Trusted Application to call the function TEE_ReadObjectData. TEE_DATA_FLAG_ACCESS_WRITE, the object is opened with the write access right. TEE_DATA_FLAG_ACCESS_WRITE_META, the object is opened with the write-meta access right.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	length of the identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion.

Returns

0 if success else error occured.

13.51.1.7 set_object_key()

```
static int set_object_key (
const void * id,
unsigned int idlen,
TEE_ObjectHandle object )  [static]
```

set_object_key - To initalize report and then attest enclave with file.

This function describes objectID as key_id to make the key dependent on it sgx report key is 128-bit. Fill another 128-bit with seal key. seal key doesn't change with enclave. Better than nothing, though. random nonce can not use for AES here because of persistency. the digest of attestation report and objectID as the last resort has been used.

Parameters

id	id of the object.
idlen	length of the id.
object	TEE_ObjectHandle type handle.

Returns

0 if success else error occured.

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13.51.1.8 TEE_CloseObject()

```
void TEE_CloseObject (
    TEE_ObjectHandle object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CloseObject() - Function closes an opened object handle.

The object can be persistent or transient.For transient objects, TEE_CloseObject is equivalent to TEE_Free↩ TransientObject.

Parameters

object	Handle of the object

Returns

TEE_SUCCESS if success else error occured.

13.51.1.9 TEE_CreatePersistentObject()

```
TEE_Result TEE_CreatePersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle attributes,
    const void * initialData,
    uint32_t initialDataLen,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_CreatePersistentObject() - Creates a persistent object with initial attributes.

An initial data stream content, and optionally returns either a handle on the created object, or TEE_HANDLE_NULL upon failure.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
attributes	A handle on a persistent object or an initialized transient object from which to take the persistent object attributes
initialData	The initial data content of the persistent object
initialDataLen	The initial data content of the persistent object
object	A pointer to the handle, which contains the opened handle upon successful completion

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Returns

0 if success, else error occured.

13.51.1.10 TEE_GenerateRandom()

```
void TEE_GenerateRandom (
    void * randomBuffer,
    uint32_t randomBufferLen )
```

Crypto, common.

TEE_GenerateRandom() - Generates random data.

This function generates random data of random bufferlength and is stored in to randomBuffer by calling sgx_read_rand().

Parameters

randomBuffer	Reference to generated random data
randomBufferLen	Byte length of requested random data

13.51.1.11 TEE_GetObjectInfo1()

```
TEE_Result TEE_GetObjectInfo1 (
    TEE_ObjectHandle object,
    TEE_ObjectInfo * objectInfo )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_GetObjectInfo1() - Function returns the characteristics of an object.

It returns a handle that can be used to access the object's attributes and data stream.

Parameters

objectInfo	Pointer to a structure filled with the object information
object	Handle of the object

Returns

0 if success else error occured.

13.51.1.12 TEE_GetREETime()

```
void TEE_GetREETime (
    TEE_Time * time )
```

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Core Functions, Time Functions.

TEE_GetREETime() - Function retrieves the current REE system time.

This function retrieves the current time as seen from the point of view of the REE.

Parameters

time	Filled with the number of seconds and milliseconds.

13.51.1.13 TEE_GetSystemTime()

```
void TEE_GetSystemTime (
    TEE_Time * time )
```

Core Functions, Time Functions.

TEE_GetSystemTime() - Retrieves the current system time.

The system time has an arbitrary implementation-defined origin that can vary across TA instances

Parameters

time	Filled with the number of seconds and milliseconds.

13.51.1.14 TEE_OpenPersistentObject()

```
TEE_Result TEE_OpenPersistentObject (
    uint32_t storageID,
    const void * objectID,
    uint32_t objectIDLen,
    uint32_t flags,
    TEE_ObjectHandle * object )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_OpenPersistentObject() - Opens a handle on an existing persistent object.

This function returns a handle that can be used to access the object's attributes and data stream.

Parameters

storageID	The storage to use.
objectID	The object identifier
objectIDLen	The object identifier
flags	The flags which determine the settings under which the object is opened.
object	A pointer to the handle, which contains the opened handle upon successful completion

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Returns

0 if success, else error occured.

13.51.1.15 TEE_ReadObjectData()

```
TEE_Result TEE_ReadObjectData (
    TEE_ObjectHandle object,
    void * buffer,
    uint32_t size,
    uint32_t * count )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_ReadObjectData() - Attempts to read size bytes from the data stream associated with the object object into the buffer pointed to by buffer.

The bytes are read starting at the position in the data stream currently stored in the object handle. The handle's position is incremented by the number of bytes actually read. On completion TEE_ReadObjectData sets the number of bytes actually read in the uint32_t pointed to by count. The value written to ∗count may be less than size if the number of bytes until the end-of3067 stream is less than size. It is set to 0 if the position at the start of the read operation is at or beyond the end-of-stream. These are the only cases where ∗count may be less than size.

Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write
count	size of the buffer.

Returns

TEE_SUCCESS if success, else error occured.

13.51.1.16 TEE_WriteObjectData()

```
TEE_Result TEE_WriteObjectData (
    TEE_ObjectHandle object,
    const void * buffer,
    uint32_t size )
```

Core Functions, Secure Storage Functions (data is isolated for each TA)

TEE_WriteObjectData() - writes size bytes from the buffer pointed to by buffer to the data stream associated with the open object handle object.

If the current data position points before the end-of-stream, then size bytes are written to the data stream, overwriting bytes starting at the current data position. If the current data position points beyond the stream's end, then the data stream is first extended with zero bytes until the length indicated by the data position indicator is reached, and then size bytes are written to the stream.

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Parameters

object	Handle of the object
buffer	The buffer containing the data to be written
size	The number of bytes to write

Returns

TEE_SUCCESS if success else error occured.

13.51.2 Variable Documentation

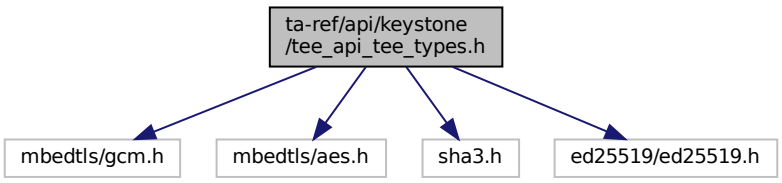
13.51.2.1 rngstr `WC_RNG rngstr [static]`

13.51.2.2 wc_rng_init `int wc_rng_init = 0 [static]`

13.52 ta-ref/api/keystone/tee_api_tee_types.h File Reference

```
#include "mbedtls/gcm.h"
#include "mbedtls/aes.h"
#include "sha3.h"
#include "ed25519/ed25519.h"
```

Include dependency graph for tee_api_tee_types.h:



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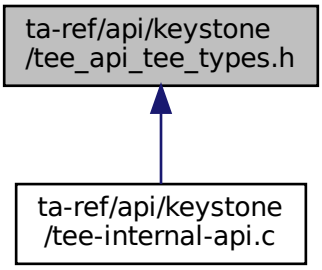
This graph shows which files directly or indirectly include this file:



Classes

- struct __TEE_OperationHandle
- struct __TEE_ObjectHandle

13.53 tee_api_tee_types.h

Go to the documentation of this file.

```
1 /*
2  * SPDX-License-Identifier: BSD-2-Clause
3  *
4  * Copyright (C) 2019 National Institute of Advanced Industrial Science
5  *                          and Technology (AIST)
6  * All rights reserved.
7  *
8  * Redistribution and use in source and binary forms, with or without
9  * modification, are permitted provided that the following conditions are met:
10  *
11  * 1. Redistributions of source code must retain the above copyright notice,
12  * this list of conditions and the following disclaimer.
13  *
14  * 2. Redistributions in binary form must reproduce the above copyright notice,
15  * this list of conditions and the following disclaimer in the documentation
16  * and/or other materials provided with the distribution.
17  *
18  * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
19  * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
20  * IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
21  * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
22  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
23  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
24  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
25  * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
26  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
27  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
28  * POSSIBILITY OF SUCH DAMAGE.
29  */
30
31 #ifndef TEE_API_TYPES_KEYSTONE_H
32 #define TEE_API_TYPES_KEYSTONE_H
33
34 #ifndef DOXYGEN_SHOULD_SKIP_THIS
35 #define MBEDCRYPT 1
36 #define WOLFCRYPT 2
37 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
38
39 #if CRYPTLIB==MBEDCRYPT
40 #ifndef DOXYGEN_SHOULD_SKIP_THIS
```

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```
41 # define MBEDTLS_CONFIG_FILE "mbed-crypto-config.h"
42 # define AES256 1
43 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
44 # include "mbedtls/gcm.h"
45 # include "mbedtls/aes.h"
46 # include "sha3.h"
47 # include "ed25519/ed25519.h"
48 #elif CRYPTLIB==WOLFCRYPT
49 #ifndef DOXYGEN_SHOULD_SKIP_THIS
50 # define HAVE_AESGCM 1
51 # define HAVE_AES_CBC 1
52 # define HAVE_AES_DECRYPT 1
53 # define HAVE_FIPS 1
54 # define HAVE_FIPS_VERSION 2
55 # define HAVE_ED25519 1
56 # define HAVE_ED25519_SIGN 1
57 # define HAVE_ED25519_VERIFY 1
58 # define WOLFSSL_SHA512 1
59 # define WOLFSSL_SHA3 1
60 # define WOLFSSL_SHA3_SMALL 1
61 # define WOLFCRYPT_ONLY 1
62 # define WOLF_CRYPT_PORT_H
63 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
64 # include "wolfssl/wolfcrypt/sha3.h"
65 # include "wolfssl/wolfcrypt/aes.h"
66 # include "wolfssl/wolfcrypt/sha512.h"
67 # include "wolfssl/wolfcrypt/ed25519.h"
68 #else
69 # include "sha3.h"
70 # include "ed25519/ed25519.h"
71 # include "tiny_AES_c/aes.h"
72 #ifndef DOXYGEN_SHOULD_SKIP_THIS
73 # define AES256 1
74 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
75 #endif
76
77 #ifndef DOXYGEN_SHOULD_SKIP_THIS
78 #define SHA_LENGTH (256/8)
79 #define TEE_OBJECT_NONCE_SIZE 16
80 #define TEE_OBJECT_KEY_SIZE 32
81 #define TEE_OBJECT_SKEY_SIZE 64
82 #define TEE_OBJECT_AAD_SIZE 16
83 #define TEE_OBJECT_TAG_SIZE 16
84 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
85
86 struct __TEE_OperationHandle
87 {
88   int mode;
89   int flags;
90   int alg;
91 #if CRYPTLIB==MBEDCRYPT
92   sha3_ctx_t ctx;
93   mbedtls_aes_context aectx;
94   mbedtls_gcm_context aegcmctx;
95 #elif CRYPTLIB==WOLFCRYPT
96   wc_Sha3 ctx;
97   Aes aectx;
98   Aes aegcmctx;
99   unsigned int aegcm_aadsz;
100   unsigned char aegcm_aad[TEE_OBJECT_AAD_SIZE];
101   ed25519_key key;
102 #else
103   sha3_ctx_t ctx;
104   struct AES_ctx aectx;
105 #endif
106   int aegcm_state;
107   unsigned char aeiv[TEE_OBJECT_NONCE_SIZE];
108   unsigned char aekey[32];
109   unsigned char pubkey[TEE_OBJECT_KEY_SIZE];
110   unsigned char prikey[TEE_OBJECT_SKEY_SIZE];
111 };
112
113 struct __TEE_ObjectHandle
114 {
115   unsigned int type;
116   int flags;
117   int desc;
118 #if CRYPTLIB==MBEDCRYPT
119   mbedtls_aes_context persist_ctx;
120   unsigned char persist_iv[TEE_OBJECT_NONCE_SIZE];
121 #elif CRYPTLIB==WOLFCRYPT
122   Aes persist_ctx;
123   unsigned char persist_iv[TEE_OBJECT_NONCE_SIZE];
124   ed25519_key key;
125 #else
```

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```
126   struct AES_ctx persist_ctx;
127 #endif
128   unsigned char public_key[TEE_OBJECT_KEY_SIZE];
129   unsigned char private_key[TEE_OBJECT_SKEY_SIZE];
130 };
131
132 // defined in tee_api_defines.h
133 // enum Data_Flag_Constants {
134 //   TEE_DATA_FLAG_ACCESS_READ = 0x00000001,
135 //   TEE_DATA_FLAG_ACCESS_WRITE = 0x00000002,
136 //   //TEE_DATA_FLAG_ACCESS_WRITE_META = 0x00000004,
137 //   //TEE_DATA_FLAG_SHARE_READ = 0x00000010,
138 //   //TEE_DATA_FLAG_SHARE_WRITE = 0x00000020,
139 //   TEE_DATA_FLAG_OVERWRITE = 0x00000400
140 // };
141 // enum Data_Flag_Constants {
142 //   TEE_DATA_FLAG_ACCESS_READ = 0x00000001,
143 //   TEE_DATA_FLAG_ACCESS_WRITE = 0x00000002,
144 //   //TEE_DATA_FLAG_ACCESS_WRITE_META = 0x00000004,
145 //   //TEE_DATA_FLAG_SHARE_READ = 0x00000010,
146 //   //TEE_DATA_FLAG_SHARE_WRITE = 0x00000020,
147 //   TEE_DATA_FLAG_OVERWRITE = 0x00000400
148 // };
149 #endif
```

13.54 ta-ref/api/optee/tee_api_tee_types.h File Reference

13.55 tee_api_tee_types.h

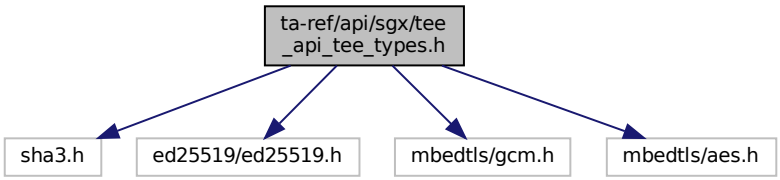
Go to the documentation of this file.

```
1 // empty
```

13.56 ta-ref/api/sgx/tee_api_tee_types.h File Reference

```
#include "sha3.h"
#include "ed25519/ed25519.h"
#include "mbedtls/gcm.h"
#include "mbedtls/aes.h"
```

Include dependency graph for tee_api_tee_types.h:



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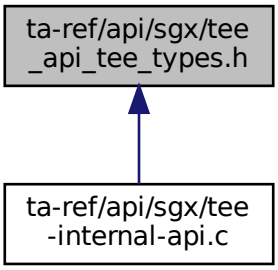
This graph shows which files directly or indirectly include this file:



Classes

- struct __TEE_OperationHandle
- struct __TEE_ObjectHandle

13.57 tee_api_tee_types.h

Go to the documentation of this file.

```
1 /*
2  * SPDX-License-Identifier: BSD-2-Clause
3  *
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5  *                          and Technology (AIST)
6  * All rights reserved.
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19  * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
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21  * ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
22  * LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
23  * CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
24  * SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
25  * INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
26  * CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
27  * ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
28  * POSSIBILITY OF SUCH DAMAGE.
29  */
30
31 #ifndef TEE_API_TYPES_KEYSTONE_H
32 #define TEE_API_TYPES_KEYSTONE_H
33
34 #ifndef DOXYGEN_SHOULD_SKIP_THIS
35 #define MBEDCRYPT 1
36 #define WOLFCRYPT 2
37 #define SHA_LENGTH (256/8)
38 #define AES256 1
39 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
40
```

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```
41 #include "sha3.h"
42 #include "ed25519/ed25519.h"
43
44 #if CRYPTLIB==MBEDCRYPT
45 #ifndef DOXYGEN_SHOULD_SKIP_THIS
46 # define MBEDTLS_CONFIG_FILE "mbed-crypto-config.h"
47 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
48 # include "mbedtls/gcm.h"
49 # include "mbedtls/aes.h"
50 #elif CRYPTLIB==WOLFCRYPT
51 #ifndef DOXYGEN_SHOULD_SKIP_THIS
52 # define HAVE_AESGCM 1
53 # define HAVE_AES_CBC 1
54 # define HAVE_AES_DECRYPT 1
55 # define HAVE_FIPS 1
56 # define HAVE_FIPS_VERSION 2
57 # define HAVE_ED25519 1
58 # define HAVE_ED25519_SIGN 1
59 # define HAVE_ED25519_VERIFY 1
60 # define WOLFSSL_SHA3 1
61 # define WOLF_CRYPT_PORT_H
62 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
63 # include "wolfssl/wolfcrypt/sha3.h"
64 # include "wolfssl/wolfcrypt/aes.h"
65 # include "wolfssl/wolfcrypt/sha512.h"
66 # include "wolfssl/wolfcrypt/ed25519.h"
67 #else
68 # include "tiny_AES_c/aes.h"
69 #endif
70
71 #ifndef DOXYGEN_SHOULD_SKIP_THIS
72 #define TEE_OBJECT_NONCE_SIZE 16
73 #define TEE_OBJECT_KEY_SIZE 32
74 #define TEE_OBJECT_SKEY_SIZE 64
75 #define TEE_OBJECT_AAD_SIZE 16
76 #define TEE_OBJECT_TAG_SIZE 16
77 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
78
79 struct __TEE_OperationHandle
80 {
81   int mode;
82   int flags;
83   int alg;
84 #if CRYPTLIB==MBEDCRYPT
85   sha3_ctx_t ctx;
86   mbedtls_aes_context aectx;
87   mbedtls_gcm_context aegcmctx;
88 #elif CRYPTLIB==WOLFCRYPT
89   wc_Sha3 ctx;
90   Aes aectx;
91   Aes aegcmctx;
92   unsigned int aegcm_aadsz;
93   unsigned char aegcm_aad[TEE_OBJECT_AAD_SIZE];
94   ed25519_key key;
95 #else
96   sha3_ctx_t ctx;
97   struct AES_ctx aectx;
98 #endif
99   int aegcm_state;
100   unsigned char aeiv[TEE_OBJECT_NONCE_SIZE];
101   unsigned char aekey[32];
102   unsigned char pubkey[TEE_OBJECT_KEY_SIZE];
103   unsigned char prikey[TEE_OBJECT_SKEY_SIZE];
104 };
105
106 struct __TEE_ObjectHandle
107 {
108   unsigned int type;
109   int flags;
110   int desc;
111 #if CRYPTLIB==MBEDCRYPT
112   mbedtls_aes_context persist_ctx;
113   unsigned char persist_iv[TEE_OBJECT_NONCE_SIZE];
114 #elif CRYPTLIB==WOLFCRYPT
115   Aes persist_ctx;
116   unsigned char persist_iv[TEE_OBJECT_NONCE_SIZE];
117   ed25519_key key;
118 #else
119   struct AES_ctx persist_ctx;
120 #endif
121   unsigned char public_key[TEE_OBJECT_KEY_SIZE];
122   unsigned char private_key[TEE_OBJECT_SKEY_SIZE];
123 };
124
125 // Minimal constant definitions
```

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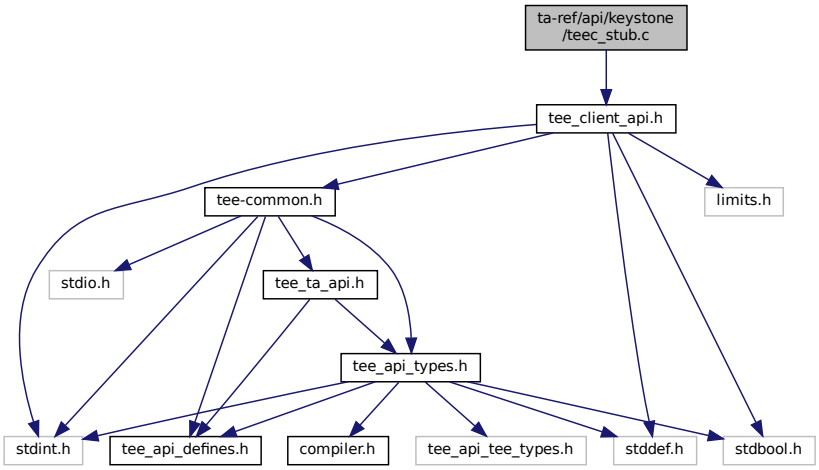
```
126 #ifndef DOXYGEN_SHOULD_SKIP_THIS
127 #define TEE_HANDLE_NULL 0
128 #endif /*DOXYGEN_SHOULD_SKIP_THIS*/
129
130 #endif
```

13.58 ta-ref/api/keystone/teec_stub.c File Reference

`#include <tee_client_api.h>`
Include dependency graph for teec_stub.c:



Functions

- TEEC_Result TEEC_InitializeContext (const char *name, TEEC_Context *context)
- void TEEC_FinalizeContext (TEEC_Context *context)
- TEEC_Result TEEC_OpenSession (TEEC_Context *context, TEEC_Session *session, const TEEC_UUID *destination, uint32_t connectionMethod, const void *connectionData, TEEC_Operation *operation, uint32_t *returnOrigin)
- void TEEC_CloseSession (TEEC_Session *session)
- TEEC_Result TEEC_RegisterSharedMemory (TEEC_Context *context, TEEC_SharedMemory *sharedMem)
- TEEC_Result TEEC_AllocateSharedMemory (TEEC_Context *context, TEEC_SharedMemory *sharedMem)
- void TEEC_ReleaseSharedMemory (TEEC_SharedMemory *sharedMemory)
- void TEEC_RequestCancellation (TEEC_Operation *operation)

13.58.1 Function Documentation

13.58.1.1 TEEC_AllocateSharedMemory()

```
TEEC_Result TEEC_AllocateSharedMemory (
    TEEC_Context * context,
    TEEC_SharedMemory * sharedMem )
```

TEEC_AllocateSharedMemory() - Allocate shared memory for TEE.

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Parameters

context	The initialized TEE context structure in which scope to open the session.
sharedMem	Pointer to the allocated shared memory.

Returns

TEEC_SUCCESS The registration was successful.

TEEC_ERROR_OUT_OF_MEMORY Memory exhaustion.

TEEC_Result Something failed.

13.58.1.2 TEEC_CloseSession()

```
void TEEC_CloseSession (
    TEEC_Session * session )
```

TEEC_CloseSession() - Closes the session which has been opened with the specific trusted application.

Parameters

session	The opened session to close.

13.58.1.3 TEEC_FinalizeContext()

```
void TEEC_FinalizeContext (
    TEEC_Context * context )
```

TEEC_FinalizeContext() - Destroys a context holding connection information on the specific TEE.

This function finalizes an initialized TEE context, closing the connection between the client application and the TEE. This function must only be called when all sessions related to this TEE context have been closed and all shared memory blocks have been released.

Parameters

context	The context to be finalized.

13.58.1.4 TEEC_InitializeContext()

```
TEEC_Result TEEC_InitializeContext (
    const char * name,
    TEEC_Context * context )
```

TEEC_InitializeContext() - Initializes a context holding connection information on the specific TEE, designated by the name string.

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Parameters

name	A zero-terminated string identifying the TEE to connect to. If name is set to NULL, the default TEE is connected to. NULL is the only supported value in this version of the API implementation.
context	The context structure which is to be initialized.

Returns

TEEC_SUCCESS The initialization was successful.

TEEC_Result Something failed.

13.58.1.5 TEEC_OpenSession()

```
TEEC_Result TEEC_OpenSession (
    TEEC_Context * context,
    TEEC_Session * session,
    const TEEC_UUID * destination,
    uint32_t connectionMethod,
    const void * connectionData,
    TEEC_Operation * operation,
    uint32_t * returnOrigin )
```

TEEC_OpenSession() - Opens a new session with the specified trusted application.

Parameters

context	The initialized TEE context structure in which scope to open the session.
session	The session to initialize.
destination	A structure identifying the trusted application with which to open a session.
connectionMethod	The connection method to use.
connectionData	Any data necessary to connect with the chosen connection method. Not supported, should be set to NULL.
operation	An operation structure to use in the session. May be set to NULL to signify no operation structure needed.
returnOrigin	A parameter which will hold the error origin if this function returns any value other than TEEC_SUCCESS.

Returns

TEEC_SUCCESS OpenSession successfully opened a new session.

TEEC_Result Something failed.

13.58.1.6 TEEC_RegisterSharedMemory()

```
TEEC_Result TEEC_RegisterSharedMemory (
    TEEC_Context * context,
    TEEC_SharedMemory * sharedMem )
```

TEEC_RegisterSharedMemory() - Register a block of existing memory as a shared block within the scope of the specified context.

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Parameters

context	The initialized TEE context structure in which scope to open the session.
sharedMem	pointer to the shared memory structure to register.

Returns

TEEC_SUCCESS The registration was successful.

TEEC_ERROR_OUT_OF_MEMORY Memory exhaustion.

TEEC_Result Something failed.

13.58.1.7 TEEC_ReleaseSharedMemory() `void TEEC_ReleaseSharedMemory ( TEEC_SharedMemory * sharedMemory )`

TEEC_ReleaseSharedMemory() - Free or deregister the shared memory.

Parameters

sharedMem	Pointer to the shared memory to be freed.

13.58.1.8 TEEC_RequestCancellation() `void TEEC_RequestCancellation ( TEEC_Operation * operation )`

TEEC_RequestCancellation() - Request the cancellation of a pending open session or command invocation.

Parameters

operation	Pointer to an operation previously passed to open session or invoke.

13.59 ta-ref/api/keystone/tools.c File Reference

```
#include <stddef.h>
#include <stdarg.h>
#include "tools.h"
#include <stdio.h>
#include "ocall_wrapper.h"
```

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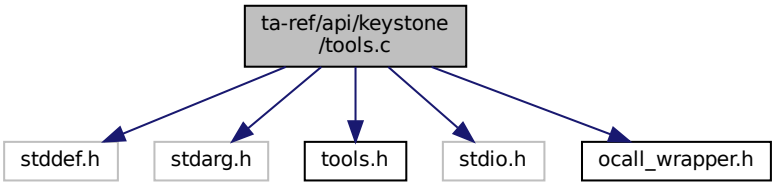
Include dependency graph for tools.c:



Functions

- static unsigned int _strlen (const char ∗str)
- int puts (const char ∗s)
- int putchar (int c)
- int printf (const char ∗fmt,...)

13.59.1 Function Documentation

13.59.1.1 _strlen()

```
static unsigned int _strlen (
    const char * str )  [inline], [static]
```

13.59.1.2 printf()

```
int printf (
    const char * fmt,
     ...  )
```

printf() - Function sends formatted output to stdout.

format can optionally contain embedded format tags that are replaced by the values specified in subsequent additional arguments and formatted as requested.

Parameters

fm	This is the string that contains the text to be written to stdout.

Returns

string length If success.

0 Error occured.

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13.59.1.3 putchar() int putchar (int c)

putchar() - Function writes a character (an unsigned char) specified by the argument char to stdout.

This function returns the character written as an unsigned char cast to an int or EOF on error.

Parameters

c	This is the character to be written. This is passed as its int promotion.

Returns

size If success.

0 Error occured.

13.59.1.4 puts() int puts (const char * s)

puts() - Function writes a string to stdout up to but not including the null character.

A newline character is appended to the output by calling putchar(). Compiler may replace simple printf to puts and putchar.

Parameters

s	This is the C string to be written

Returns

size If success.

0 Error occured.

13.60 ta-ref/api/sgx/tools.c File Reference

```
#include <stddef.h>
#include <stdarg.h>
#include "tools.h"
#include <stdio.h>
#include "ocall_wrapper.h"
```

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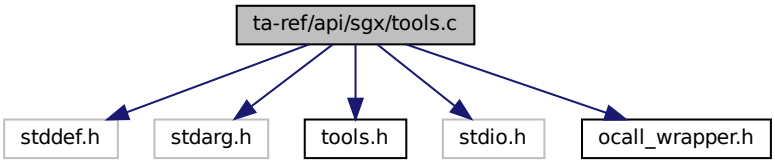
Include dependency graph for tools.c:



Functions

- static unsigned int _strlen (const char *str)
- int puts (const char *s)
- int putchar (int c)
- int printf (const char *fmt,...)

13.60.1 Function Documentation

13.60.1.1 _strlen()

```
static unsigned int _strlen (
    const char * str )  [inline], [static]
```

13.60.1.2 printf()

```
int printf (
    const char * fmt,
     ...  )
```

printf() - Function sends formatted output to stdout.

format can optionally contain embedded format tags that are replaced by the values specified in subsequent additional arguments and formatted as requested.

Parameters

fm	This is the string that contains the text to be written to stdout.

Returns

string length If success.

0 Error occured.

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13.60.1.3 putchar() `int putchar ( int c )`

putchar() - Function writes a character (an unsigned char) specified by the argument char to stdout.

This function returns the character written as an unsigned char cast to an int or EOF on error.

Parameters

c	This is the character to be written. This is passed as its int promotion.

Returns

size If success.

0 Error occured.

13.60.1.4 puts() `int puts ( const char * s )`

puts() - Function writes a string to stdout up to but not including the null character.

A newline character is appended to the output by calling putchar(). Compiler may replace simple printf to puts and putchar.

Parameters

s	This is the C string to be written

Returns

size If success.

0 Error occured.

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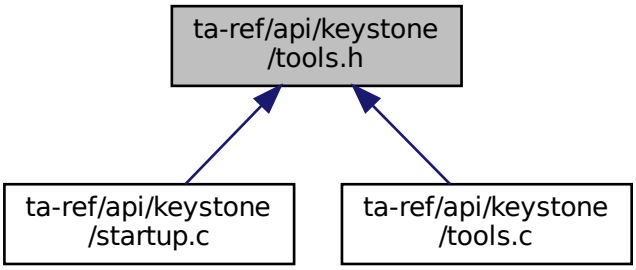
13.61 ta-ref/api/keystone/tools.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- int puts (const char ∗s)
- int putchar (int c)
- int printf (const char ∗fmt,...)

13.61.1 Function Documentation

13.61.1.1 printf()

```
int printf (
    const char * fmt,
    ... )
```

printf() - Function sends formatted output to stdout.

format can optionally contain embedded format tags that are replaced by the values specified in subsequent additional arguments and formatted as requested.

Parameters

fm	This is the string that contains the text to be written to stdout.

Returns

string length If success.

0 Error occured.

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13.61.1.2 putchar() int putchar (int c)

putchar() - Function writes a character (an unsigned char) specified by the argument char to stdout.

This function returns the character written as an unsigned char cast to an int or EOF on error.

Parameters

c	This is the character to be written. This is passed as its int promotion.

Returns

size If success.

0 Error occured.

13.61.1.3 puts() int puts (const char * s)

puts() - Function writes a string to stdout up to but not including the null character.

A newline character is appended to the output by calling putchar(). Compiler may replace simple printf to puts and putchar.

Parameters

s	This is the C string to be written

Returns

size If success.

0 Error occured.

13.62 tools.h

Go to the documentation of this file.

```
1 int puts(const char *s);
2 int putchar(int c);
3 int printf(const char* fmt, ...);
```

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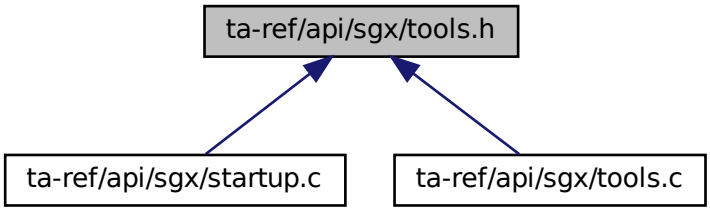
13.63 ta-ref/api/sgx/tools.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- int puts (const char *s)
- int putchar (int c)
- int printf (const char *fmt,...)

13.63.1 Function Documentation

13.63.1.1 printf()

```
int printf (
    const char * fmt,
    ... )
```

printf() - Function sends formatted output to stdout.

format can optionally contain embedded format tags that are replaced by the values specified in subsequent additional arguments and formatted as requested.

Parameters

fm	This is the string that contains the text to be written to stdout.

Returns

string length If success.

0 Error occured.

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13.63.1.2 putchar() int putchar (int c)

putchar() - Function writes a character (an unsigned char) specified by the argument char to stdout.

This function returns the character written as an unsigned char cast to an int or EOF on error.

Parameters

c	This is the character to be written. This is passed as its int promotion.

Returns

size If success.

0 Error occured.

13.63.1.3 puts() int puts (const char * s)

puts() - Function writes a string to stdout up to but not including the null character.

A newline character is appended to the output by calling putchar(). Compiler may replace simple printf to puts and putchar.

Parameters

s	This is the C string to be written

Returns

size If success.

0 Error occured.

13.64 tools.h

Go to the documentation of this file.

```
1 int puts(const char *s);
2 int putchar(int c);
3 int printf(const char* fmt, ...);
```

13.65 ta-ref/api/keystone/trace.c File Reference

```
#include <stdarg.h>
#include "trace.h"
```

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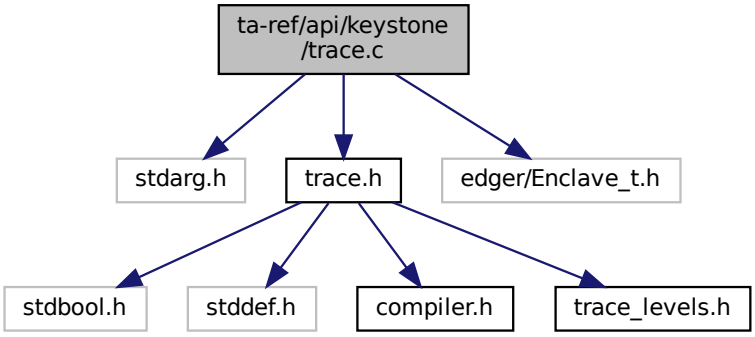
```
#include "edger/Enclave_t.h"
```

Include dependency graph for trace.c:



Functions

- void trace_vprintf (const char *func, int line, int level, bool level_ok, const char *fmt, va_list ap)
- void trace_printf (const char *func, int line, int level, bool level_ok, const char *fmt,...)

13.65.1 Function Documentation

13.65.1.1 trace_printf()

```
void trace_printf (
    const char * func,
    int line,
    int level,
    bool level_ok,
    const char * fmt,
     ...  )
```

trace_printf() - Prints the formatted data to stdout.

This function returns the value of ap by calling va_end().

Parameters

func	Pointer to a buffer where the resulting C-string is stored.
line	integer type of line
level_ok	boolen value
fmt	C string that contains a format string
ap	A value identifying a variable arguments list

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Returns

Total number of characters is returned.

13.65.1.2 trace_vprintf()

```
void trace_vprintf (
    const char * func,
    int line,
    int level,
    bool level_ok,
    const char * fmt,
    va_list ap )
```

trace_vprintf() - Writes the formatted data from variable argument list to sized buffer.

This function returns the buffer character by calling ocall_print_string()

Parameters

func	Pointer to a buffer where the resulting C-string is stored.
line	integer type of line
level_ok	boolen value
fmt	C string that contains a format string
ap	A value identifying a variable arguments list

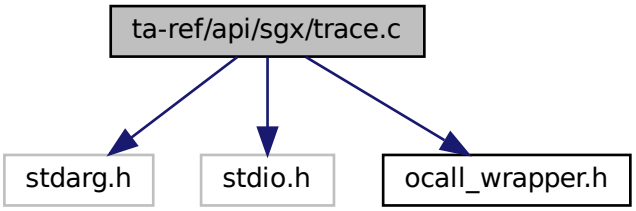
Returns

buf The total number of characters written is returned.

13.66 ta-ref/api/sgx/trace.c File Reference

```
#include <stdarg.h>
#include <stdio.h>
#include "ocall_wrapper.h"
```

Include dependency graph for trace.c:



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Functions

- static unsigned int _strlen (const char ∗str)
- int tee_printf (const char ∗fmt,...)

13.66.1 Function Documentation

13.66.1.1 _strlen() static unsigned int _strlen (const char * str) [inline], [static]

_strlen() - calculate the length of characters in a str.

Parameters

str	str is an argument of type pointer.

Returns

string length on success.

13.66.1.2 tee_printf() int tee_printf (const char * fmt, ...)

tee_printf() - For tracing GP API.

Initializes ap variable. Formats data under control of the format control string and stores the result in buf and ends the processing of ap. Finally print the buffer value.

Parameters

fmt	fmt is a constant character argument of type pointer.

Returns

buffer If successfully executed, else error occured.

13.67 ta-ref/api/keystone/trace2.c File Reference

```
#include <stdarg.h>
#include <stdio.h>
```

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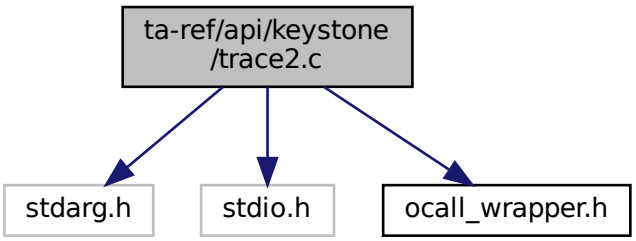
```
#include "ocall_wrapper.h"
```
Include dependency graph for trace2.c:



Functions

- static unsigned int _strlen (const char ∗str)
- int tee_printf (const char ∗fmt,...)

13.67.1 Function Documentation

13.67.1.1 _strlen()

```
static unsigned int _strlen (
    const char * str )  [inline], [static]
```

_strlen() - calculate the length of characters in str.

Parameters

str	str is argument of type pointer.

Returns

string string length.

13.67.1.2 tee_printf()

```
int tee_printf (
    const char * fmt,
     ... )
```

tee_printf() - For trace GP API.

Initializes ap variable. Formats data under control of the format control string and stores the result in buf and ends the processing of ap. Finally prints the buffer value.

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Parameters

fmt	fmt is constant character argument of type pointer.

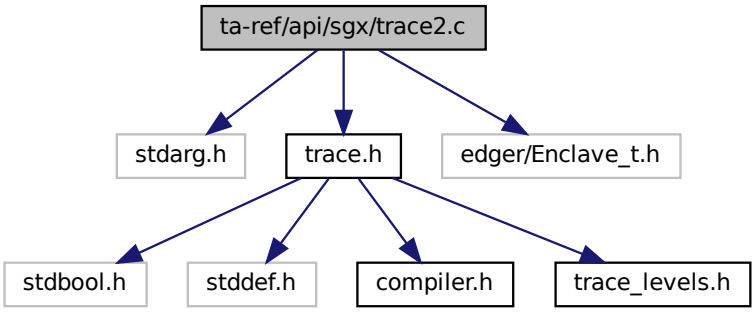
Returns

res Based on the condition check it will return string length else returns 0.

13.68 ta-ref/api/sgx/trace2.c File Reference

```
#include <stdarg.h>
#include "trace.h"
#include "edger/Enclave_t.h"
```

Include dependency graph for trace2.c:



Functions

- void trace_vprintf (const char *func, int line, int level, bool level_ok, const char *fmt, va_list ap)
- void trace_printf (const char *func, int line, int level, bool level_ok, const char *fmt,...)

13.68.1 Function Documentation

13.68.1.1 trace_printf()

```
void trace_printf (
    const char * func,
    int line,
    int level,
    bool level_ok,
    const char * fmt,
     ...  )
```

trace_printf() - Prints the formatted data to stdout.

This function returns the value of ap by calling va_end().

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Parameters

func	Pointer to a buffer where the resulting C-string is stored.
line	integer type of line
level_ok	boolen value
fmt	C string that contains a format string
ap	A value identifying a variable arguments list

Returns

Total number of characters is returned.

13.68.1.2 trace_vprintf()

```
void trace_vprintf (
    const char * func,
    int line,
    int level,
    bool level_ok,
    const char * fmt,
    va_list ap )
```

trace_vprintf() - Writes the formatted data from variable argument list to sized buffer.

This function returns the buffer character by calling ocall_print_string()

Parameters

func	Pointer to a buffer where the resulting C-string is stored.
line	integer type of line
level_ok	boolen value
fmt	C string that contains a format string
ap	A value identifying a variable arguments list

Returns

buf The total number of characters written is returned.

13.69 ta-ref/api/keystone/vsnprintf.c File Reference

```
#include <stdbool.h>
#include <stdint.h>
#include <stdarg.h>
```

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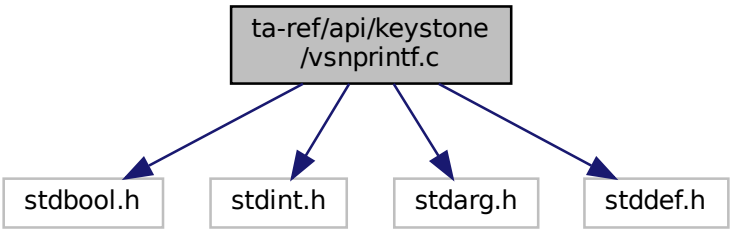
```
#include <stddef.h>
```

Include dependency graph for vsnprintf.c:



Classes

- struct out_fct_wrap_type

Typedefs

- typedef void(∗ out_fct_type) (char character, void ∗buffer, size_t idx, size_t maxlen)

Functions

- static void _out_buffer (char character, void ∗buffer, size_t idx, size_t maxlen)
- static void _out_null (char character, void ∗buffer, size_t idx, size_t maxlen)
- static void _out_char (char character, void ∗buffer, size_t idx, size_t maxlen)
- static void _out_fct (char character, void ∗buffer, size_t idx, size_t maxlen)
- static unsigned int _strlen (const char ∗str)
- static bool _is_digit (char ch)
- static unsigned int _atoi (const char ∗∗str)
- static size_t _ntoa_format (out_fct_type out, char ∗buffer, size_t idx, size_t maxlen, char ∗buf, size_t len, bool negative, unsigned int base, unsigned int prec, unsigned int width, unsigned int flags)
- static size_t _ntoa_long (out_fct_type out, char ∗buffer, size_t idx, size_t maxlen, unsigned long value, bool negative, unsigned long base, unsigned int prec, unsigned int width, unsigned int flags)
- static int _vsnprintf (out_fct_type out, char ∗buffer, const size_t maxlen, const char ∗format, va_list va)
- int sprintf (char ∗buffer, const char ∗format,...)
- int snprintf (char ∗buffer, size_t count, const char ∗format,...)
- int vsnprintf (char ∗buffer, size_t count, const char ∗format, va_list va)
- int fctprintf (void(∗out)(char character, void ∗arg), void ∗arg, const char ∗format,...)

13.69.1 Typedef Documentation

13.69.1.1 out_fct_type `typedef void(* out_fct_type) (char character, void *buffer, size_t idx, size_t maxlen)`

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13.69.2 Function Documentation

13.69.2.1 _atoi()

```
static unsigned int _atoi (
    const char ** str )  [static]
```

13.69.2.2 _is_digit()

```
static bool _is_digit (
    char ch )  [inline], [static]
```

13.69.2.3 _ntoa_format()

```
static size_t _ntoa_format (
    out_fct_type out,
    char * buffer,
    size_t idx,
    size_t maxlen,
    char * buf,
    size_t len,
    bool negative,
    unsigned int base,
    unsigned int prec,
    unsigned int width,
    unsigned int flags )  [static]
```

13.69.2.4 _ntoa_long()

```
static size_t _ntoa_long (
    out_fct_type out,
    char * buffer,
    size_t idx,
    size_t maxlen,
    unsigned long value,
    bool negative,
    unsigned long base,
    unsigned int prec,
    unsigned int width,
    unsigned int flags )  [static]
```

13.69.2.5 _out_buffer()

```
static void _out_buffer (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

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13.69.2.6 _out_char()

```
static void _out_char (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

13.69.2.7 _out_fct()

```
static void _out_fct (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

13.69.2.8 _out_null()

```
static void _out_null (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

13.69.2.9 _strlen()

```
static unsigned int _strlen (
    const char * str )  [inline], [static]
```

13.69.2.10 _vsnprintf()

```
static int _vsnprintf (
    out_fct_type out,
    char * buffer,
    const size_t maxlen,
    const char * format,
    va_list va )  [static]
```

13.69.2.11 fctprintf()

```
int fctprintf (
    void(*)(char character, void *arg) out,
    void * arg,
    const char * format,
     ... )
```

13.69.2.12 snprintf()

```
int snprintf (
    char * buffer,
    size_t count,
    const char * format,
     ... )
```

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13.69.2.13 sprintf()

```
int sprintf (
    char * buffer,
    const char * format,
    ... )
```

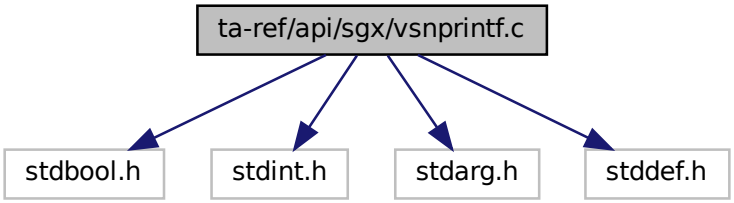
13.69.2.14 vsnprintf()

```
int vsnprintf (
    char * buffer,
    size_t count,
    const char * format,
    va_list va )
```

13.70 ta-ref/api/sgx/vsnprintf.c File Reference

```
#include <stdbool.h>
#include <stdint.h>
#include <stdarg.h>
#include <stddef.h>
```

Include dependency graph for vsnprintf.c:



Classes

- struct out_fct_wrap_type

Macros

- #define PRINTF_NTOA_BUFFER_SIZE 32U
- #define PRINTF_FTOA_BUFFER_SIZE 32U
- #define PRINTF_SUPPORT_FLOAT
- #define PRINTF_SUPPORT_LONG_LONG
- #define PRINTF_SUPPORT_PTRDIFF_T
- #define FLAGS_ZEROPAD (1U << 0U)
- #define FLAGS_LEFT (1U << 1U)
- #define FLAGS_PLUS (1U << 2U)
- #define FLAGS_SPACE (1U << 3U)
- #define FLAGS_HASH (1U << 4U)

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- #define FLAGS_UPPERCASE (1U << 5U)
- #define FLAGS_CHAR (1U << 6U)
- #define FLAGS_SHORT (1U << 7U)
- #define FLAGS_LONG (1U << 8U)
- #define FLAGS_LONG_LONG (1U << 9U)
- #define FLAGS_PRECISION (1U << 10U)
- #define _putchar putchar

Typedefs

- typedef void(* out_fct_type) (char character, void *buffer, size_t idx, size_t maxlen)

Functions

- int putchar (char ch)
- static void _out_buffer (char character, void *buffer, size_t idx, size_t maxlen)
- static void _out_null (char character, void *buffer, size_t idx, size_t maxlen)
- static void _out_char (char character, void *buffer, size_t idx, size_t maxlen)
- static void _out_fct (char character, void *buffer, size_t idx, size_t maxlen)
- static unsigned int _strlen (const char *str)
- static bool _is_digit (char ch)
- static unsigned int _atoi (const char **str)
- static size_t _ntoa_format (out_fct_type out, char *buffer, size_t idx, size_t maxlen, char *buf, size_t len, bool negative, unsigned int base, unsigned int prec, unsigned int width, unsigned int flags)
- static size_t _ntoa_long (out_fct_type out, char *buffer, size_t idx, size_t maxlen, unsigned long value, bool negative, unsigned long base, unsigned int prec, unsigned int width, unsigned int flags)
- static size_t _ntoa_long_long (out_fct_type out, char *buffer, size_t idx, size_t maxlen, unsigned long long value, bool negative, unsigned long long base, unsigned int prec, unsigned int width, unsigned int flags)
- static size_t _ftoa (out_fct_type out, char *buffer, size_t idx, size_t maxlen, double value, unsigned int prec, unsigned int width, unsigned int flags)
- static int _vsnprintf (out_fct_type out, char *buffer, const size_t maxlen, const char *format, va_list va)
- int sprintf (char *buffer, const char *format,...)
- int snprintf (char *buffer, size_t count, const char *format,...)
- int vsnprintf (char *buffer, size_t count, const char *format, va_list va)
- int fctprintf (void(*out)(char character, void *arg), void *arg, const char *format,...)

13.70.1 Macro Definition Documentation

13.70.1.1 _putchar `#define _putchar putchar`

13.70.1.2 FLAGS_CHAR `#define FLAGS_CHAR (1U << 6U)`

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13.70.1.3 FLAGS_HASH #define FLAGS_HASH (1U << 4U)

13.70.1.4 FLAGS_LEFT #define FLAGS_LEFT (1U << 1U)

13.70.1.5 FLAGS_LONG #define FLAGS_LONG (1U << 8U)

13.70.1.6 FLAGS_LONG_LONG #define FLAGS_LONG_LONG (1U << 9U)

13.70.1.7 FLAGS_PLUS #define FLAGS_PLUS (1U << 2U)

13.70.1.8 FLAGS_PRECISION #define FLAGS_PRECISION (1U << 10U)

13.70.1.9 FLAGS_SHORT #define FLAGS_SHORT (1U << 7U)

13.70.1.10 FLAGS_SPACE #define FLAGS_SPACE (1U << 3U)

13.70.1.11 FLAGS_UPPERCASE #define FLAGS_UPPERCASE (1U << 5U)

13.70.1.12 FLAGS_ZEROPAD #define FLAGS_ZEROPAD (1U << 0U)

13.70.1.13 PRINTF_FTOA_BUFFER_SIZE #define PRINTF_FTOA_BUFFER_SIZE 32U

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13.70.1.14 PRINTF_NTOA_BUFFER_SIZE `#define PRINTF_NTOA_BUFFER_SIZE 32U`

13.70.1.15 PRINTF_SUPPORT_FLOAT `#define PRINTF_SUPPORT_FLOAT`

13.70.1.16 PRINTF_SUPPORT_LONG_LONG `#define PRINTF_SUPPORT_LONG_LONG`

13.70.1.17 PRINTF_SUPPORT_PTRDIFF_T `#define PRINTF_SUPPORT_PTRDIFF_T`

13.70.2 Typedef Documentation

13.70.2.1 out_fct_type `typedef void(* out_fct_type) (char character, void *buffer, size_t idx, size_t maxlen)`

13.70.3 Function Documentation

13.70.3.1 _atoi() `static unsigned int _atoi ( const char ** str ) [static]`

_atoi() - Converts the internal ASCII string into an unsigned integer.

This function is to convert the internal ASCII string into unsigned integer.

Parameters

str	string representation of an integral number.

Returns

i unsigned integer value.

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13.70.3.2 _ftoa() static size_t _ftoa (

```
out_fct_type out,
char * buffer,
size_t idx,
size_t maxlen,
double value,
unsigned int prec,
unsigned int width,
unsigned int flags )  [static]
```

_ftoa() - Converts a given floating-point number or a double to a string with the use of standard library functions.

This function checks whether the value is negative or not, then it checks with if condtion default precision to 6, if it not set it will set explicitly. Using the while loop it limits the precision to 9,because it causes a overflow error when precision crosses above 10. Using the if condition rollover or round If the precsion value is greater than 0.5 up the precision value.it round up to

1. Using the while_loop condition adding extra zeros and append decimal value to the lenghth. Finally using the conditional statement executes pad leading zeros, handling the hash value, padding spaces up to given width and reverses the string.

Parameters

out	type of out_fct_type
buffer	Pointer to a character string to write the result.
idx	idx bytes of size_t
maxlen	Maximum number of characters to write.
negative	boolean type
base	an unsigned long data type
prec	an unsigned integral data type
width	an unsigned integral data type
flags	an unsigned integral data type

Returns

non integer value if success else error occur

13.70.3.3 _is_digit() static bool _is_digit (

```
char ch )  [inline], [static]
```

_is_digit() - Is for the internal test if char is a digit from 0 to 9

Parameters

ch	This is the character to be checked.

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Returns

true if char is a digit and internal test if char is a digit from 0 to 9

13.70.3.4 _ntoa_format()

```
static size_t _ntoa_format (
    out_fct_type out,
    char * buffer,
    size_t idx,
    size_t maxlen,
    char * buf,
    size_t len,
    bool negative,
    unsigned int base,
    unsigned int prec,
    unsigned int width,
    unsigned int flags )  [static]
```

_ntoa_format() - Converts the string into the defined format structure.

This function uses the while condition for padding the leading zeroes and also applies the if conditions to handle the hash. Using the if condtion pad spaces up to given width what specifies in that. It reverse the string and again append pad spaces up to given width.

Parameters

out	type of out_fct_type
buffer	Pointer to a character string to write the result.
idx	idx bytes of size_t
maxlen	Maximum number of characters to write.
negative	boolean type
base	an unsigned long data type
prec	an unsigned integer data type
width	an unsigned integer data type
flags	an unsigned integer data type

Returns

idx non integer value if success else error occur.

13.70.3.5 _ntoa_long()

```
static size_t _ntoa_long (
    out_fct_type out,
    char * buffer,
    size_t idx,
    size_t maxlen,
    unsigned long value,
    bool negative,
    unsigned long base,
```

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```
    unsigned int prec,
    unsigned int width,
    unsigned int flags )  [static]
```

_ntoa_long() - Converts string into long value.

This function begins with an if condition value then it assigns ∼FLAGS_HASH into flags & value. Later it uses the if condition and do while write if precision not equal to zero and value is not equals to zero.

Parameters

out	type of out_fct_type
buffer	Pointer to a character string to write the result.
id	idx bytes of size_t
maxlen	Maximum number of characters to write.
negative	boolean type
base	an unsigned long data type
prec	an unsigned integral data type
width	an unsigned integral data type
flags	an unsigned integral data type

Returns

idx non integer value if success else error occur.

13.70.3.6 _ntoa_long_long() `static size_t _ntoa_long_long (`

```
    out_fct_type out,
    char * buffer,
    size_t idx,
    size_t maxlen,
    unsigned long long value,
    bool negative,
    unsigned long long base,
    unsigned int prec,
    unsigned int width,
    unsigned int flags )  [static]
```

_ntoa_long_long() - Function to convert string to long value.

This function begins with an if condition then it assigns ∼FLAGS_HASH into flags & value. Later it uses the if condition and do while write if precision not equal to zero and value is not equals to zero.

Parameters

out	type of out_fct_type
buffer	Pointer to a character string to write the result.
idx	idx bytes of size_t
maxlen	Maximum number of characters to write.
	Paramter list continued on next page

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negative	boolean type
base	an unsigned long data type
prec	an unsigned integral data type
width	an unsigned integral data type
flag	an unsigned integral data type

Returns

idx non integer value if success else error occur.

13.70.3.7 _out_buffer()

```
static void _out_buffer (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

_out_buffer() - Internal buffer output

This function compares the idx and maxlen, If "idx" is less than "maxlen" then it will assign "character" value into the typecasting char "buffer[idx]"

Parameters

character	character type string
buffer	Pointer to a character string to write the result.
idx	bytes of size_t
maxlen	Maximum number of characters to write.

13.70.3.8 _out_char()

```
static void _out_char (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

_out_char() - Internal putchar wrapper

The typecasting of arguments with void is to avoid unused variable warnings in some compilers. Checks the character value once the if condtion is success then putchar() writes a character into stdout.

Parameters

character	character type string
	Paramter list continued on next page

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buffer	Pointer to a character string to write the result.
idx	bytes of size_t
maxlen	Maximum number of characters to write.

13.70.3.9 _out_fct()

```
static void _out_fct (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

_out_fct() - Internal output function wrapper

This function typecasting idx and maxlen arguments is to avoid compiler error. And then output function wrapper and the buffer is the output fct pointer.

Parameters

character	character type string
buffer	Pointer to a character string to write the result.
idx	bytes of size_t
maxlen	Maximum number of characters to write.

13.70.3.10 _out_null()

```
static void _out_null (
    char character,
    void * buffer,
    size_t idx,
    size_t maxlen )  [inline], [static]
```

_out_null() - Internal null output.

The typecasting of arguments with void is applied to avoid unused variable warnings in some compilers.

Parameters

character	character type string
buffer	Pointer to a character string to write the result.
idx	bytes of size_t
maxlen	Maximum number of characters to write.

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13.70.3.11 _strlen()

```
static unsigned int _strlen (
    const char * str )  [inline], [static]
```

_strlen() - calculates the length of the string.

Parameters

str	str is an argument of type pointer.

Returns

string length if successfully executed,else error occured.

13.70.3.12 _vsnprintf()

```
static int _vsnprintf (
    out_fct_type out,
    char * buffer,
    const size_t maxlen,
    const char * format,
    va_list va )  [static]
```

_vsnprintf() - Function writes formatted output to a character array, up to a maximum number of characters.

The _vsnprintf fucntion firstly initializes the varibles of format specifers like flags, width, precsion in this they evaluate all the specifiers invidually.First it checks the buffer equal to zero or not for null output function. After that flags evaluation will start using the switch case, then width field evalucation take process using if condition.

Parameters

out	type of out_fct_type.
buffer	pointer to the buffer where you want to function to store the formatted string.
maxlen	maximum number of characters to store in the buffer.
format	string that specifies the format of the output.
va	variable-argument list of the additional argument.

Returns

Its return the typecasted int of idx if success otherwise error occured.

13.70.3.13 fctprintf()

```
int fctprintf (
    void(*)(char character, void *arg) out,
    void * arg,
    const char * format,
     ...  )
```

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fctprintf() - Function is using the libary macros of variable aruguments like vastart and vaend.

This function initializes the va_list variable and invokes the va_start(). Invokes _vsnprintf function and stores the value into ret. It applies the functions va_start and va_end on va and returns ret.

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Parameters

out	An output function which takes one character and an argument pointer.
arg	An argument pointer for user data passed to output function.
format	A string that specifies the format of the output.

Returns

The number of characters that are sent to the output function, not counting the terminating null character.

13.70.3.14 putchar() `int putchar (`

```
char ch )
```

13.70.3.15 snprintf() `int snprintf (`

```
char * buffer,
size_t count,
const char * format,
 ... )
```

snprintf() - Places the generated output into the character array pointed to by buf, instead of writing it to a file

This function initializes the va_list variable and invokes the va_start(). Invokes _vsnprintf function and stores the value into ret. It applies the functions va_start and va_end on va and returns ret.

Parameters

buffer	pointer to buffer where you want to function to store the formatted string.
count	maximum number of characters to store in the buffer.
format	string that specifies the format of the output.

Returns

ret returns the ret value as an integer type.

13.70.3.16 sprintf() `int sprintf (`

```
char * buffer,
const char * format,
 ... )
```

sprintf() - Sends formatted output to a string pointed to by the argument buffer.

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This function initialize the va_list variable and invokes the va_start(). Invokes _vsnprintf function and store the value into ret. It applies the functions va_start and va_end on va and returns ret.

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Parameters

buffer	pointer to an array of char elements resulting string will store.
format	string that contains the text to be written to buffer.

Returns

ret It returns the ret value as an integer type.

13.70.3.17 vsnprintf()

```
int vsnprintf (
    char * buffer,
    size_t count,
    const char * format,
    va_list va )
```

vsnprintf() - Invokes another function called _vsnprintf(). with some arguments.

Parameters

buffer	Pointer to the buffer where you want to function to store the formatted string.
count	maximum number of characters to store in the buffer.
format	string that specifies the format of the output.

Returns

Its return the typecasted int of idx if success otherwise error occured.

13.71 ta-ref/api/tee-internal-api-cryptlib.c File Reference

```
#include "tee_api_types.h"
#include "tee-common.h"
#include "tee-ta-internal.h"
#include "edger/Enclave_t.h"
#include "syscall.h"
#include "report.h"
#include <string.h>
#include <stdlib.h>
```

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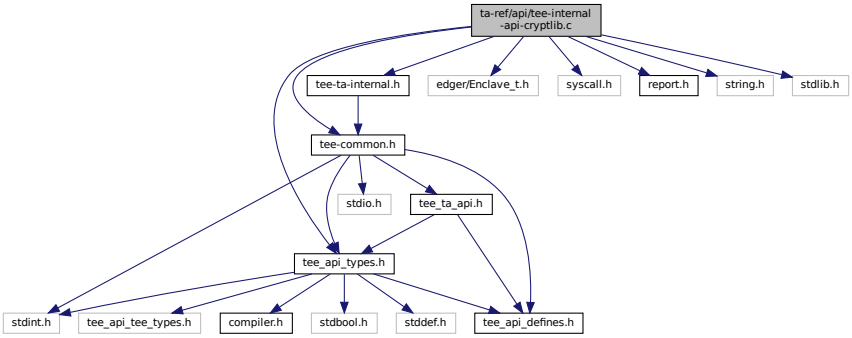
Include dependency graph for tee-internal-api-cryptlib.c:



Functions

- void wolfSSL_Free (void ∗p)
- void ∗ wolfSSL_Malloc (size_t n)
- TEE_Result TEE_AllocateOperation (TEE_OperationHandle ∗operation, uint32_t algorithm, uint32_t mode, uint32_t maxKeySize)

  Crypto, for all Crypto Functions.
- void TEE_FreeOperation (TEE_OperationHandle operation)

  Crypto, for all Crypto Functions.
- void TEE_DigestUpdate (TEE_OperationHandle operation, const void ∗chunk, uint32_t chunkSize)

  Crypto, Message Digest Functions.
- TEE_Result TEE_DigestDoFinal (TEE_OperationHandle operation, const void ∗chunk, uint32_t chunkLen, void ∗hash, uint32_t ∗hashLen)
- TEE_Result TEE_SetOperationKey (TEE_OperationHandle operation, TEE_ObjectHandle key)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEInit (TEE_OperationHandle operation, const void ∗nonce, uint32_t nonceLen, uint32_t tagLen, uint32_t AADLen, uint32_t payloadLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- void TEE_AEUpdateAAD (TEE_OperationHandle operation, const void ∗AADdata, uint32_t AADdataLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEUpdate (TEE_OperationHandle operation, const void ∗srcData, uint32_t srcLen, void ∗destData, uint32_t ∗destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEEncryptFinal (TEE_OperationHandle operation, const void ∗srcData, uint32_t srcLen, void ∗destData, uint32_t ∗destLen, void ∗tag, uint32_t ∗tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_AEDecryptFinal (TEE_OperationHandle operation, const void ∗srcData, uint32_t srcLen, void ∗destData, uint32_t ∗destLen, void ∗tag, uint32_t tagLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- void TEE_CipherInit (TEE_OperationHandle operation, const void ∗nonce, uint32_t nonceLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_CipherUpdate (TEE_OperationHandle operation, const void ∗srcData, uint32_t srcLen, void ∗destData, uint32_t ∗destLen)

  Crypto, Authenticated Encryption with Symmetric key Verification Functions.
- TEE_Result TEE_CipherDoFinal (TEE_OperationHandle operation, const void ∗srcData, uint32_t srcLen, void ∗destData, uint32_t ∗destLen)

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- TEE_Result TEE_GenerateKey (TEE_ObjectHandle object, uint32_t keySize, const TEE_Attribute *params, uint32_t paramCount)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AllocateTransientObject (TEE_ObjectType objectType, uint32_t maxKeySize, TEE_ObjectHandle *object)

  Crypto, Asymmetric key Verification Functions.
- void TEE_InitRefAttribute (TEE_Attribute *attr, uint32_t attributeID, const void *buffer, uint32_t length)

  Crypto, Asymmetric key Verification Functions.
- void TEE_InitValueAttribute (TEE_Attribute *attr, uint32_t attributeID, uint32_t a, uint32_t b)

  Crypto, Asymmetric key Verification Functions.
- void TEE_FreeTransientObject (TEE_ObjectHandle object)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AsymmetricSignDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, void *signature, uint32_t *signatureLen)

  Crypto, Asymmetric key Verification Functions.
- TEE_Result TEE_AsymmetricVerifyDigest (TEE_OperationHandle operation, const TEE_Attribute *params, uint32_t paramCount, const void *digest, uint32_t digestLen, const void *signature, uint32_t signatureLen)

  Crypto, Asymmetric key Verification Functions.

13.71.1 Function Documentation

13.71.1.1 TEE_AEDecryptFinal()

```
TEE_Result TEE_AEDecryptFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen,
    void * tag,
    uint32_t tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEDecryptFinal() - Processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData.

This function completes the AE operation and compares the computed tag with the tag supplied in the parameter tag .The operation handle can be reused or newly initialized.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output

TEE_ERROR_MAC_INVALID If the computed tag does not match the supplied tag

13.71.1.2 TEE_AEEncryptFinal()

```
TEE_Result TEE_AEEncryptFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen,
    void * tag,
    uint32_t * tagLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEEncryptFinal() - processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData .

TEE_AEEncryptFinal completes the AE operation and computes the tag. The operation handle can be reused or newly initialized. The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation may be in either initial or active state and enters initial state afterwards.

Parameters

operation	Handle of a running AE operation
srcData	Reference to final chunk of input data to be encrypted
srcLen	length of the input data
destData	Output buffer. Can be omitted if the output is to be discarded.
destLen	length of the buffer.
tag	Output buffer filled with the computed tag
tagLen	length of the tag.

Returns

0 on success.

TEE_ERROR_SHORT_BUFFER If the output or tag buffer is not large enoughto contain the output.

13.71.1.3 TEE_AEInit()

```
TEE_Result TEE_AEInit (
    TEE_OperationHandle operation,
    const void * nonce,
    uint32_t nonceLen,
    uint32_t tagLen,
    uint32_t AADLen,
    uint32_t payloadLen )
```

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Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEInit() - Initializes an Authentication Encryption operation.

The operation must be in initial state and remains in the initial state afterwards.

Parameters

operation	A handle on the operation.
nonce	The operation nonce or IV
nonceLen	length of nonce
tagLen	Size in bits of the tag
AADLen	Length in bytes of the AAD
payloadLen	Length in bytes of the payload.

Returns

0 on success.

TEE_ERROR_NOT_SUPPORTED If the tag length is not supported by the algorithm.

13.71.1.4 TEE_AEUpdate()

```
TEE_Result TEE_AEUpdate (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEUpdate() - Accumulates data for an Authentication Encryption operation

This function describes Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data,no output is generated. when using this routine to decrypt the returned data may be corrupt since the integrity check is not performed until all the data has been processed. If this is a concern then only use the TEE_AEDecryptFinal routine.

Parameters

operation	Handle of a running AE operation.
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of the input buffer.
destData	Output buffer
destLen	length of the out put buffer.

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Returns

0 on success.

TEE_ERROR_SHORT_BUFFER if the output buffer is not large enough to contain the output.

13.71.1.5 TEE_AEUpdateAAD()

```
void TEE_AEUpdateAAD (
    TEE_OperationHandle operation,
    const void * AADdata,
    uint32_t AADdataLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_AEUpdateAAD() - Feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.

The TEE_AEUpdateAAD function feeds a new chunk of Additional Authentication Data (AAD) to the AE operation. Subsequent calls to this function are possible.The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation SHALL be in initial state and remains in initial state afterwards.

Parameters

operation	Handle on the AE operation
AADdata	Input buffer containing the chunk of AAD
AADdataLen	length of the chunk of AAD.

13.71.1.6 TEE_AllocateOperation()

```
TEE_Result TEE_AllocateOperation (
    TEE_OperationHandle * operation,
    uint32_t algorithm,
    uint32_t mode,
    uint32_t maxKeySize )
```

Crypto, for all Crypto Functions.

TEE_AllocateOperation() - Allocates a handle for a new cryptographic operation and sets the mode and algorithm type.

If this function does not return with TEE_SUCCESS then there is no valid handle value.Once a cryptographic operation has been created, the implementation shall guarantee that all resources necessary for the operation are allocated and that any operation with a key of at most maxKeySize bits can be performed. For algorithms that take multiple keys, for example the AES XTS algorithm, the maxKeySize parameter specifies the size of the largest key. It is up to the implementation to properly allocate space for multiple keys if the algorithm so requires.

Parameters

operation	reference to generated operation handle.
algorithm	One of the cipher algorithms.
mode	The operation mode.
maxKeySize	Maximum key size in bits for the operation.

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Returns

0 in case of success

TEE_ERROR_OUT_OF_MEMORY If there are not enough resources to allocate the operation.

TEE_ERROR_NOT_SUPPORTED If the mode is not compatible with the algorithm or key size or if the algorithm is not one of the listed algorithms or if maxKeySize is not appropriate for the algorithm.

13.71.1.7 TEE_AllocateTransientObject()

```
TEE_Result TEE_AllocateTransientObject (
    TEE_ObjectType objectType,
    uint32_t maxKeySize,
    TEE_ObjectHandle * object )
```

Crypto, Asymmetric key Verification Functions.

TEE_AllocateTransientObject() - Allocates an uninitialized transient object. Transient objects are used to hold a cryptographic object (key or key-pair).

The value TEE_KEYSIZE_NO_KEY should be used for maxObjectSize for object types that do not require a key so that all the container resources can be pre-allocated. As allocated, the container is uninitialized. It can be initialized by subsequently importing the object material,generating an object, deriving an object, or loading an object from the Trusted Storage.

Parameters

objectType	Type of uninitialized object container to be created
maxKeySize	Key Size of the object.
object	Filled with a handle on the newly created key container.

Returns

0 on success

TEE_ERROR_OUT_OF_MEMORY If not enough resources are available to allocate the object handle.

TEE_ERROR_NOT_SUPPORTED If the key size is not supported or the object type is not supported.

13.71.1.8 TEE_AsymmetricSignDigest()

```
TEE_Result TEE_AsymmetricSignDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    void * signature,
    uint32_t * signatureLen )
```

Crypto, Asymmetric key Verification Functions.

TEE_AsymmetricSignDigest() - Signs a message digest within an asymmetric operation.

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Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

0 on sccess

TEE_ERROR_SHORT_BUFFER If the signature buffer is not large enough to hold the result

13.71.1.9 TEE_AsymmetricVerifyDigest()

```
TEE_Result TEE_AsymmetricVerifyDigest (
    TEE_OperationHandle operation,
    const TEE_Attribute * params,
    uint32_t paramCount,
    const void * digest,
    uint32_t digestLen,
    const void * signature,
    uint32_t signatureLen )
```

Crypto, Asymmetric key Verification Functions.

TEE_AsymmetricVerifyDigest() - verifies a message digest signature within an asymmetric operation.

This function describes the message digest signature verify by calling ed25519_verify().

Parameters

operation	Handle on the operation, which SHALL have been suitably set up with an operation key.
params	Optional operation parameters
paramCount	size of param.
digest	Input buffer containing the input message digest
digestLen	length of input buffer.
signature	Output buffer written with the signature of the digest
signatureLen	length of output buffer.

Returns

TEE_SUCCESS on success

TEE_ERROR_SIGNATURE_INVALID if the signature is invalid.

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13.71.1.10 TEE_CipherDoFinal()

```
TEE_Result TEE_CipherDoFinal (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

TEE_CipherDoFinal() - Finalizes the cipher operation, processing data that has not been processed by previous calls to TEE_CipherUpdate as well as data supplied in srcData .

This function describes The operation handle can be reused or re-initialized. The buffers srcData and destData shall be either completely disjoint or equal in their starting positions.The operation SHALL be in active state and is set to initial state afterwards.

Parameters

operation	Handle of a running Cipher operation
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of input buffer
destData	output buffer
destLen	ouput buffer length.

Returns

0 on success

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output

13.71.1.11 TEE_CipherInit()

```
void TEE_CipherInit (
    TEE_OperationHandle operation,
    const void * nonce,
    uint32_t nonceLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_CipherInit() - starts the symmetric cipher operation.

The operation shall have been associated with a key. If the operation is in active state, it is reset and then initialized. If the operation is in initial state, it is moved to active state.

Parameters

operation	A handle on an opened cipher operation setup with a key
nonce	Buffer containing the operation Initialization Vector as appropriate.
nonceLen	length of the buffer

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13.71.1.12 TEE_CipherUpdate()

```
TEE_Result TEE_CipherUpdate (
    TEE_OperationHandle operation,
    const void * srcData,
    uint32_t srcLen,
    void * destData,
    uint32_t * destLen )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

TEE_CipherUpdate() - encrypts or decrypts input data.

Input data does not have to be a multiple of block size. Subsequent calls to this function are possible. Unless one or more calls of this function have supplied sufficient input data, no output is generated. The cipher operation is finalized with a call to TEE_CipherDoFinal .The buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.The operation SHALL be in active state.

Parameters

operation	Handle of a running Cipher operation
srcData	Input data buffer to be encrypted or decrypted
srcLen	length of input buffer
destData	output buffer
destLen	ouput buffer length.

Returns

0 on success else

TEE_ERROR_SHORT_BUFFER If the output buffer is not large enough to contain the output. In this case, the input is not fed into the algorithm.

13.71.1.13 TEE_DigestDoFinal()

```
TEE_Result TEE_DigestDoFinal (
    TEE_OperationHandle operation,
    const void * chunk,
    uint32_t chunkLen,
    void * hash,
    uint32_t * hashLen )
```

TEE_DigestDoFinal() - Finalizes the message digest operation and produces the message hash.

This function finalizes the message digest operation and produces the message hash. Afterwards the Message Digest operation is reset to initial state and can be reused.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed.
chunkLen	size of the chunk.
hash	Output buffer filled with the message hash.
hashLen	lenth of the mesaage hash.

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Returns

0 on success

TEE_ERROR_SHORT_BUFFER If the output buffer is too small. In this case, the operation is not finalized.

13.71.1.14 TEE_DigestUpdate()

```
void TEE_DigestUpdate (
    TEE_OperationHandle operation,
    const void * chunk,
    uint32_t chunkSize )
```

Crypto, Message Digest Functions.

TEE_DigestUpdate()- Accumulates message data for hashing.

This function describes the message does not have to be block aligned. Subsequent calls to this function are possible.The operation may be in either initial or active state and becomes active.

Parameters

operation	Handle of a running Message Digest operation.
chunk	Chunk of data to be hashed
chunkSize	size of the chunk.

13.71.1.15 TEE_FreeOperation()

```
void TEE_FreeOperation (
    TEE_OperationHandle operation )
```

Crypto, for all Crypto Functions.

TEE_FreeOperation() - Deallocates all resources associated with an operation handle.

This function deallocates all resources associated with an operation handle. After this function is called, the operation handle is no longer valid. All cryptographic material in the operation is destroyed. The function does nothing if operation is TEE_HANDLE_NULL.

Parameters

operation	Reference to operation handle.

Returns

nothing after the operation free.

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13.71.1.16 TEE_FreeTransientObject() `void TEE_FreeTransientObject (`

```
TEE_ObjectHandle object )
```

Crypto, Asymmetric key Verification Functions.

TEE_FreeTransientObject() - Deallocates a transient object previously allocated with TEE_AllocateTransientObject .

this function describes the object handle is no longer valid and all resources associated with the transient object shall have been reclaimed after the TEE_AllocateTransientObject() call.

Parameters

object	Handle on the object to free.

13.71.1.17 TEE_GenerateKey() `TEE_Result TEE_GenerateKey (`

```
TEE_ObjectHandle object,
uint32_t keySize,
const TEE_Attribute * params,
uint32_t paramCount )
```

Crypto, Asymmetric key Verification Functions.

TEE_GenerateKey () - Generates a random key or a key-pair and populates a transient key object with the generated key material.

The size of the desired key is passed in the keySize parameter and shall be less than or equal to the maximum key size specified when the transient object was created.

Parameters

object	Handle on an uninitialized transient key to populate with the generated key.
keySize	Requested key size shall be less than or equal to the maximum key size specified when the object container was created
params	Parameters for the key generation.
paramCount	The values of all parameters are copied nto the object so that the params array and all the memory buffers it points to may be freed after this routine returns without affecting the object.

Returns

0 on succes

TEE_ERROR_BAD_PARAMETERS If an incorrect or inconsistent attribute is detected. The checks that are performed depend on the implementation.

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13.71.1.18 TEE_InitRefAttribute()

```
void TEE_InitRefAttribute (
    TEE_Attribute * attr,
    uint32_t attributeID,
    const void * buffer,
    uint32_t length )
```

Crypto, Asymmetric key Verification Functions.

TEE_InitRefAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

In TEE_InitRefAttribute () only the buffer pointer is copied, not the content of the buffer. This means that the attribute structure maintains a pointer back to the supplied buffer. It is the responsibility of the TA author to ensure that the contents of the buffer maintain their value until the attributes array is no longer in use.

Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
buffer	input buffer that holds the content of the attribute.
length	buffer length.

13.71.1.19 TEE_InitValueAttribute()

```
void TEE_InitValueAttribute (
    TEE_Attribute * attr,
    uint32_t attributeID,
    uint32_t a,
    uint32_t b )
```

Crypto, Asymmetric key Verification Functions.

TEE_InitValueAttribute() - The helper function can be used to populate a single attribute either with a reference to a buffer or with integer values.

Parameters

attr	attribute structure to initialize.
attributeID	Identifier of the attribute to populate.
a	unsigned integer value to assign to the a member of the attribute structure.
b	unsigned integer value to assign to the b member of the attribute structure

13.71.1.20 TEE_SetOperationKey()

```
TEE_Result TEE_SetOperationKey (
    TEE_OperationHandle operation,
    TEE_ObjectHandle key )
```

Crypto, Authenticated Encryption with Symmetric key Verification Functions.

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TEE_SetOperationKey() - Programs the key of an operation; that is, it associates an operation with a key.

The key material is copied from the key object handle into the operation. After the key has been set, there is no longer any link between the operation and the key object. The object handle can be closed or reset and this will not affect the operation. This copied material exists until the operation is freed using TEE_FreeOperation or another key is set into the operation.

Parameters

operation	Operation handle.
key	A handle on a key object.

Returns

0 on success return

TEE_ERROR_CORRUPT_OBJECT If the object is corrupt. The object handle is closed.

TEE_ERROR_STORAGE_NOT_AVAILABLE If the persistent object is stored in a storage area which is currently inaccessible.

13.71.1.21 wolfSSL_Free() `void wolfSSL_Free ( void * p )`

wolfSSL_Free() - Deallocates the memory which allocated previously.

Parameters

p	This is the pointer to a memory block.

13.71.1.22 wolfSSL_Malloc() `void * wolfSSL_Malloc ( size_t n )`

wolfSSL_Malloc() - Allocates the requested memory and returns a pointer to it.

Parameters

n	size of the memory block.

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