THE STANDARD FOR SECURE DIGITAL SERVICES AND DEVICES

GlobalPlatform Technology

TEE Internal Core API Specification

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1 Introduction

This specification defines a set of C APIs for the development of Trusted Applications (TAs) running inside a Trusted Execution Environment (TEE). For the purposes of this document a TEE is expected to meet the requirements defined in the GlobalPlatform TEE System Architecture ([Sys Arch]) specification, i.e. it is accessible from a Regular Execution Environment (REE) through the GlobalPlatform TEE Client API (described in the GlobalPlatform TEE Client API Specification [Client API]) but is specifically protected against malicious attacks and only runs code trusted in integrity and authenticity.

The APIs defined in this document target the C language and provide the following set of functionalities to TA developers:

- Basic OS-like functionalities, such as memory management, timer, and access to configuration properties
- Communication means with Client Applications (CAs) running in the Regular Execution Environment
- Trusted Storage facilities
- Cryptographic facilities
- Time management facilities
- Peripheral interface and Event handling facilities

The scope of this document is the development of Trusted Applications in the C language and their interactions with the TEE Client API. It does not cover other possible language bindings or the run-time installation and management of Trusted Applications.

If you are implementing this specification and you think it is not clear on something:

1. **Check with a colleague.**

And if that fails:

2. **Contact GlobalPlatform at TEE-issues-GPD_SPE_010_v1.3@globalplatform.org**

1.1 Audience

This document is suitable for software developers implementing Trusted Applications running inside the TEE which need to expose an externally visible interface to Client Applications and to use resources made available through the TEE Internal Core API, such as cryptographic capabilities and Trusted Storage.

This document is also intended for implementers of the TEE itself, its Trusted OS, Trusted Core Framework, the TEE APIs, and the communications infrastructure required to access Trusted Applications.

1.2 IPR Disclaimer

Attention is drawn to the possibility that some of the elements of this GlobalPlatform specification or other work product may be the subject of intellectual property rights (IPR) held by GlobalPlatform members or others. For additional information regarding any such IPR that have been brought to the attention of GlobalPlatform, please visit https://globalplatform.org/specifications/ip-disclaimers/. GlobalPlatform shall not be held responsible for identifying any or all such IPR, and takes no position concerning the possible existence or the evidence, validity, or scope of any such IPR.

1.3 References

The tables below list references applicable to this specification. The latest version of each reference applies unless a publication date or version is explicitly stated.

See also Annex C: Normative References for Algorithms.

Table 1-1: Normative References

Standard / Specification	Description	Ref
GPD_SPE_007	GlobalPlatform Technology TEE Client API Specification	[Client API]
GPD_SPE_009	GlobalPlatform Technology TEE System Architecture	[Sys Arch]
GPD_SPE_025	GlobalPlatform Technology TEE TA Debug Specification	[TEE TA Debug]
GPD_SPE_120	GlobalPlatform Technology TEE Management Framework (including ASN.1 Profile) [Initially published as TEE Management Framework]	[TMF ASN.1]
GPD_SPE_123	GlobalPlatform Technology TEE Management Framework: Open Trust Protocol (OTrP) Profile	[TMF OTrP]
GPD_SPE_042	GlobalPlatform Technology TEE TUI Extension: Biometrics API	[TEE TUI Bio]
GPD_SPE_055	GlobalPlatform Technology TEE Trusted User Interface Low-level API	[TEE TUI Low]
GPD_SPE_021	GlobalPlatform Technology TEE Protection Profile	[TEE PP]
BSI-CC-PP-0084-2014	Security IC Platform BSI Protection Profile 2014 with Augmentation Packages.	[PP-0084]
BSI TR-03111	BSI Technical Guideline TR-03111: Elliptic Curve Cryptography	[BSI TR 03111]
ISO/IEC 9899:1999	Programming languages – C	[C99]
NIST Recommended Elliptic Curves	Recommended Elliptic Curves for Federal Government Use	[NIST Re Cur]
NIST SP800-56B	Recommendation for Pair-Wise Key Establishment Schemes Using Integer Factorization Cryptography	[NIST SP800-56B]

Standard / Specification	Description	Ref
NIST SP800-185	SHA-3 Derived Functions: cSHAKE, KMAC, TupleHash, and ParallelHash	[NIST SP800-185]
RFC 2045	Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies	[RFC 2045]
RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	[RFC 2119]
RFC 4122	A Universally Unique IDentifier (UUID) URN Namespace	[RFC 4122]
RFC 7748	Elliptic Curves for Security	[X25519]
RFC 8032	Edwards-Curve Digital Signature Algorithm	[Ed25519]
SM2	Organization of State Commercial Administration of China, "Public Key Cryptographic Algorithm SM2 Based on Elliptic Curves", December 2010	[SM2]
SM2-2	Organization of State Commercial Administration of China, "Public Key Cryptographic Algorithm SM2 Based on Elliptic Curves – Part 2: Digital Signature Algorithm", December 2010	[SM2-2]
SM2-4	Organization of State Commercial Administration of China, "Public Key Cryptographic Algorithm SM2 Based on Elliptic Curves – Part 4: Public Key Encryption Algorithm", December 2010	[SM2-4]
SM2-5	Organization of State Commercial Administration of China, "Public Key Cryptographic Algorithm SM2 Based on Elliptic Curves – Part 5: Parameter definitions", December 2010	[SM2-5]
SM3	Organization of State Commercial Administration of China, "SM3 Cryptographic Hash Algorithm", December 2010	[SM3]
SM4	Organization of State Commercial Administration of China, "SM4 block cipher algorithm", December 2010	[SM4]

Table 1-2: Informative References

Standard / Specification	Description	Ref
GP_GUI_001	GlobalPlatform Document Management Guide	[Doc Mgmt]
ISO/IEC 10118-3	Information technology – Security techniques – Hash-functions – Part 3: Dedicated hash-functions (English language reference for SM3)	[ISO 10118-3]
ISO/IEC 14888-3	Information technology – Security techniques – Digital signatures with appendix – Part 3: Discrete logarithm based mechanisms (English Language reference for SM2)	[ISO 14888-3]

Standard / Specification	Description	Ref
ISO/IEC 15408	Information technology – Security techniques – Evaluation criteria for IT security	[ISO 15408]
ISO/IEC 18033-3	Information technology – Security techniques – Encryption algorithms – Part 3: Block ciphers (English Language reference for SM4)	[ISO 18033-3]

1.4 Terminology and Definitions

The following meanings apply to SHALL, SHALL NOT, MUST, MUST NOT, SHOULD, SHOULD NOT, and MAY in this document (refer to [RFC 2119]):

- **SHALL** indicates an absolute requirement, as does **MUST**.
- **SHALL NOT** indicates an absolute prohibition, as does **MUST NOT**.
- **SHOULD** and **SHOULD NOT** indicate recommendations.
- **MAY** indicates an option.

Selected terms used in this document are included in the following table.

Table 1-3: Terminology and Definitions

Term	Definition
Cancellation Flag	An indicator that a Client has requested cancellation of an operation.
Client	Either of the following: • a Client Application using the TEE Client API • a Trusted Application acting as a client of another Trusted Application, using the Internal Client API
Client Application (CA)	An application running outside of the Trusted Execution Environment (TEE) making use of the TEE Client API ([Client API]) to access facilities provided by Trusted Applications inside the TEE. Contrast *Trusted Application (TA)*.
Client Properties	A set of properties associated with the Client of a Trusted Application.
Command	A message (including a Command Identifier and four Operation Parameters) send by a Client to a Trusted Application to initiate an operation.
Command Identifier	A 32-bit integer identifying a Command.
Cryptographic Key Object	An object containing key material.
Cryptographic Key-Pair Object	An object containing material associated with both keys of a key-pair.
Cryptographic Operation Handle	An opaque reference that identifies a particular cryptographic operation.
Cryptographic Operation Key	The key to be used for a particular operation.
Data Object	An object containing a data stream but no key material.

Term	Definition
Data Stream	Data associated with a Persistent Object (excluding Object Attributes and metadata).
Event API	An API that supports the event loop. See Chapter 9.
Event loop	A mechanism by which a TA can enquire for and then process messages from types of peripherals including pseudo-peripherals.
Function Number	Identifies a function within a specification. With the Specification Number, forms a unique identifier for a function. May be displayed when a Panic occurs or in debug messages where supported.
Implementation Properties	A set of properties describing the TEE implementation, including the associated hardware and Trusted OS.
Initialized	Describes a transient object whose attributes have been populated.
Instance	A particular execution of a Trusted Application, having physical memory space that is separated from the physical memory space of all other TA instances.
Key Size	The key size associated with a Cryptographic Object; values are limited by the key algorithm used.
Key Usage Flags	Indicators of the operations permitted with a Cryptographic Object.
Memory Reference Parameter	An Operation Parameter that carries a pointer to a client-owned memory buffer. Contrast *Value Parameter*.
Metadata	Additional data associated with a Cryptographic Object: Key Size and Key Usage Flags.
Multi Instance Trusted Application	Denotes a Trusted Application for which each session opened by a client is directed to a separate TA instance.
Object Attribute	Small amounts of data used to store key material in a structured way.
Object Handle	An opaque reference that identifies a particular object.
Object Identifier	A variable-length binary buffer identifying a persistent object.
Operation Parameter	One of four data items passed in a Command, which can contain integer values or references to client-owned shared memory blocks.
Panic	An exception that kills a whole TA instance. See section 2.3.3 for full definition.
Panic Reason	A programmer error that makes it impossible to produce the result of a function and requires that the API panic the calling TA instance. See section 2.3.3 for further information.
Parameter Annotation	Denotes the pattern of usage of a function parameter or pair of function parameters.
Peripheral API	A low-level API that enables a Trusted Application to interact with peripherals via the Trusted OS. See Chapter 9.
Persistent Object	An object identified by an Object Identifier and including a Data Stream. Contrast *Transient Object*.

Term	Definition
Property	An immutable value identified by a name.
Property Set	Any of the following: • The configuration properties of a Trusted Application • Properties associated with a Client Application by the Regular Execution Environment • Properties describing characteristics of a TEE implementation
Protection Profile (PP)	A document according to the Common Criteria, as described in [ISO 15408], used as part of the security certification process; defines the specific set of security features required of a technology to claim compliance.
REE Time	A time value that is as trusted as the REE.
Regular Execution Environment (REE)	An Execution Environment comprising at least one Regular OS and all other components of the device (SoCs, other discrete components, firmware, and software) which execute, host, and support the Regular OS (excluding any Secure Components included in the device). From the viewpoint of a Secure Component, everything in the REE is considered untrusted, though from the Regular OS point of view there may be internal trust structures. (Formerly referred to as a *Rich Execution Environment (REE)*.) Contrast *Trusted Execution Environment (TEE)*.
Regular OS	An OS executing in a Regular Execution Environment. May be anything from a large OS such as Linux down to a minimal set of statically linked libraries providing services such as a TCP/IP stack. (Formerly referred to as a *Rich OS* or *Device OS*.) Contrast *Trusted OS*.
Secure Component	GlobalPlatform terminology to represent either a Secure Element or a Trusted Execution Environment.
Secure Element	A tamper-resistant secure hardware component which is used in a device to provide the security, confidentiality, and multiple application environment required to support various business models. May exist in any form factor, such as embedded or integrated SE, SIM/UICC, smart card, smart microSD, etc.
Security Domain	An on-device representative of an Authority in the TEE Management Framework security model. Security Domains are responsible for the control of administration operations. SDs are used to perform the provisioning of TEE properties and to manage the life cycle of Trusted Applications and SDs associated with them.
Session	Logically connects multiple commands invoked on a Trusted Application or a Security Domain.
Simple Symmetric Key Type	In the context of this specification, any of a set of object types defined in Table 5-10.
Single Instance Trusted Application	Denotes a Trusted Application for which all sessions opened by clients are directed to a single TA instance.

Term	Definition
Specification Number	Identifies the specification within which a function is defined. May be displayed when a Panic occurs or in debug messages where supported.
Storage Identifier	A 32-bit identifier for a Trusted Storage Space that can be accessed by a Trusted Application.
System Time	A time value that can be used to compute time differences and operation deadlines.
TA Persistent Time	A time value set by the Trusted Application that persists across platform reboots and whose level of trust can be queried.
Tamper-resistant secure hardware	Hardware designed to isolate and protect embedded software and data by implementing appropriate security measures. The hardware and embedded software meet the requirements of the latest Security IC Platform Protection Profile ([PP-0084]) including resistance to physical tampering scenarios described in that Protection Profile.
Task	The entity that executes any code executed in a Trusted Application.
TEE Client API	The software interface used by clients running in the REE to communicate with the TEE and with the Trusted Applications executed by the TEE. For details, see [Client API].
TEE Management Framework	A security model for administration of Trusted Execution Environments (TEEs) and for administration and life cycle management of Trusted Applications (TAs) and corresponding Security Domains (SDs).
Transient Object	An object containing attributes but no data stream, which is reclaimed when closed or when the TA instance is destroyed. Contrast *Persistent Object*.
Trusted Application (TA)	An application running inside the Trusted Execution Environment that provides security related functionality to Client Applications outside of the TEE or to other Trusted Applications inside the TEE. Contrast *Client Application (CA)*.
Trusted Application Configuration Properties	A set of properties associated with the installation of a Trusted Application.
Trusted Core Framework or "Framework"	The part of the Trusted OS responsible for implementing the Trusted Core Framework API[1] that provides OS-like facilities to Trusted Applications and a way for the Trusted OS to interact with the Trusted Applications.

[1] The Trusted Core Framework API is described in Chapter 4.

Term	Definition
Trusted Execution Environment (TEE)	An Execution Environment that runs alongside but isolated from an REE. A TEE has security capabilities and meets certain security-related requirements: It protects TEE assets against a set of defined threats which include general software attacks as well as some hardware attacks, and defines rigid safeguards as to data and functions that a program can access. There are multiple technologies that can be used to implement a TEE, and the level of security achieved varies accordingly. Contrast *Regular Execution Environment (REE)*.
Trusted OS	An OS executing in a Secure Component. Contrast *Regular OS*.
Trusted Storage Space	Storage that is protected either by the hardware of the TEE or cryptographically by keys held in the TEE. Data held in such storage is either private to the Trusted Application that created it or is shared according to the rules of a Security Domain hierarchy. See [TMF ASN.1] sections 4.1 and 5.5 regarding Security Domains and Trusted Storage.
Trusted User Interface (TUI)	A hardware protected user interface that may be used to limit exposure of information exchanged between a Trusted Application and a user. For example, a TA may use the TUI to display transaction data and obtain user confirmation of the data's correctness.
Uninitialized	Describes a transient object allocated with a certain object type and maximum size but with no attributes.
Universally Unique Identifier (UUID)	An identifier as specified in RFC 4122 ([RFC 4122]).
Value Parameter	An Operation Parameter that carries two 32-bit integers. Contrast *Memory Reference Parameter*.

1.5 Abbreviations and Notations

Table 1-4: Abbreviations

Abbreviation / Notation	Meaning
AAD	Additional Authenticated Data
AE	Authenticated Encryption
AES	Advanced Encryption Standard
API	Application Programming Interface
CA	Client Application
CMAC	Cipher-based MAC
CRT	Chinese Remainder Theorem
CTS	CipherText Stealing

Abbreviation / Notation	Meaning
DES	Data Encryption Standard
DH	Diffie-Hellman
DSA	Digital Signature Algorithm
ECC	Elliptic Curve Cryptography
ECDH	Elliptic Curve Diffie-Hellman
ECDSA	Elliptic Curve Digital Signature Algorithm
ETSI	European Telecommunications Standards Institute
FMM	Fast Modular Multiplication
gcd	Greatest Common Divisor
HMAC	Hash-based Message Authentication Code
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
IV	Initialization Vector
LS	Liaison Statement
MAC	Message Authentication Code
MD5	Message Digest 5
MGF	Mask Generating Function
NIST	National Institute of Standards and Technology
OAEP	Optimal Asymmetric Encryption Padding
OS	Operating System
PKCS	Public Key Cryptography Standards
PSS	Probabilistic Signature Scheme
REE	Regular Execution Environment
RFC	Request For Comments; may denote a memorandum published by the IETF
RSA	Rivest, Shamir, Adleman asymmetric algorithm
SDO	Standards Defining Organization
SHA	Secure Hash Algorithm
TA	Trusted Application
TEE	Trusted Execution Environment
UTC	Coordinated Universal Time
UTF	Unicode Transformation Format
UUID	Universally Unique Identifier

Abbreviation / Notation	Meaning
XOF	eXtendable-Output Functions
XTS	XEX-based Tweaked Codebook mode with ciphertext stealing (CTS)

1.6 Revision History

GlobalPlatform technical documents numbered *n*.0 are major releases. Those numbered *n*.1, *n*.2, etc., are minor releases where changes typically introduce supplementary items that do not impact backward compatibility or interoperability of the specifications. Those numbered *n.n*.1, *n.n*.2, etc., are maintenance releases that incorporate errata and precisions; all non-trivial changes are indicated, often with revision marks.

Table 1-5: Revision History

Date	Version	Description
December 2011	1.0	Initial Public Release, as “TEE Internal API Specification”.
June 2014	1.1	Public Release, as “TEE Internal Core API Specification”.
June 2016	1.1.1	Public Release, showing all non-trivial changes since v1.1. Significant changes include: • Many parameters were defined as `size_t` in v1.0 then changed to `uint32_t` in v1.1, and have now been reverted. • Improved clarity of specification with regard to `TEE_GenerateKey` parameter checking. Reverted over-prescriptive requirements for parameter vetting, re-enabling practical prime checking. • Clarification of invalid storage ID handling with regard to `TEE_CreatePersistentObject` and `TEE_OpenPersistentObject`. • Clarified which algorithms may use an IV. • Clarified the availability of `TEE_GetPropertyAsBinaryBlock`. • Clarified mismatches between Table 6-12 and elsewhere. • Deprecated incorrectly defined algorithm identifiers and defined a distinct set. • Corrected an error in `TEE_BigIntComputeExtendedGcd` range validation. • Clarified operation of `TEEC_OpenSession` with NULL `TEEC_Operation`. • Clarified relationship of specification with FIPS 186-2 and FIPS 186-4. • Clarified uniqueness of `gpd.tee.deviceID` in case of multiple TEEs on a device. • Corrected details of when `TEE_HANDLE_FLAG_INITIALIZED` is set. • Clarified the security of the location of operation parameters that the TA is acting on. • Clarified the handling and validation of storage identifiers. • Clarified the protection level relationships with anti-rollback, and the way anti-rollback violation is signaled to a TA. • Clarified the data retention requirement for an unused “b” attribute value. • Clarified the acceptable bit size for some security operations. • Relaxed attribute restrictions such that `TEE_PopulateTransientObject` and `TEE_GenerateKey` are aligned. • Clarified the handling of `ACCESS_WRITE_META`.

Date	Version	Description
November 2016	1.1.2	Public Release, showing all non-trivial changes since v1.1, both those included in v1.1.1 and the following: • New section 3.1.1, API Version – Added `#define TEE_CORE_API` specific to API specification version. • Section 4.7, Implementation Properties – Clarified existing `gpd.tee.apiversion`, and noted that it is deprecated. • Section 4.7 – Added more precise `gpd.tee.internalCore.version`. • New section 4.7.1, Specification Version Number Property – Defined structure of integer version field structure as used in other GlobalPlatform specs.

October 2018	1.2	Public Release
		• Introduced:
		  o Curve 25519 & BSI related curves and algorithms support
		  o Chinese Algorithms
		  o Peripheral API and Event API
		  o `TEE_IsAlgorithmSupported` to interrogate available algorithms
		  o `TEE_BigIntAbs`, `TEE_BigIntExpMod`, `TEE_BigIntSetBit`, `TEE_BigIntAssign` bignum functions
		  o Memory allocation options with No Share and No Fill hints
		• Clarified principles used in defining Panic Reasons.
		• Improved version control allowing TA builder to potentially request an API version.
		• Improved support for 32-bit or 64-bit TA operation.
		• Clarified functionality:
		  o Cryptographic operation states with regard to reset
		  o Use of identical keys in `TEE_SetOperationKey2`
		  o State transitions in `TEE_AEUpdateAAD` and associated functionality

May 2019	1.2.1	Public Release, showing all non-trivial changes since v1.2 • Clarified `TEE_ERROR_CIPHERTEXT_INVALID` return code. • Clarified generic payloads with reference to [TEE TUI Low] v1.0.1 in section 9.6.9, Generic Payloads. • In Figure 5-1, State Diagram for `TEE_ObjectHandle`, corrected `TEE_RestrictObjectInfo1` references to `TEE_RestrictObjectUsage1`. Updated the associated text in section 5.5.2. • Updated Figure 6-1, State Diagram for `TEE_OperationHandle`, to include the missing `TEE_SetOperationKey and TEE_SetOperationKey2` transitions.
Oct 2019	1.2.1.9	Committee Review

Date	Version	Description

April 2020	1.2.1.25	Member Review
		• Introduced:
		  o Storage types `TEE_STORAGE_PERSO` and `TEE_STORAGE_PROTECTED`
		  o Support for ed448 and x448 algorithms
		  o Support for SHA-3 including SHAKE128 and SHAKE256
		• Updated section 5.7.2, `TEE_CreatePersistentObject`, to support transition from a transient object to a persistent object.
		• In section 6, Cryptographic Operations API, added the **extracting** state signifying digest extraction.
		• Added section 6.3.3, `TEE_DigestExtract`, for use with XOF.
		• Clarified functionality:
		  o Genericized the Peripheral and Event APIs (section 9) where the text specifically mentioned a TUI session.
		  o Resolved inconsistency in the input data buffer annotation between `TEE_WriteObjectData` and `TEE_CreatePersistentObject`.
		• In section 5.9.4, `TEE_SeekObjectData`, corrected the offset parameter type.
		• Clarified throughout the use of illegal values reserved for testing.

September 2020	1.2.1.31	Public Review • Added `TEE_ALG_HKDF` to support key derivation operations. • Added `gpd.ta.doesNotCloseHandleOnCorruptObject` property to define corrupted object behavior and clarified throughout. • `TEE_ERROR_OLD_VERSION` renamed to `TEE_ERROR_UNSUPPORTED_VERSION`. • Clarified behavior when calling `TEE_GetObjectBufferAttribute` with a `NULL` buffer. • Defined 'Simple Symmetric Key Types'. • Clarified behavior of `keySize` parameter in `TEE_GenerateKey`. • Updated Table 6-4 to associate the algorithm, object type, and mode of operation.
TBD	1.3	Public Release

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2 Overview of the TEE Internal Core API Specification

This specification defines a set of C APIs for the development of Trusted Applications (TAs) running inside a Trusted Execution Environment (TEE). For the purposes of this document a TEE is expected to meet the requirements defined in [Sys Arch], i.e. it is accessible from a Regular Execution Environment (REE) through the GlobalPlatform TEE Client API ([Client API]) but is specifically protected against malicious attacks and runs only code trusted in integrity and authenticity.

All security statements expressed in this document are themselves bound by the relevant Protection Profile ([TEE PP]). Comments such as “an asset is immune to modification”, or “is only accessible by appropriate authorization” are therefore limited by the security requirements of the Protection Profile.

A TEE provides the Trusted Applications an execution environment with defined security boundaries, a set of security enabling capabilities, and means to communicate with Client Applications (CAs) running in the Regular Execution Environment. This document specifies how to use these capabilities and communication means for Trusted Applications developed using the C programming language. It does not cover how Trusted Applications are installed or managed (described in TEE Management Framework (including ASN.1 Profile) – [TMF ASN.1] and TEE Management Framework: Open Trust Protocol (OTrP) Profile – [TMF OTrP]) and does not cover other language bindings.

Sections below provide an overview of the TEE Internal Core API specification.

- Section 2.1 describes Trusted Applications and their operations and interactions with other TEE components.
- Section 2.2 gives an overview of the TEE Internal Core APIs that provide core secure services to the Trusted Applications.
- Section 2.3 describes error handling, including how errors are handled by TEE internal specifications, whether detected during TA execution or in a Panic situation.
- Section 2.4 describes different opaque handle types used in the specification. These opaque handles refer to objects created by the API implementation for a TA instance.
- Section 2.5 describes TEE properties that refer to configuration parameters, permissions, or implementation characteristics.

2.1 Trusted Applications

A Trusted Application (TA) is a program that runs in a Trusted Execution Environment (TEE) and exposes security services to its Clients.

A Trusted Application is command-oriented. Clients access a Trusted Application by opening a session with the Trusted Application and invoking commands within the session. When a Trusted Application receives a command, it parses the messages associated with the command, performs any required processing, and then sends a response back to the client.

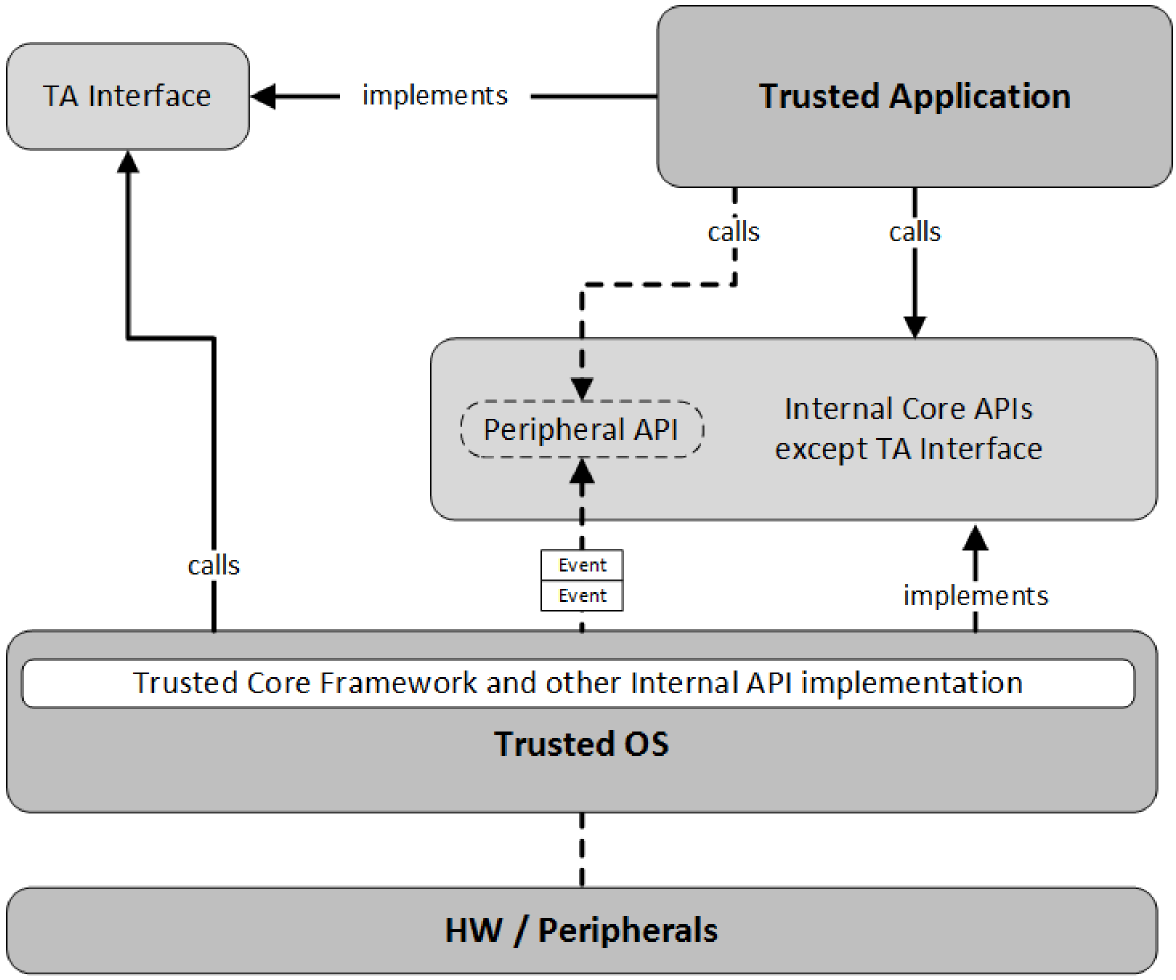
A Client typically runs in the Regular Execution Environment and communicates with a Trusted Application using the TEE Client API [Client API]. It is then called a "Client Application". It is also possible for a Trusted Application to act as a client of another Trusted Application, using the Internal Client API (see section 4.9). The term "Client" covers both cases.

2.1.1 TA Interface

Each Trusted Application exposes an interface (the TA interface) composed of a set of entry point functions that the Trusted Core Framework implementation calls to inform the TA about life cycle changes and to relay communication between Clients and the TA. Once the Trusted Core Framework has called one of the TA entry points, the TA can make use of the TEE Internal Core API to access the facilities of the Trusted OS, as illustrated in Figure 2-1. For more information on the TA interface, see section 4.3.

Each Trusted Application is identified by a Universally Unique Identifier (UUID) as specified in [RFC 4122]. Each Trusted Application also comes with a set of Trusted Application Configuration Properties. These properties are used to configure the Trusted OS facilities exposed to the Trusted Application. Properties can also be used by the Trusted Application itself as a means of configuration.

Figure 2-1: Trusted Application Interactions with the Trusted OS



2.1.2 Instances, Sessions, Tasks, and Commands

When a Client creates a session with a Trusted Application, it connects to an Instance of that Trusted Application. A Trusted Application instance has physical memory space which is separated from the physical memory space of all other Trusted Application instances. The Trusted Application instance memory space holds the Trusted Application instance heap and writable global and static data.

All code executed in a Trusted Application is said to be executed by Tasks. A Task keeps a record of its execution history (typically realized with a stack) and current execution state. This record is collectively called a Task context. A Task SHALL be created each time the Trusted OS calls an entry point of the Trusted Application. Once the entry point has returned, an implementation may recycle a Task to call another entry point but this SHALL appear like a completely new Task was created to call the new entry point.

A Session is used to logically connect multiple commands invoked in a Trusted Application. Each session has its own state, which typically contains the session context and the context(s) of the Task(s) executing the session.

A Command is issued within the context of a session and contains a Command Identifier, which is a 32-bit integer, and four Operation Parameters, which can contain integer values or references to client-owned shared memory blocks.

It is up to the Trusted Application implementer to define the combinations of commands and their parameters that are supported by the Trusted Application. This is out of scope of this specification.

2.1.3 Sequential Execution of Entry Points

All entry point calls within a given Trusted Application instance are called in sequence, i.e. no more than one entry point is executed at any point in time. The Trusted Core Framework implementation SHALL guarantee that a commenced entry point call is completed before any new entry point call is allowed to begin execution.

If there is more than one entry point call to complete at any point in time, all but one call SHALL be queued by the Framework. The order in which the Framework queues and picks enqueued calls for execution is implementation-defined.

It is not possible to execute multiple concurrent commands within a session. The TEE guarantees that a pending command has completed before a new command is executed.

Since all entry points of a given Trusted Application instance are called in sequence, there is no need to use any dedicated synchronization mechanisms to maintain consistency of any Trusted Application instance memory. The sequential execution of entry points inherently guarantees this consistency.

2.1.4 Cancellations

Clients can request the cancellation of open-session and invoke-command operations at any time.

If an operation is requested to be cancelled and has not reached the Trusted Application yet but has been queued, then the operation is simply retired from the queue.

If the operation has already been transmitted to the Trusted Application, then the task running the operation is put in the cancelled state. This has an effect on a few "cancellable" functions, such as `TEE_Wait`, but this effect may also be masked by the Trusted Application if it does not want to be affected by client cancellations. See section 4.10 for more details on how a Trusted Application can handle cancellation requests and mask their effect.

2.1.5 Unexpected Client Termination

When the client of a Trusted Application dies or exits abruptly and when it can be properly detected, then this SHALL appear to the Trusted Application as if the client requests cancellation of all pending operations and gracefully closes all its client sessions. It SHALL be indistinguishable from a clean session closing.

More precisely, the REE SHOULD detect when a Client Application dies or exits. When this happens, the REE SHALL initiate a termination process that SHALL result in the following sequence of events for all Trusted Application instances that are serving a session with the terminating client:

- If an operation is pending in the closing session, it SHALL appear as if the client had requested its cancellation.
- When no operation remains pending in the session, the session SHALL be closed.

If a TA client is a TA itself, this sequence of events SHALL happen when the client TA panics or exits due to the termination of its own Client Application.[2]

2.1.6 Instance Types

At least two Trusted Application instance types SHALL be supported: Multi Instance and Single Instance. Whether a Trusted Application is Multi Instance or Single Instance is part of its configuration properties and SHALL be enforced by the Trusted OS. See section 4.5 for more information on configuration properties.

- For a Multi Instance Trusted Application, each session opened by a client is directed to a separate Trusted Application instance, created on demand when the session is opened and destroyed when the session closes. By definition, every instance of such a Trusted Application accepts and handles one and only one session at a given time.
- For a Single Instance Trusted Application, all sessions opened by the clients are directed to a single Trusted Application instance. From the Trusted Application point of view, all sessions share the same Trusted Application instance memory space, which means for example that memory dynamically allocated for one session is accessible in all other sessions. It is also configurable whether a Single Instance Trusted Application accepts multiple concurrent sessions or not.

2.1.7 Configuration, Development, and Management

Trusted Applications as discussed in this document are developed using the C language. The way Trusted Applications are compiled and linked is implementation-dependent.

[TMF ASN.1] and [TMF OTrP] define mechanisms by which Trusted Applications can be configured and installed in a TEE. The scope of this specification does not include configuration, installation, de-installation, signing, verification, or any other life cycle or deployment aspects.

[2] Panics are discussed in section 2.3.3.

2.2 TEE Internal Core APIs

The TEE Internal Core APIs provide specified functionality that SHALL be available on a GlobalPlatform TEE implementation alongside optional functionality that MAY be available in a GlobalPlatform TEE implementation. The Trusted OS implements TEE Internal Core APIs that are used by Trusted Applications to develop secure tasks. These APIs provide building blocks to TAs by offering them a set of core services.

A guiding principle for the TEE Internal Core APIs is that it should be possible for a TA implementer to write source code which is portable to different TEE implementations. In particular, the TEE Internal Core APIs are designed to be used portably on TEE implementations which might have very different CPU architectures running the Trusted OS.

The TEE Internal Core APIs are further classified into six broad categories described below.

2.2.1 Trusted Core Framework API

This specification defines an API that provides OS functionality – integration, scheduling, communication, memory management, and system information retrieval interfaces – and channels communications from Client Applications or other Trusted Applications to the Trusted Application.

2.2.2 Trusted Storage API for Data and Keys

This specification defines an API that defines Trusted Storage for keys or general purpose data. This API provides access to the following facilities:

- Trusted Storage for general purpose data and key material with guarantees on the confidentiality and integrity of the data stored and atomicity of the operations that modify the storage
    - The Trusted Storage may be backed by non-secure resources as long as suitable cryptographic protection is applied, which SHALL be as strong as the means used to protect the TEE code and data itself.
    - The Trusted Storage SHALL be bound to a particular device, which means that it SHALL be accessible or modifiable only by authorized TAs running in the same TEE and on the same device as when the data was created.
    - See [Sys Arch] section 2.2 for more details on the security requirements for the Trusted Storage.
- Ability to hide sensitive key material from the TA itself
- Association of data and key: Any key object can be associated with a data stream and pure data objects contain only the data stream and no key material.
- Separation of storage among different TAs:
    - Each TA has access to its own storage space that is shared among all the instances of that TA but separated from the other TAs.

2.2.3 Cryptographic Operations API

This specification defines an API that provides the following cryptographic facilities:

- Generation and derivation of keys and key-pairs
- Support for the following types of cryptographic algorithms:
  - Digests
  - Symmetric Ciphers
  - Message Authentication Codes (MAC)
  - Authenticated Encryption (AE) algorithms such as AES-CCM and AES-GCM
  - Asymmetric Encryption and Signature
  - Key Exchange algorithms
- Pre-allocation of cryptographic operations and key containers so that resources can be allocated ahead of time and reused for multiple operations and with multiple keys over time

2.2.4 Time API

This specification defines an API to access three sources of time:

- The System Time has an arbitrary non-persistent origin. It may use a secure dedicated hardware timer or be based on the REE timers.
- The TA Persistent Time is real-time and persistent but its origin is individually controlled by each TA. This allows each TA to independently synchronize its time with the external source of trusted time of its choice. The TEE itself is not required to have a defined trusted source of time.
- The REE Time is real-time but SHOULD NOT be more trusted than the REE and the user.

The level of trust that a Trusted Application can put in System Time and its TA Persistent Time is implementation-defined as a given implementation may not include fully trustable hardware sources of time and hence may have to rely on untrusted real-time clocks and timers managed by the Regular Execution Environment. However, when a more trustable source of time is available, it is expected that it will be exposed to Trusted Applications through this Time API. Note that a Trusted Application can programmatically determine the level of protection of time sources by querying implementation properties `gpd.tee.systemTime.protectionLevel` and `gpd.tee.TAPersistentTime.protectionLevel`.

2.2.5 TEE Arithmetical API

The TEE Arithmetical API is a low-level API that complements the Cryptographic API when a Trusted Application needs to implement asymmetric algorithms, modes, or paddings not supported by the Cryptographic API.

The API provides arithmetical functions to work on big numbers and prime field elements. It provides operations including regular arithmetic, modular arithmetic, primality test, and fast modular multiplication that can be based on the Montgomery reduction or a similar technique.

2.2.6 Peripheral and Event APIs

The Peripheral and Event APIs are low-level APIs that enable a Trusted Application to interact with peripherals via the Trusted OS.

The Peripheral and Event APIs offer mechanisms to:

- Discover and identify the peripherals available to a Trusted Application.
- Determine the level of trust associated with data coming to and from the peripheral.
- Configure peripherals.
- Open and close connections between the Trusted Application and peripherals.
- Interact with peripherals using polling mechanism.
- Receive input from peripherals and other event sources using an asynchronous event mechanism.

2.3 Error Handling

2.3.1 Normal Errors

The TEE Internal Core API functions usually return a return code of type `TEE_Result` to indicate errors to the caller. This is used to denote "normal" run-time errors that the TA code is expected to catch and handle, such as out-of-memory conditions or short buffers. Unless specified otherwise (e.g. for `TEE_ERROR_CORRUPT_OBJECT` and `TEE_ERROR_CORRUPT_OBJECT_2`, see section 5.1), if any function returns a code other than `TEE_SUCCESS`, it SHALL have no other effect.

Routines defined in this specification SHOULD only return the return codes defined in their definition in this specification. Where return codes are defined, they SHOULD only be returned with the meaning defined by this specification: Errors which are detected for which no return code has been defined SHALL cause the routine to panic.

2.3.2 Programmer Errors

There are a number of conditions in this specification that can only occur as a result of programmer error, i.e. they are triggered by incorrect use of the API by a Trusted Application, such as wrong parameters, wrong state, invalid pointers, etc., rather than by run-time errors such as out-of-memory conditions.

Some programmer errors are explicitly tagged as "Panic Reasons" and SHALL be reliably detected by an implementation. These errors make it impossible to produce the result of the function and require that the API panic the calling TA instance, which kills the instance. If such a Panic Reason occurs, it SHALL NOT go undetected and, e.g. produce incorrect results or corrupt TA data.

However, it is accepted that some programmer errors cannot be realistically detected at all times and that precise behavior cannot be specified without putting too much of a burden on the implementation. In case of such a programmer error, an implementation is therefore not required to gracefully handle the error or even to behave consistently, but the implementation SHOULD still make a best effort to detect the error and panic the calling TA. In any case, a Trusted Application SHALL NOT be able to use a programmer error on purpose to circumvent the security boundaries enforced by an implementation.

In general, incorrect handles—i.e. handles not returned by the API, already closed, with the wrong owner, type, or state—are definite Panic Reasons while incorrect pointers are imprecise programmer errors.

Any routine defined by this specification MAY generate a Panic if it detects a relevant hardware failure or is passed invalid arguments that could have been detected by the programmer, even if no Panic Reasons are listed for that routine.

2.3.3 Panics

The GlobalPlatform TA interface assumes that parameters have been validated prior to calling. While some platforms might return errors for invalid parameters, security vulnerabilities are often created by incorrect error handling. Thus, rather than returning errors, the general design of the GlobalPlatform interfaces invokes a Panic in the TA.

To avoid TA Panics, the TA implementer SHALL handle potential fault conditions before calling the Trusted OS. This approach reduces the likelihood of a TA implementer introducing security vulnerabilities.

A Panic is an instance-wide uncatchable exception that kills a whole TA instance.

1. A Panic SHALL be raised when the implementation detects an avoidable programmer error and there is no specifically defined error code which covers the problem.
2. A Panic SHALL be raised when the Trusted Application itself requests a Panic by calling the function `TEE_Panic`.
3. A Panic MAY be raised if the TA's action results in detection of a fault in the TEE itself (e.g. a corrupted TEE library) which renders the called services temporarily or permanently unavailable.
4. A Trusted OS MAY raise a TA Panic under implementation-defined circumstances.

In earlier versions of this and other GlobalPlatform TEE specifications, function definitions frequently contain the "catch all" statement that a TA may panic if an error occurs which is not one of those specified for an API which has been called by the TA.

With the introduction of the Peripheral API, and in particular the Event API, it should be noted that:

- A function SHALL NOT cause a Panic if the error detected during the call is not specifically defined for or occurring within that function.
- A function SHALL NOT cause a Panic due to an error detected during an asynchronous operation.
- It is the responsibility of the Trusted OS to cause a Panic based on the criteria of a specific function/operation.
- An asynchronous operation SHALL cause a Panic in the background of any function if one or more of the Panic Reasons defined for that asynchronous operation is met.
- In all cases, any reported specification number and function number SHALL be for the operation or function that met one or more of its Panic Reasons and SHALL NOT be for any other operation or function that is occurring at the same time.

When a Panic occurs, the Trusted Core Framework kills the panicking TA instance and does the following:

- It discards all client entry point calls queued on the TA instance and closes all sessions opened by Clients.
- It closes all resources that the TA instance opened, including all handles and all memory, and destroys the instance. Note that multiple instances can reference a common resource, for example an object. If an instance sharing a resource is destroyed, the Framework does not destroy the shared resource immediately, but will wait until no other instances reference the resource before reclaiming it.

After a Panic, no TA function of the instance is ever called again, not even `TA_DestroyEntryPoint`.

From the client's point of view, when a Trusted Application panics, the client commands SHALL return the error `TEE_ERROR_TARGET_DEAD` with an origin value of `TEE_ORIGIN_TEE` until the session is closed. (For details about return origins, see the function `TEE_InvokeTACommand` in section 4.9.3 or the function `TEEC_InvokeCommand` in [Client API] section 4.5.9.)

When a Panic occurs, an implementation in a non-production environment, such as in a development or pre-production state, is encouraged to issue precise diagnostic information using the mechanisms defined in GlobalPlatform TEE TA Debug Specification ([TEE TA Debug]) or an implementation-specific alternative to help the developer understand the programmer error. Diagnostic information SHOULD NOT be exposed outside of a secure development environment.

The debug API defined mechanism [TEE TA Debug] passes a Panic code among the information it returns. This SHALL either be the Panic code passed to `TEE_Panic` or any standard or implementation-specific error code which best indicates the reason for the Panic.

2.4 Opaque Handles

This specification makes use of handles that opaquely refer to objects created by the API implementation for a particular TA instance. A handle is only valid in the context of the TA instance that creates it and SHALL always be associated with a type.

The special value `TEE_HANDLE_NULL`, which SHALL always be `0`, is used to denote the absence of a handle. It is typically used when an error occurs or sometimes to trigger a special behavior in some function. For example, the function `TEE_SetOperationKey` clears the operation key if passed `TEE_HANDLE_NULL`. In general, the "close"-like functions do nothing if they are passed the `NULL` handle.

Other than the particular case of `TEE_HANDLE_NULL`, this specification does not define any constraint on the actual value of a handle.

Passing an invalid handle, i.e. a handle not returned by the API, already closed, or of the wrong type, is always a programmer error, except sometimes for the specific value `TEE_HANDLE_NULL`. When a handle is dereferenced by the API, the implementation SHALL always check its validity and panic the TA instance if it is not valid.

This specification defines a C type for each high-level type of handle. The following types are defined:

Table 2-1: Handle Types

Handle Type	Handle Purpose
`TEE_TASessionHandle`	Handle on sessions opened by a TA on another TA
`TEE_PropSetHandle`	Handle on a property set or a property enumerator
`TEE_ObjectHandle`	Handle on a cryptographic object
`TEE_ObjectEnumHandle`	Handle on a persistent object enumerator
`TEE_OperationHandle`	Handle on a cryptographic operation
`TEE_PeripheralHandle`	Handle on a peripheral
`TEE_EventQueueHandle`	Handle on an event queue
`TEE_EventSourceHandle`	Handle on an event source

These C types are defined as pointers on undefined structures. For example, `TEE_TASessionHandle` is defined as `struct __TEE_TASessionHandle*`. This is just a means to leverage the C language type-system to help separate different handle types. It does not mean that an implementation has to define the structure, and handles do not need to represent addresses.

2.5 Properties

This specification makes use of Properties to represent configuration parameters, permissions, or implementation characteristics.

A property is an immutable value identified by a name, which is a Unicode string. The property value can be retrieved in a variety of formats: Unicode string, binary block, 32-bit integer, Boolean, and Identity.

Property names and values are intended to be rather small with a few hundreds of characters at most, although the specification defines no limit on the size of names or values.

In this specification, Unicode strings are always encoded in zero-terminated UTF-8, which means that a Unicode string cannot contain the U+0000 code point.

The value of a property is immutable: A Trusted Application can only retrieve it and cannot modify it. The value is set and controlled by the implementation and SHALL be trustable by the Trusted Applications.

The following Property Sets are exposed in the API:

- Each Trusted Application can access its own configuration properties. Some of these parameters affect the behavior of the Trusted OS itself. Others can be used to configure the behavior of the TAs that this TA connects to.
- A TA instance can access a set of properties for each of its Clients. When the Client is a Trusted Application, the property set contains the configuration properties of that Trusted Application. Otherwise, it contains properties set by the Regular Execution Environment.
- Finally, a TA can access properties describing characteristics of the implementation, including the hardware platform on which it is executing.

Property names are case-sensitive and have a hierarchical structure with levels in the hierarchy separated by the dot character "`.`". Property names SHOULD use the reverse domain name convention to minimize the risk of collisions between properties defined by different organization, although this cannot really be enforced by an implementation. For example, the ACME company SHOULD use the "`com.acme.`" prefix and properties standardized at ISO will use the "`org.iso.`" namespace.

This specification reserves the "`gpd.`" namespace and defines the meaning of a few properties in this namespace. Any implementation SHALL refuse to define properties in this namespace unless they are defined in the GlobalPlatform specifications.

2.6 Peripheral Support

This specification defines support for managing peripherals. There are functions for communicating directly, in a low-level manner, with peripherals and support for an event loop which can receive events from peripherals such as touch screens and biometric authenticators.

In this specification, the Peripheral API and Event API are optional. Implementation of other GlobalPlatform specifications may make the presence of the Peripheral API and Event API mandatory. As an example, at the time of writing the GlobalPlatform TEE TUI Extension: Biometrics API ([TEE TUI Bio]) and GlobalPlatform TEE Trusted User Interface Low-level API ([TEE TUI Low]) specifications require support of the Peripheral and Event APIs.

3 Common Definitions

This chapter specifies the header file, common data types, constants, and parameter annotations used throughout the specification.

3.1 Header File

Since: TEE Internal API v1.0

The header file for the TEE Internal Core API SHALL have the name "`tee_internal_api.h`".

```
#include "tee_internal_api.h"
```

3.1.1 API Version

Since: TEE Internal Core API v1.1.2

The header file SHALL contain version specific definitions from which TA compilation options can be selected.

```
#define TEE_CORE_API_MAJOR_VERSION ([Major version number])
#define TEE_CORE_API_MINOR_VERSION ([Minor version number])
#define TEE_CORE_API_MAINTENANCE_VERSION ([Maintenance version number])
#define TEE_CORE_API_VERSION (TEE_CORE_API_MAJOR_VERSION << 24) +
(TEE_CORE_API_MINOR_VERSION << 16) +
(TEE_CORE_API_MAINTENANCE_VERSION << 8)
```

The document version-numbering format is ***X.Y[.z]***, where:

- Major Version (X) is a positive integer identifying the major release.
- Minor Version (Y) is a positive integer identifying the minor release.
- The optional Maintenance Version (z) is a positive integer identifying the maintenance release.

`TEE_CORE_API_MAJOR_VERSION` indicates the major version number of the TEE Internal Core API. It SHALL be set to the major version number of this specification.

`TEE_CORE_API_MINOR_VERSION` indicates the minor version number of the TEE Internal Core API. It SHALL be set to the minor version number of this specification. If the minor version is zero, then one zero shall be present.

`TEE_CORE_API_MAINTENANCE_VERSION` indicates the maintenance version number of the TEE Internal Core API. It SHALL be set to the maintenance version number of this specification. If the maintenance version is zero, then one zero shall be present.

The definitions of "Major Version", "Minor Version", and "Maintenance Version" in the version number of this specification are determined as defined in the GlobalPlatform Document Management Guide ([Doc Mgmt]). In particular, the value of `TEE_CORE_API_MAINTENANCE_VERSION` SHALL be zero if it is not already defined as part of the version number of this document. The "Draft Revision" number SHALL NOT be provided as an API version indication.

A compound value SHALL also be defined. If the Maintenance version number is `0`, the compound value SHALL be defined as:

```
#define TEE_CORE_API_[Major version number]_[Minor version number]
```

If the Maintenance version number is not zero, the compound value SHALL be defined as:

```
#define TEE_CORE_API_[Major version number]_[Minor version
number]_[Maintenance version number]
```

Some examples of version definitions:

For GlobalPlatform TEE Internal Core API Specification v1.3, these would be:

```
#define TEE_CORE_API_MAJOR_VERSION       (1)
#define TEE_CORE_API_MINOR_VERSION       (3)
#define TEE_CORE_API_MAINTENANCE_VERSION  (0)
#define TEE_CORE_API_1_3
```

And the value of `TEE_CORE_API_VERSION` would be `0x01030000`.

For a maintenance release of the specification as v2.14.7, these would be:

```
#define TEE_CORE_API_MAJOR_VERSION       (2)
#define TEE_CORE_API_MINOR_VERSION       (14)
#define TEE_CORE_API_MAINTENANCE_VERSION  (7)
#define TEE_CORE_API_2_14_7
```

And the value of `TEE_CORE_API_VERSION` would be `0x020E0700`.

3.1.2 Target and Version Optimization

This specification supports definitions that TA vendors can use to specialize behavior at compile time to provide version and target-specific optimizations.

This version of the specification is designed so that it can be used in conjunction with mechanisms to:

- Provide information about the target platform and Trusted OS
- Configure the compile and link environment to the configuration best suited to a Trusted Application

The detail of these mechanisms and their output is out of scope of this document, but it is intended that the output could be generated automatically from build system metadata and included by `tee_internal_api.h`.

The file prefix "`gpd_ta_build_`" is reserved for files generated by the build system, possibly derived from metadata.

The model for TA construction supported by this specification assumes that a TA will be built to comply to a specific target and set of API versions which is fixed at compile time. A Trusted OS MAY support more than one set of target and API versions at run-time by mechanisms which are out of scope of this specification.

3.1.3 Support for Optional Capabilities

Since: TEE Internal Core API v1.2

A Trusted OS supporting the optional Peripheral and Event APIs SHALL define the following sentinel:

```
#define TEE_CORE_API_EVENT
```

Since: TEE Internal Core API v1.3

To support TMF audit capabilities, the following value is defined in alignment with [TMF ASN.1] Table 9-7.

Table 3-0: Internal API Names Strings Definition

Strings	Description
`Core-EP`	Peripheral and Event APIs

3.2 Data Types

In general, comparison of values of given data types is only valid within the scope of a TA instance. Even in the same Trusted OS, other TA instances may have different endianness and word length. It is up to the TA implementer to make sure their TA to TA protocols take this in to account.

3.2.1 Basic Types

This specification makes use of the integer and Boolean C types as defined in the C99 standard (ISO/IEC 9899:1999 – [C99]). In the event of any difference between the definitions in this specification and those in [C99], C99 shall prevail.

The following basic types are used:

`size_t`	The unsigned integer type of the result of the `sizeof` operator.
`uintptr_t`	An unsigned integer type with the property that any valid pointer to `void` can be converted to this type, then converted back to `void*` in a given TA instance, and the result will compare equal to the original pointer.
`intptr_t`	A signed integer type with the property that any valid pointer to `void` can be converted to this type, then converted back to `void*` in a given TA instance, and the result will compare equal to the original pointer.
`intmax_t`	A signed integer type capable of representing any value of any signed integer type.
`uint64_t`	Unsigned 64-bit integer
`int64_t`	Signed 64-bit integer
`uint32_t`	Unsigned 32-bit integer
`int32_t`	Signed 32-bit integer
`uint16_t`	Unsigned 16-bit integer
`int16_t`	Signed 16-bit integer
`uint8_t`	Unsigned 8-bit integer
`int8_t`	Signed 8-bit integer
`bool`	Boolean type with the values `true` and `false`
`char`	Character; used to denote a byte in a zero-terminated string encoded in UTF-8

3.2.2 Bit Numbering

In this specification, bits in integers are numbered from `0` (least-significant bit) to n (most-significant bit), where n + 1 bits are used to represent the integer, e.g. for a 2048-bit `TEE_BigInt`, the bits would be numbered `0` to `2047` and for a 32-bit `uint32_t` they would be numbered from `0` to `31`.

3.2.3 TEE_Result, TEEC_Result

Since: TEE Internal API v1.0

```
typedef uint32_t TEE_Result;
```

`TEE_Result` is the type used for return codes from the APIs.

For compatibility with [Client API], the following alias of this type is also defined:

Since: TEE Internal API v1.0

```
typedef TEE_Result TEEC_Result;
```

3.2.4 TEE_UUID, TEEC_UUID

Since: TEE Internal API v1.0

```
typedef struct
{
   uint32_t timeLow;
   uint16_t timeMid;
   uint16_t timeHiAndVersion;
   uint8_t  clockSeqAndNode[8];
} TEE_UUID;
```

`TEE_UUID` is the Universally Unique Resource Identifier type as defined in [RFC 4122]. This type is used to identify Trusted Applications and clients.

UUIDs can be directly hard-coded in the Trusted Application code. For example, the UUID `79B77788-9789-4a7a-A2BE-B60155EEF5F3` can be hard-coded using the following code:

```
static const TEE_UUID myUUID =
{
    0x79b77788, 0x9789, 0x4a7a,
    { 0xa2, 0xbe, 0xb6, 0x1, 0x55, 0xee, 0xf5, 0xf3 }
};
```

For compatibility with [Client API], the following alias of this type is also defined:

> **Note:** The `TEE_UUID` structure is sensitive to differences in the endianness of the Client API and the TA. It is the responsibility of the Trusted OS to ensure that any endianness difference between client and TA is managed internally when those structures are passed through one of the defined APIs. The definition below assumes that the endianness of both Client API and TA are the same, and needs to be changed appropriately if this is not the case.

Since: TEE Internal API v1.0

```
typedef TEE_UUID TEEC_UUID;
```

Universally Unique Resource Identifiers come in a number of different versions. The following reservations of usage are made:

Since: TEE Internal Core API v1.1, based on [TMF ASN.1] v1.0

Table 3-1: UUID Usage Reservations

Version	Reservation
UUID v5	If a TEE supports [TMF ASN.1], then TA and Security Domain (SD) UUIDs using version 5 SHALL conform to the extended v5 requirements found in that specification.

3.3 Constants

3.3.1 Return Code Ranges and Format

The format of return codes and the reserved ranges are defined in the following table.

Table 3-2: Return Code Formats and Ranges

Range	Value	Format Notes
`TEE_SUCCESS`	`0x00000000`	
Reserved for use in GlobalPlatform specifications, providing non-error information	`0x00000001` – `0x6FFFFFFF`	The return code may identify the specification, as discussed following the table.
Reserved for implementation-specific return code providing non-error information	`0x70000000` – `0x7FFFFFFF`	
Reserved for implementation-specific errors	`0x80000000` – `0x8FFFFFFF`	
Reserved for future use in GlobalPlatform specifications	`0x90000000` – `0xEFFFFFFF`	
Reserved for GlobalPlatform TEE API defined errors	`0xF0000000` – `0xFFFEFFFF`	The return code may identify the specification, as discussed following the table.
Client API defined Errors (`TEEC_*`) Note that some return codes from this and other specifications have incorrectly been defined in this range and are therefore grandfathered in.	`0xFFFF0000` – `0xFFFFFFFF`	

An error code is a return code that denotes some failure: These are the return codes above `0x7FFFFFFF`.

Return codes in specified ranges in Table 3-2 MAY include the specification number as a 3-digit BCD (Binary Coded Decimal) value in nibbles 7 through 5 (where the high nibble is considered nibble 8).

For example, GPD_SPE_**123** may define return codes as follows:

- Specification unique non-error return codes may be numbered `0x0`**`123`**`0000` to `0x0`**`123`**`FFFF`.
- Specification unique error codes may be numbered `0xF`**`123`**`0000` to `0xF`**`123`**`FFFF`.

3.3.2 Return Codes

Table 3-3 lists return codes that are used throughout the APIs.

Note: While a minor specification version update does not intentionally break backwards compatibility, it does occasionally have to add new return codes to existing API. For this reason, we advise the developer not only to check for known return codes but to assume that there may be other unknown error codes reported by a function when a TA is running in a newer environment than that for which the TA was originally developed. By default, only `TEE_SUCCESS` is a success and ANYTHING else should be considered a failure.

Table 3-3: API Return Codes

Constant Names and Aliases		Value
TEE_SUCCESS	TEEC_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_UNSUPPORTED_VERSION		0xF0100005
TEE_ERROR_CIPHERTEXT_INVALID		0xF0100006
TEE_ERROR_GENERIC	TEEC_ERROR_GENERIC	0xFFFF0000
TEE_ERROR_ACCESS_DENIED	TEEC_ERROR_ACCESS_DENIED	0xFFFF0001
TEE_ERROR_CANCEL	TEEC_ERROR_CANCEL	0xFFFF0002
TEE_ERROR_ACCESS_CONFLICT	TEEC_ERROR_ACCESS_CONFLICT	0xFFFF0003
TEE_ERROR_EXCESS_DATA	TEEC_ERROR_EXCESS_DATA	0xFFFF0004
TEE_ERROR_BAD_FORMAT	TEEC_ERROR_BAD_FORMAT	0xFFFF0005
TEE_ERROR_BAD_PARAMETERS	TEEC_ERROR_BAD_PARAMETERS	0xFFFF0006
TEE_ERROR_BAD_STATE	TEEC_ERROR_BAD_STATE	0xFFFF0007
TEE_ERROR_ITEM_NOT_FOUND	TEEC_ERROR_ITEM_NOT_FOUND	0xFFFF0008
TEE_ERROR_NOT_IMPLEMENTED	TEEC_ERROR_NOT_IMPLEMENTED	0xFFFF0009
TEE_ERROR_NOT_SUPPORTED	TEEC_ERROR_NOT_SUPPORTED	0xFFFF000A
TEE_ERROR_NO_DATA	TEEC_ERROR_NO_DATA	0xFFFF000B
TEE_ERROR_OUT_OF_MEMORY	TEEC_ERROR_OUT_OF_MEMORY	0xFFFF000C
TEE_ERROR_BUSY	TEEC_ERROR_BUSY	0xFFFF000D
TEE_ERROR_COMMUNICATION	TEEC_ERROR_COMMUNICATION	0xFFFF000E
TEE_ERROR_SECURITY	TEEC_ERROR_SECURITY	0xFFFF000F
TEE_ERROR_SHORT_BUFFER	TEEC_ERROR_SHORT_BUFFER	0xFFFF0010
TEE_ERROR_EXTERNAL_CANCEL	TEEC_ERROR_EXTERNAL_CANCEL	0xFFFF0011
TEE_ERROR_TIMEOUT		0xFFFF3001
TEE_ERROR_OVERFLOW		0xFFFF300F
TEE_ERROR_TARGET_DEAD	TEEC_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
TEE_ERROR_TIME_NEEDS_RESET		0xFFFF5001

3.4 Parameter Annotations

This specification uses a set of patterns on the function parameters. Instead of repeating this pattern again on each occurrence, these patterns are referred to with Parameter Annotations. It is expected that this will also help with systematically translating the APIs into languages other than the C language.

The following sub-sections list all the parameter annotations used in the specification.

Note that these annotations cannot be expressed in the C language. However, the *[in]*, *[inbuf]*, *[instring]*, *[instringopt]*, and *[ctx]* annotations can make use of the `const` C keyword. This keyword is omitted in the specification of the functions to avoid mixing the formal annotations and a less expressive C keyword. However, the C header file of a compliant implementation SHOULD use the `const` keyword when these annotations appear.

3.4.1 [in], [out], and [inout]

The annotation *[in]* applies to a parameter that has a pointer type on a structure, a base type, or more generally a buffer of a size known in the context of the API call. If the size needs to be clarified, the syntax *[in(size)]* is used.

When the *[in]* annotation is present on a parameter, it means that the API implementation uses the pointer only for reading and does not accept shared memory.

When a Trusted Application calls an API function that defines a parameter annotated with *[in]*, the parameter SHALL be entirely readable by the Trusted Application and SHALL be entirely owned by the calling Trusted Application instance, as defined in section 4.11.1. In particular, this means that the parameter SHALL NOT reside in a block of shared memory owned by a client of the Trusted Application. The implementation SHALL check these conditions and if they are not satisfied, the API call SHALL panic the calling Trusted Application instance.

The annotations *[out]* and *[inout]* are equivalent to *[in]* except that they indicate write access and read-and-write access respectively.

Note that, as described in section 4.11.1, the `NULL` pointer SHALL never be accessible to a Trusted Application. This means that a Trusted Application SHALL NOT pass the `NULL` pointer in an *[in]* parameter, except perhaps if the buffer size is zero.

See the function `TEE_CheckMemoryAccessRights` in section 4.11.1 for more details about shared memory and the `NULL` pointer. See the function `TEE_Panic` in section 4.8.1 for information about Panics.

3.4.2 [outopt]

The *[outopt]* annotation is equivalent to *[out]* except that the caller can set the parameter to `NULL`, in which case the result SHALL be discarded.

3.4.3 [inbuf] and [inoutbuf]

The *[inbuf]* annotation applies to a pair of parameters, the first of which is of pointer type, such as a `void*`, and the second of which is of type `size_t`. It means that the parameters describe an input data buffer. The entire buffer SHALL be readable by the Trusted Application and there is no restriction on the owner of the buffer: It can reside in shared memory or in private memory.

The implementation SHALL check that the buffer is entirely readable and SHALL panic the calling Trusted Application instance if that is not the case.

Because the `NULL` pointer is never accessible, a Trusted Application cannot pass `NULL` in the first (pointer) parameter unless the second (`size_t`) parameter is set to `0`.

The *[inoutbuf]* annotation is equivalent to *[inbuf]* except that it indicates read-and-write access to the data buffer. The implementation SHALL check that the buffer is entirely readable and writable and SHALL panic the calling Trusted Application instance if that is not the case.

3.4.4 [outbuf]

The *[outbuf]* annotation applies to a pair of parameters, the first of which is of pointer type, such as a `void*`, and the second of which is of type `size_t*`, herein referenced with the names `buffer` and `size`. It is used by API functions to return an output data buffer. The data buffer SHALL be allocated by the calling Trusted Application and passed in the `buffer` parameter. Because the size of the output buffer cannot generally be determined in advance, the following convention is used:

- On entry, `*size` contains the number of bytes actually allocated in `buffer`. The buffer with this number of bytes SHALL be entirely writable by the Trusted Application; otherwise the implementation SHALL panic the calling Trusted Application instance. In any case, the implementation SHALL NOT write beyond this limit.
- On return:
  - If the output fits in the output buffer, then the implementation SHALL write the output in `buffer` and SHALL update `*size` with the actual size of the output in bytes.
  - If the output does not fit in the output buffer, then the implementation SHALL update `*size` with the required number of bytes and SHALL return `TEE_ERROR_SHORT_BUFFER`. It is implementation-dependent whether the output buffer is left untouched or contains part of the output. In any case, the TA SHOULD consider that its content is undefined after the function returns.

When the function returns `TEE_ERROR_SHORT_BUFFER`, it SHALL return the size of the output data.

Note that if the caller sets `*size` to `0`, the function will always return `TEE_ERROR_SHORT_BUFFER` unless the actual output data is empty. In this case, the parameter `buffer` can take any value, e.g. `NULL`, as it will not be accessed by the implementation. If `*size` is set to a non-zero value on entry, then `buffer` cannot be `NULL` because the buffer starting from the `NULL` address is never writable.

There is no restriction on the owner of the buffer: It can reside in shared memory or in private memory.

The parameter `size` SHALL be considered as *[inout]*. That is, `size` SHALL be readable and writable by the Trusted Application. The parameter `size` SHALL NOT be `NULL` and SHALL NOT reside in shared memory. The implementation SHALL check these conditions and panic the calling Trusted Application instance if they are not satisfied.

3.4.5 [outbufopt]

The *[outbufopt]* annotation is equivalent to *[outbuf]* but if the parameter `size` is set to `NULL`, then the function SHALL behave as if the output buffer was not large enough to hold the entire output data and the output data SHALL be discarded. In this case, the parameter `buffer` is ignored, but SHOULD normally be set to `NULL`, too.

Note the difference between passing a `size` pointer set to `NULL` and passing a `size` that points to `0`. Assuming the function does not fail for any other reasons:

- If `size` is set to `NULL`, the function performs the operation, returns `TEE_SUCCESS`, and the output data is discarded.
- If `size` points to `0`, the function does not perform the operation. It just updates `*size` with the output size and returns `TEE_ERROR_SHORT_BUFFER`.

3.4.6 [instring] and [instringopt]

The *[instring]* annotation applies to a single *[in]* parameter, which SHALL contain a zero-terminated string of `char` characters. Because the buffer is *[in]*, it cannot reside in shared memory.

The *[instringopt]* annotation is equivalent to *[instring]* but the parameter can be set to `NULL` to denote the absence of a string.

3.4.7 [outstring] and [outstringopt]

The *[outstring]* annotation is equivalent to *[outbuf]*, but the output data is specifically a zero-terminated string of `char` characters. The size of the buffer SHALL account for the zero terminator. The buffer may reside in shared memory.

The *[outstringopt]* annotation is equivalent to *[outstring]* but with *[outbufopt]* instead of *[outbuf]*, which means that `size` can be set to `NULL` to discard the output.

3.4.8 [ctx]

The *[ctx]* annotation applies to a `void*` parameter. It means that the parameter is not accessed by the implementation, but will merely be stored to be provided to the Trusted Application later. Although a Trusted Application typically uses such parameters to store pointers to allocated structures, they can contain any value.

3.5 Backward Compatibility

It is an explicit principle of the design of the TEE Internal Core API that backward compatibility is supported between specification versions with the same major version number. It is, in addition, a principle of the design of this specification that the API should not depend on details of the implementation platform.

There are cases where previous versions of the TEE Internal Core API contain API definitions which depend on memory accesses being expressible using 32-bit representations for pointers and buffer sizes. In TEE Internal Core API v1.2 and later we resolve this issue in a way which is backward compatible with idiomatic C99 code, but which may cause issues with code which has been written making explicit assumptions about C language type coercions to 32-bit integers.

From TEE Internal Core API v1.2 onward, definitions are available which allow a TA or its build environment to define the API version it requires. A Trusted OS or the corresponding TA build system can use these to select how TEE Internal Core API features are presented to the TA.

3.5.1 Version Compatibility Definitions

A TA can set the definitions in this section to non-zero values if it was written in a way that requires strict compatibility with a specific version of this specification. These definitions could, for example, be set in the TA source code, or they could be set by the build system provided by the Trusted OS, based on metadata that is out of scope of this specification.

This mechanism can be used where a TA depends for correct operation on the older definition. TA authors are warned that older versions are updated to clarify intended behavior rather than to change it, and there may be inconsistent behavior between different Trusted OS platforms where these definitions are used.

This mechanism resolves all necessary version information when a TA is compiled to run on a given Trusted OS.

Since: TEE Internal Core API v1.2

```
#define TEE_CORE_API_REQUIRED_MAJOR_VERSION          (major)
#define TEE_CORE_API_REQUIRED_MINOR_VERSION          (minor)
#define TEE_CORE_API_REQUIRED_MAINTENANCE_VERSION    (maintenance)
```

The following rules govern the use of `TEE_CORE_API_REQUIRED_MAJOR_VERSION`, `TEE_CORE_API_REQUIRED_MINOR_VERSION`, and `TEE_CORE_API_REQUIRED_MAINTENANCE_VERSION` by TA implementers:

- If `TEE_CORE_API_REQUIRED_MAINTENANCE_VERSION` is defined by a TA, then `TEE_CORE_API_REQUIRED_MAJOR_VERSION` and `TEE_CORE_API_REQUIRED_MINOR_VERSION` SHALL also be defined by the TA.
- If `TEE_CORE_API_REQUIRED_MINOR_VERSION` is defined by a TA, then `TEE_CORE_API_REQUIRED_MAJOR_VERSION` SHALL also be defined by the TA.

If the TA violates any rule above, TA compilation SHALL stop with an error indicating the reason.

`TEE_CORE_API_REQUIRED_MAJOR_VERSION` is used by a TA to indicate that it requires strict compatibility with a specific major version of this specification in order to operate correctly. If this value is set to `0` or is unset, it indicates that the latest major version of this specification SHALL be used.

`TEE_CORE_API_REQUIRED_MINOR_VERSION` is used by a TA to indicate that it requires strict compatibility with a specific minor version of this specification in order to operate correctly. If this value is unset, it indicates that the latest minor version of this specification associated with the determined `TEE_CORE_API_REQUIRED_MAJOR_VERSION` SHALL be used.

`TEE_CORE_API_REQUIRED_MAINTENANCE_VERSION` is used by a TA to indicate that it requires strict compatibility with a specific major version of this specification in order to operate correctly. If this value is unset, it indicates that the latest maintenance version of this specification associated with `TEE_CORE_API_REQUIRED_MAJOR_VERSION` and `TEE_CORE_API_REQUIRED_MINOR_VERSION` SHALL be used.

If **none** of the definitions above is set, a Trusted OS or its build system SHALL select the most recent version of this specification that it supports, as defined in section 3.1.1.

If the Trusted OS is unable to provide an implementation matching the request from the TA, compilation of the TA against that Trusted OS or its build system SHALL fail with an error indicating that the Trusted OS is incompatible with the TA. This ensures that TAs originally developed against previous versions of this specification can be compiled with identical behavior, or will fail to compile.

If the above definitions are set, a Trusted OS SHALL behave exactly according to the definitions for the indicated version of the specification, with only the definitions in that version of the specification being exported to a TA by the trusted OS or its build system. In particular an implementation SHALL NOT enable APIs which were first defined in a later version of this specification than the version requested by the TA.

If the above definitions are set to `0` or are not set, then the Trusted OS SHALL behave according to this version of the specification.

To assist TA developers wishing to make use of backward-compatible behavior, each API in this document is marked with the version of this specification in which it was last modified. Where strict backward compatibility is not maintained, information has been provided to explain any changed behavior.

As an example, consider a TA which requires strict compatibility with TEE Internal Core API v1.1:

```
#define TEE_CORE_API_REQUIRED_MAJOR_VERSION          (1)
#define TEE_CORE_API_REQUIRED_MINOR_VERSION          (1)
#define TEE_CORE_API_REQUIRED_MAINTENANCE_VERSION    (0)
```

Due to the semantics of the C preprocessor, the above definitions SHALL be defined before the main body of definitions in "`tee_internal_api.h`" is processed. The mechanism by which this occurs is out of scope of this specification.

4 Trusted Core Framework API

This chapter defines the Trusted Core Framework API, defining OS-like APIs and infrastructure. It contains the following sections:

- Section 4.1, Data Types
- Section 4.2, Constants

  Common definitions used throughout the chapter.
- Section 4.3, TA Interface

  Defines the entry points that each TA SHALL define.
- Section 4.4, Property Access Functions

  Defines the generic functions to access properties. These functions can be used to access TA Configuration Properties, Client Properties, and Implementation Properties.
- Section 4.5, Trusted Application Configuration Properties

  Defines the standard Trusted Application Configuration Properties.
- Section 4.6, Client Properties

  Defines the standard Client Properties.
- Section 4.7, Implementation Properties

  Defines the standard Implementation Properties of the TEE.
- Section 4.8, Panics

  Defines the function `TEE_Panic`.
- Section 4.9, Internal Client API

  Defines the Internal Client API that allows a Trusted Application to act as a Client of another Trusted Application.
- Section 4.10, Cancellation Functions

  Defines how a Trusted Application can handle client cancellation requests, acknowledge them, and mask or unmask the propagated effects of cancellation requests on cancellable functions.
- Section 4.11, Memory Management Functions

  Defines how to check the access rights to memory buffers, how to access global variables, how to allocate memory (similar to malloc), and a few utility functions to fill or copy memory blocks.

4.1 Data Types

4.1.1 TEE_Identity

Since: TEE Internal API v1.0

```
typedef struct
{
   uint32_t   login;
   TEE_UUID   uuid;
} TEE_Identity;
```

The `TEE_Identity` structure defines the full identity of a Client:

- `login` is one of the `TEE_LOGIN_XXX` constants. (See section 4.2.2.)
- `uuid` contains the client UUID or Nil (as defined in [RFC 4122]) if not applicable.

4.1.2 TEE_Param

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
typedef union
{
   struct
   {
      void*    buffer; size_t   size;
   } memref;
   struct
   {
      uint32_t a;
      uint32_t b;
   } value;
} TEE_Param;
```

This union describes one parameter passed by the Trusted Core Framework to the entry points `TA_OpenSessionEntryPoint` or `TA_InvokeCommandEntryPoint` or by the TA to the functions `TEE_OpenTASession` or `TEE_InvokeTACommand`.

Which of the field `value` or `memref` to select is determined by the parameter type specified in the argument `paramTypes` passed to the entry point. See section 4.3.6.1 and section 4.9.4 for more details on how this type is used.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `size`.

4.1.3 TEE_TASessionHandle

Since: TEE Internal API v1.0

```
typedef struct __TEE_TASessionHandle* TEE_TASessionHandle;
```

`TEE_TASessionHandle` is an opaque handle (as defined in section 2.4) on a TA Session. These handles are returned by the function `TEE_OpenTASession` specified in section 4.9.1.

4.1.4 TEE_PropSetHandle

Since: TEE Internal API v1.0

```
typedef struct __TEE_PropSetHandle* TEE_PropSetHandle;
```

`TEE_PropSetHandle` is an opaque handle (as defined in section 2.4) on a property set or enumerator. These handles either are returned by the function `TEE_AllocatePropertyEnumerator` specified in section 4.4.7 or are one of the pseudo-handles defined in section 4.2.4.

Since: TEE Internal Core API v1.2

`TEE_PropSetHandle` values use interfaces that are shared between defined constants and real opaque handles.

The Trusted OS SHALL take precautions that it will never generate a real opaque handle of type `TEE_PropSetHandle` using constant values defined in section 4.2.4, and that when acting upon a `TEE_PropSetHandle` it will, where appropriate, filter for these constant values first.

4.2 Constants

4.2.1 Parameter Types

Table 4-1: Parameter Type Constants

Constant Name	Equivalent on Client API	Constant Value
TEE_PARAM_TYPE_NONE	TEEC_NONE	0
TEE_PARAM_TYPE_VALUE_INPUT	TEEC_VALUE_INPUT	1
TEE_PARAM_TYPE_VALUE_OUTPUT	TEEC_VALUE_OUTPUT	2
TEE_PARAM_TYPE_VALUE_INOUT	TEEC_VALUE_INOUT	3
TEE_PARAM_TYPE_MEMREF_INPUT	TEEC_MEMREF_TEMP_INPUT or TEEC_MEMREF_PARTIAL_INPUT	5
TEE_PARAM_TYPE_MEMREF_OUTPUT	TEEC_MEMREF_TEMP_OUTPUT or TEEC_MEMREF_PARTIAL_OUTPUT	6
TEE_PARAM_TYPE_MEMREF_INOUT	TEEC_MEMREF_TEMP_INOUT or TEEC_MEMREF_PARTIAL_INOUT	7

4.2.2 Login Types

Table 4-2: Login Type Constants

Constant Name	Equivalent on Client API	Constant Value
TEE_LOGIN_PUBLIC	TEEC_LOGIN_PUBLIC	0x00000000
TEE_LOGIN_USER	TEEC_LOGIN_USER	0x00000001
TEE_LOGIN_GROUP	TEEC_LOGIN_GROUP	0x00000002
TEE_LOGIN_APPLICATION	TEEC_LOGIN_APPLICATION	0x00000004
TEE_LOGIN_APPLICATION_USER	TEEC_LOGIN_APPLICATION_USER	0x00000005
TEE_LOGIN_APPLICATION_GROUP	TEEC_LOGIN_APPLICATION_GROUP	0x00000006
Reserved for future GlobalPlatform defined login types		0x00000007 – 0x7FFFFFFF
Reserved for implementation-specific login types		0x80000000 – 0xEFFFFFFF
TEE_LOGIN_TRUSTED_APP		0xF0000000
Reserved for future GlobalPlatform defined login types		0xF0000001 – 0xFFFFFFFF

4.2.3 Origin Codes

Table 4-3: Origin Code Constants

Constant Names		Constant Value
`TEE_ORIGIN_API`	`TEEC_ORIGIN_API`	`0x00000001`
`TEE_ORIGIN_COMMS`	`TEEC_ORIGIN_COMMS`	`0x00000002`
`TEE_ORIGIN_TEE`	`TEEC_ORIGIN_TEE`	`0x00000003`
`TEE_ORIGIN_TRUSTED_APP`	`TEEC_ORIGIN_TRUSTED_APP`	`0x00000004`
Reserved for future GlobalPlatform use		`0x00000005 – 0xEFFFFFFF`
Reserved for implementation-specific origin values		`0xF0000000 – 0xFFFFFFFF`

Note: Other specifications can define additional origin code constants, so TA implementers SHOULD ensure that they include default handling for other values.

4.2.4 Property Set Pseudo-Handles

Table 4-4: Property Set Pseudo-Handle Constants

Constant Name	Constant Value
Reserved for use by allocated property set pseudo-handles	All 32-bit address boundary aligned values (i.e. any value with the least significant two address bits zero) are reserved for use as non-constant values allocated by the API as opaque handles.
Reserved	Non 32-bit boundary aligned values in the range `0x00000000 – 0xEFFFFFFF`
Reserved for implementation-specific property sets	Non 32-bit boundary aligned values in the range: `0xF0000000 – 0xFFFEFFFF`
Reserved for future GlobalPlatform use	Non 32-bit boundary aligned values in the range: `0xFFFF0000 – 0xFFFFFFFC`
`TEE_PROPSET_TEE_IMPLEMENTATION`	`(TEE_PropSetHandle)0xFFFFFFFD`
`TEE_PROPSET_CURRENT_CLIENT`	`(TEE_PropSetHandle)0xFFFFFFFE`
`TEE_PROPSET_CURRENT_TA`	`(TEE_PropSetHandle)0xFFFFFFFF`

4.2.5 Memory Access Rights

Table 4-5: Memory Access Rights Constants

Constant Name	Constant Value
`TEE_MEMORY_ACCESS_READ`	`0x00000001`
`TEE_MEMORY_ACCESS_WRITE`	`0x00000002`
`TEE_MEMORY_ACCESS_ANY_OWNER`	`0x00000004`

4.3 TA Interface

Each Trusted Application SHALL 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. These entry points cannot be registered dynamically by the Trusted Application code: They SHALL be bound to the framework before the Trusted Application code is started.

The following table lists the functions in the TA interface.

Table 4-6: TA Interface Functions

TA Interface Function (Entry Point)	Description
`TA_CreateEntryPoint`	This is the Trusted Application constructor. It is called once and only once in the lifetime of the Trusted Application instance. If this function fails, the instance is not created.
`TA_DestroyEntryPoint`	This is the Trusted Application destructor. The Trusted Core Framework calls this function just before the Trusted Application instance is terminated. The Framework SHALL guarantee that no sessions are open when this function is called. When `TA_DestroyEntryPoint` returns, the Framework SHALL collect all resources claimed by the Trusted Application instance.
`TA_OpenSessionEntryPoint`	This function is called whenever a client attempts to connect to the Trusted Application instance to open a new session. If this function returns an error, the connection is rejected and no new session is opened. In this function, the Trusted Application can attach an opaque `void*` context to the session. This context is recalled in all subsequent TA calls within the session.
`TA_CloseSessionEntryPoint`	This function is called when the client closes a session and disconnects from the Trusted Application instance. The implementation guarantees that there are no active commands in the session being closed. The session context reference is given back to the Trusted Application by the Framework. It is the responsibility of the Trusted Application to deallocate the session context if memory has been allocated for it.
`TA_InvokeCommandEntryPoint`	This function is called whenever a client invokes a Trusted Application command. The Framework gives back the session context reference to the Trusted Application in this function call.

The following table summarizes client operations and the resulting Trusted Application effect.

Table 4-7: Effect of Client Operation on TA Interface

Client Operation	Trusted Application Effect

`TEEC_OpenSession`
or
`TEE_OpenTASession`
	If a new Trusted Application instance is needed to handle the session, `TA_CreateEntryPoint` is called.
	Then, `TA_OpenSessionEntryPoint` is called.

`TEEC_InvokeCommand`
or
`TEE_InvokeTACommand`
	`TA_InvokeCommandEntryPoint` is called.

`TEEC_CloseSession`
or
`TEE_CloseTASession`
	`TA_CloseSessionEntryPoint` is called.
	For a multi-instance TA or for a single-instance, non keep-alive TA, if the session closed was the last session on the instance, then `TA_DestroyEntryPoint` is called. Otherwise, the instance is kept until the TEE shuts down.

`TEEC_RequestCancellation` *or* The function `TEE_OpenTASession` or `TEE_InvokeTACommand` is cancelled.	See section 4.10 for details on the effect of cancellation requests.
Client terminates unexpectedly	From the point of view of the TA instance, the behavior SHALL be identical to the situation where the client does not terminate unexpectedly but, for all opened sessions: • requests the cancellation of all pending operations in that session, • waits for the completion of all these operations in that session, • and finally closes that session. Note that there is no way for the TA to distinguish between the client gracefully cancelling all its operations and closing all its sessions and the implementation taking over when the client dies unexpectedly.

Interface Operation Parameters

When a Client opens a session on a Trusted Application or invokes a command, it can send Operation Parameters to the Trusted Application. The parameters encode the data associated with the operation. Up to four parameters can be sent in an operation. If these are insufficient, then one of the parameters may be used to carry further parameter data via a Memory Reference.

Each parameter can be individually typed by the Client as a Value Parameter, carrying two 32-bit integers, or a Memory Reference Parameter, carrying a pointer to a client-owned memory buffer. Each parameter is also tagged with a direction of data flow (input, output, or both input and output). For output Memory References, there is a built-in mechanism for the Trusted Applications to report the necessary size of the buffer in case of a too-short buffer. See section 4.3.6 for more information about the handling of parameters in the TA interface.

Note that Memory Reference Parameters typically point to memory owned by the client and shared with the Trusted Application for the duration of the operation. This is especially useful in the case of REE Clients to minimize the number of memory copies and the data footprint in case a Trusted Application needs to deal with large data buffers, for example to process a multimedia stream protected by DRM.

Security Considerations

The fact that Memory References may use memory directly shared with the client implies that the Trusted Application needs to be especially careful when handling such data: Even if the client is not allowed to access the shared memory buffer during an operation on this buffer, the Trusted OS usually cannot enforce this restriction. A badly-designed or rogue client may well change the content of the shared memory buffer at any time, even between two consecutive memory accesses by the Trusted Application. This means that the Trusted Application needs to be carefully written to avoid any security problem if this happens. If values in the buffer are security critical, the Trusted Application SHOULD always read data only once from a shared buffer and then validate it. It SHALL NOT assume that data written to the buffer can be read unchanged later on.

Error Handling

All TA interface functions except `TA_DestroyEntryPoint` and `TA_CloseSessionEntryPoint` return a return code of type `TEE_Result`. The behavior of the Framework when an entry point returns an error depends on the entry point called:

- If `TA_CreateEntryPoint` returns an error, the Trusted Application instance is not created.
- If `TA_OpenSessionEntryPoint` returns an error code, the client connection is rejected. Additionally, the error code is propagated to the client as described below.
- If `TA_InvokeCommandEntryPoint` returns an error code, this error code is propagated to the client.
- `TA_CloseSessionEntryPoint` and `TA_DestroyEntryPoint` cannot return an error.

`TA_OpenSessionEntryPoint` and `TA_InvokeCommandEntryPoint` return codes are propagated to the client via the TEE Client API (see [Client API]) or the Internal Client API (see section 4.9) with the origin set to `TEEC_ORIGIN_TRUSTED_APP`.

Client Properties

When a Client connects to a Trusted Application, the Framework associates the session with Client Properties. Trusted Applications can retrieve the identity and properties of their client by calling one of the property access functions with the `TEE_PROPSET_CURRENT_CLIENT`. The standard Client Properties are fully specified in section 4.6.

The TA_EXPORT keyword

Depending on the compiler used and the targeted platform, a TA entry point may need to be decorated with an annotation such as `__declspec(dllexport)` or similar. This annotation SHALL be defined in the TEE Internal Core API header file as `TA_EXPORT` and placed between the entry point return type and function name as shown in the specification of each entry point.

4.3.1 TA_CreateEntryPoint

Since: TEE Internal API v1.0

```
TEE_Result TA_EXPORT TA_CreateEntryPoint( void );
```

Description

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_SetInstanceData` (described in section 4.11.2).

Specification Number: 10 **Function Number:** 0x102

Return Code

- `TEE_SUCCESS`: If the instance is successfully created, the function SHALL return `TEE_SUCCESS`.
- Any other value: If any other code is returned, then the instance is not created, and no other entry points of this instance will be called. The Framework SHALL 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 return code is returned to the client and the session is not opened.

Panic Reasons

- If the implementation detects any error that cannot be represented by any defined or implementation defined error code.

4.3.2 TA_DestroyEntryPoint

Since: TEE Internal API v1.0

```
void TA_EXPORT TA_DestroyEntryPoint( void );
```

Description

The function `TA_DestroyEntryPoint` is the Trusted Application's 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 SHALL start automatically reclaiming resources left open.

After this function returns, the implementation SHALL consider the instance destroyed and SHALL reclaim all resources left open by the instance.

Specification Number: 10 **Function Number:** 0x103

Panic Reasons

- If the implementation detects any error.

4.3.3 TA_OpenSessionEntryPoint

Since: TEE Internal API v1.0

```
TEE_Result TA_EXPORT TA_OpenSessionEntryPoint(
                uint32_t   paramTypes,
        [inout] TEE_Param  params[4],
     [out][ctx] void**     sessionContext );
```

Description

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 by the `gpd.ta.singleInstance` property described 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 return code and the current content of the parameters to the client. The return origin is then set to `TEEC_ORIGIN_TRUSTED_APP`.

The Trusted Application instance can register a session data pointer by setting `*sessionContext`. The framework SHALL ensure that `sessionContext` is a valid address of a pointer, and that it is unique per TEE Client session.

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, such as 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 SHALL consider the session as successfully opened and explicitly close it if necessary.

Parameters

- `paramTypes`: The types of the four parameters. See section 4.3.6.1 for more information.
- `params`: A pointer to an array of four parameters. See section 4.3.6.2 for more information.

  The `params` parameter is defined in the prototype as an array of length 4. Implementers should be aware that the address of the start of the array is passed to the callee.
- `sessionContext`: A pointer to a variable that can be filled by the Trusted Application instance with an opaque `void*` data pointer

Specification Number: 10 **Function Number:** 0x105

Return Code

- `TEE_SUCCESS`: If the session is successfully opened.
- Any other value: If the session could not be opened.
  - The return code may be one of the pre-defined codes, or may be a new return code defined by the Trusted Application implementation itself. In any case, the implementation SHALL report the return code to the client with the origin `TEEC_ORIGIN_TRUSTED_APP`.

Panic Reasons

- If the implementation detects any error that cannot be expressed by any defined or implementation defined error code.

4.3.4 TA_CloseSessionEntryPoint

Since: TEE Internal API v1.0

```
void TA_EXPORT TA_CloseSessionEntryPoint(
    [ctx] void*    sessionContext);
```

Description

The Framework calls the function `TA_CloseSessionEntryPoint` to close a client session.

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 a return code.

Parameters

- `sessionContext`: The value of the `void*` opaque data pointer set by the Trusted Application in the function `TA_OpenSessionEntryPoint` for this session.

Specification Number: 10 **Function Number:** 0x101

Return Value

This function can return no success or error code.

Panic Reasons

- If the implementation detects any error.

4.3.5 TA_InvokeCommandEntryPoint

Since: TEE Internal API v1.0

```
TEE_Result TA_EXPORT TA_InvokeCommandEntryPoint(
      [ctx] void*       sessionContext,
            uint32_t    commandID,
            uint32_t    paramTypes,
    [inout] TEE_Param   params[4] );
```

Description

The Framework calls the function `TA_InvokeCommandEntryPoint` 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 arguments to transfer response data back to the client. See section 4.3.6 for a specification of how to handle the operation parameters.

During the call to `TA_InvokeCommandEntryPoint` the client may request to cancel the operation. See section 4.10 for more details on cancellations.

A command is always invoked within the context of a client session. Thus, any Client Property (see section 4.6) can be accessed by the command implementation.

Parameters

- `sessionContext`: The value of the `void*` opaque data pointer set by the Trusted Application in the function `TA_OpenSessionEntryPoint`
- `commandID`: A Trusted Application-specific code that identifies the command to be invoked
- `paramTypes`: The types of the four parameters. See section 4.3.6.1 for more information.
- `params`: A pointer to an array of four parameters. See section 4.3.6.2 for more information.

  The `params` parameter is defined in the prototype as an array of length 4. Implementers should be aware that the address of the start of the array is passed to the callee.

Specification Number: 10 **Function Number:** 0x104

Return Code

- `TEE_SUCCESS`: If the command is successfully executed, the function SHALL return this value.
- Any other value: If the invocation of the command fails for any reason
  - The return code may be one of the pre-defined codes, or may be a new return code defined by the Trusted Application implementation itself. In any case, the implementation SHALL report the return code to the client with the origin `TEEC_ORIGIN_TRUSTED_APP`.

Panic Reasons

- If the implementation detects any error that cannot be expressed by any defined or implementation defined error code.

4.3.6 Operation Parameters in the TA Interface

When a client opens a session or invokes a command within a session, it can transmit operation parameters to the Trusted Application instance and receive response data back from the Trusted Application instance.

Arguments `paramTypes` and `params` are used to encode the operation parameters and their types which are passed to the Trusted Application instance. While executing the open session or invoke command entry points, the Trusted Application can also write in `params` to encode the response data.

4.3.6.1 Content of `paramTypes` Argument

The argument `paramTypes` encodes the type of each of the four parameters passed to an entry point. The content of `paramTypes` is implementation-dependent.

Each parameter type can take one of the `TEE_PARAM_TYPE_XXX` values listed in section 4.2.1. The type of each parameter determines whether the parameter is used or not, whether it is a Value or a Memory Reference, and the direction of data flow between the Client and the Trusted Application instance: Input (Client to Trusted Application instance), Output (Trusted Application instance to Client), or both Input and Output. The parameter type is set to `TEE_PARAM_TYPE_NONE` when no parameters are passed by the client in either `TEEC_OpenSession` or `TEEC_InvokeCommand`; this includes when the operation parameter itself is set to `NULL`.

The following macros are available to decode `paramTypes`:

```
#define TEE_PARAM_TYPES(t0,t1,t2,t3) \
   ((t0) | ((t1) << 4) | ((t2) << 8) | ((t3) << 12))

#define TEE_PARAM_TYPE_GET(t, i) (((t) >> ((i)*4)) & 0xF)
```

The macro `TEE_PARAM_TYPES` can be used to construct a value that you can compare against an incoming `paramTypes` to check the type of all the parameters in one comparison, as in the following example:

```
if (paramTypes !=
            TEE_PARAM_TYPES(
                  TEE_PARAM_TYPE_MEMREF_INPUT,
                  TEE_PARAM_TYPE_MEMREF_OUTPUT,
                  TEE_PARAM_TYPE_NONE,
                  TEE_PARAM_TYPE_NONE))
{
   /* Bad parameter types */
   return TEE_ERROR_BAD_PARAMETERS;
}
```

The macro `TEE_PARAM_TYPE_GET` can be used to extract the type of a given parameter from `paramTypes` if you need more fine-grained type checking.

4.3.6.2 Initial Content of `params` Argument

When the Framework calls the Trusted Application entry point, it initializes the content of `params[i]` as described in the following table.

Table 4-8: Content of `params[i]` when Trusted Application Entry Point Is Called

Value of `type[i]`	Content of `params[i]` when the Entry Point is Called
`TEE_PARAM_TYPE_NONE` `TEE_PARAM_TYPE_VALUE_OUTPUT`	Filled with zeroes.
`TEE_PARAM_TYPE_VALUE_INPUT` `TEE_PARAM_TYPE_VALUE_INOUT`	`params[i].value.a` and `params[i].value.b` contain the two integers sent by the client

`TEE_PARAM_TYPE_MEMREF_INPUT`
`TEE_PARAM_TYPE_MEMREF_OUTPUT`
`TEE_PARAM_TYPE_MEMREF_INOUT`
	`params[i].memref.buffer` is a pointer to memory buffer shared by the client. This can be `NULL`.
	`params[i].memref.size` describes the size of the buffer. If `buffer` is `NULL`, `size` is guaranteed to be zero.

Note that if the Client is a Client Application that uses the TEE Client API ([Client API]), the Trusted Application cannot distinguish between a registered and a temporary Memory Reference. Both are encoded as one of the `TEE_PARAM_TYPE_MEMREF_XXX` types and a pointer to the data is passed to the Trusted Application.

Security Warning: *For a Memory Reference Parameter, the buffer may concurrently exist within the client and Trusted Application instance memory spaces. It SHALL therefore be assumed that the client is able to make changes to the content of this buffer asynchronously at any moment. It is a security risk to assume otherwise.*

Any Trusted Application which implements functionality that needs some guarantee that the contents of a buffer are constant SHOULD copy the contents of a shared buffer into Trusted Application instance-owned memory.

To determine whether a given buffer is a Memory Reference or a buffer owned by the Trusted Application itself, the function `TEE_CheckMemoryAccessRights` defined in section 4.11.1 can be used.

4.3.6.3 Behavior of the Framework when the Trusted Application Returns

When the Trusted Application entry point returns, the Framework reads the content of each `params[i]` to determine what response data to send to the client, as described in the following table.

Table 4-9: Interpretation of `params[i]` when Trusted Application Entry Point Returns

Value of `type[i]`	Behavior of the Framework when Entry Point Returns

`TEE_PARAM_TYPE_NONE`
`TEE_PARAM_TYPE_VALUE_INPUT`
`TEE_PARAM_TYPE_MEMREF_INPUT`
	The content of `params[i]` is ignored.

`TEE_PARAM_TYPE_VALUE_OUTPUT` `TEE_PARAM_TYPE_VALUE_INOUT`	`params[i].value.a` and `params[i].value.b` contain the two integers sent to the client.
`TEE_PARAM_TYPE_MEMREF_OUTPUT` `TEE_PARAM_TYPE_MEMREF_INOUT`	The Framework reads `params[i].memref.size`: • If it is equal or less than the original value of `size`, it is considered as the actual size of the memory buffer. In this case, the Framework assumes that the Trusted Application has not written beyond this actual size and only this actual size will be synchronized with the client. • If it is greater than the original value of `size`, it is considered as a request for a larger buffer. In this case, the Framework assumes that the Trusted Application has not written anything in the buffer and no data will be synchronized.

4.3.6.4 Memory Reference and Memory Synchronization

Note that if a parameter is a Memory Reference, the memory buffer may be released or unmapped immediately after the operation completes. Also, some implementations may explicitly synchronize the contents of the memory buffer before the operation starts and after the operation completes.

As a consequence:

- The Trusted Application SHALL NOT access the memory buffer after the operation completes. In particular, it cannot be used as a long-term communication means between the client and the Trusted Application instance. A Memory Reference SHALL be accessed only during the lifetime of the operation.
- The Trusted Application SHALL NOT attempt to write into a memory buffer of type `TEE_PARAM_TYPE_MEMREF_INPUT`.
  - It is a programmer error to attempt to do this but the implementation is not required to detect this and the access may well be just ignored.
- For a Memory Reference Parameter marked as `OUTPUT` or `INOUT`, the Trusted Application can write in the entire range described by the initial content of `params[i].memref.size`. However, the implementation SHALL only guarantee that the client will observe the modifications below the final value of `size` and only if the final value is equal or less than the original value.

  For example, assume the original value of `size` is 100:

  - If the Trusted Application does not modify the value of `size`, the complete buffer is synchronized and the client is guaranteed to observe all the changes.
  - If the Trusted Application writes 50 in `size`, then the client is only guaranteed to observe the changes within the range from index `0` to index `49`.
  - If the Trusted Application writes 200 in `size`, then no data is guaranteed to be synchronized with the client. However, the client will receive the new value of `size`. The Trusted Application can typically use this feature to tell the client that the Memory Reference was too small and request that the client retry with a Memory Reference of at least 200 bytes.

Failure to comply with these constraints will result in undefined behavior and is a programmer error.

4.4 Property Access Functions

This section defines a set of functions to access individual properties in a property set, to convert them into a variety of types (printable strings, integers, Booleans, binary blocks, etc.), and to enumerate the properties in a property set. These functions can be used to access TA Configuration Properties, Client Properties, and Implementation Properties.

The property set is passed to each function in a pseudo-handle parameter. The following table lists the defined property sets.

Table 4-10: Property Sets

Pseudo-Handle	Meaning
`TEE_PROPSET_CURRENT_TA`	The configuration properties for the current Trusted Application. See section 4.5 for a definition of these properties.
`TEE_PROPSET_CURRENT_CLIENT`	The properties of the current client. This pseudo-handle is valid only in the context of the following entry points: ○ `TA_OpenSessionEntryPoint` ○ `TA_InvokeCommandEntryPoint` ○ `TA_CloseSessionEntryPoint` See section 4.6 for a definition of these properties.
`TEE_PROPSET_TEE_IMPLEMENTATION`	The properties of the TEE implementation. See section 4.7.

Properties can be retrieved and converted using `TEE_GetPropertyAsXXX` access functions (described in the following sections).

A property may be retrieved and converted into a printable string or into the type defined for the property which will be one of the following types:

- Binary block
- 32-bit unsigned integer
- 64-bit unsigned integer
- Boolean
- UUID
- Identity (a pair composed of a login method and a UUID)

Retrieving as a String

While implementations have latitude on how they set and store properties internally, a property that is retrieved via the function `TEE_GetPropertyAsString` SHALL always be converted into a printable string encoded in UTF-8.

To ensure consistency between the representation of a property as one of the above types and its representation as a printable string encoded in UTF-8, the following conversion rules apply:

- Binary block

  is converted into a string that is consistent with a Base64 encoding of the binary block as defined in RFC 2045 ([RFC 2045]) section 6.8 but with the following tolerance:

  - An implementation is allowed not to encode the final padding '=' characters.
  - An implementation is allowed to insert characters that are not in the Base64 character set.

- 32-bit and 64-bit unsigned integers

  are converted into strings that are consistent with the following syntax:

```
integer:               decimal-integer
                     | hexadecimal-integer
                     | binary-integer

decimal-integer:       [0-9,_]+{K,M}?
hexadecimal-integer:  0[x,X][0-9,a-f,A-F,_]+
binary-integer:        0[b,B][0,1,_]+
```

  Note that the syntax allows returning the integer either in decimal, hexadecimal, or binary format, that the representation can mix cases and can include underscores to separate groups of digits, and finally that the decimal representation may use 'K' or 'M' to denote multiplication by 1024 or 1048576 respectively.

  For example, here are a few acceptable representations of the number 1024: "`1K`", "`0X400`", "`0b100_0000_0000`".

- Boolean

  is converted into a string equal to "`true`" or "`false`" case-insensitive, depending on the value of the Boolean.

- UUID

  is converted into a string that is consistent with the syntax defined in [RFC 4122]. Note that this string may mix character cases.

- Identity

  is converted into a string consistent with the following syntax:

```
identity: integer (':' uuid)?
```

  where:

  - The integer is consistent with the integer syntax described above
  - If the identity UUID is Nil, then it can be omitted from the string representation of the property

Enumerating Properties

Properties in a property set can also be enumerated. For this:

- Allocate a property enumerator using the function `TEE_AllocatePropertyEnumerator`.
- Start the enumeration by calling `TEE_StartPropertyEnumerator`, passing the pseudo-handle on the desired property set.
- Call the functions `TEE_GetProperty[AsXXX]` with the enumerator handle and a `NULL` name.

An enumerator provides the properties in an arbitrary order. In particular, they are not required to be sorted by name although a given implementation may ensure this.

4.4.1 TEE_GetPropertyAsString

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_GetPropertyAsString(
                  TEE_PropSetHandle propsetOrEnumerator,
   [instringopt] char*              name,
   [outstring]   char*              valueBuffer, size_t* valueBufferLen );
```

Description

The `TEE_GetPropertyAsString` function performs a lookup in a property set to retrieve an individual property and convert its value into a printable string.

When the lookup succeeds, the implementation SHALL convert the property into a printable string and copy the result into the buffer described by `valueBuffer` and `valueBufferLen`.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and it SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`
- `valueBuffer, valueBufferLen`: Output buffer for the property value

Specification Number: 10 **Function Number:** 0x207

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_SHORT_BUFFER`: If the value buffer is not large enough to hold the whole property value

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `valueBufferLen`.

4.4.2 TEE_GetPropertyAsBool

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetPropertyAsBool(
                      TEE_PropSetHandle  propsetOrEnumerator,
        [instringopt] char*              name,
        [out]         bool*              value );
```

Description

The `TEE_GetPropertyAsBool` function retrieves a single property in a property set and converts its value to a Boolean.

If a property cannot be viewed as a Boolean, this function SHALL return `TEE_ERROR_BAD_FORMAT`.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`.
- `value`: A pointer to the variable that will contain the value of the property on success or `false` on error.

Specification Number: 10 **Function Number:** 0x205

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property value is not defined as a Boolean

Panic Reasons

- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

4.4.3 TEE_GetPropertyAsU*nn*

4.4.3.1 TEE_GetPropertyAsU32

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetPropertyAsU32(
                      TEE_PropSetHandle  propsetOrEnumerator,
        [instringopt] char*              name,
        [out]         uint32_t*          value );
```

Description

The `TEE_GetPropertyAsU32` function retrieves a single property in a property set and converts its value to a 32-bit unsigned integer.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`.
- `value`: A pointer to the variable that will contain the value of the property on success, or zero on error.

Specification Number: 10 **Function Number:** 0x208

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property value is not defined as an unsigned 32-bit integer

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.4.3.2 TEE_GetPropertyAsU64

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_GetPropertyAsU64(
                      TEE_PropSetHandle  propsetOrEnumerator,
        [instringopt] char*              name,
        [out]         uint64_t*          value );
```

Description

The `TEE_GetPropertyAsU64` function retrieves a single property in a property set and converts its value to a 64-bit unsigned integer. If the underlying value is a 32-bit integer, the Trusted OS SHALL zero extend it.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
    - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
    - Otherwise, `name` SHALL NOT be `NULL`.
- `value`: A pointer to the variable that will contain the value of the property on success, or zero on error.

Specification Number: 10 **Function Number:** 0x20D

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property value is not defined as an unsigned 64-bit integer

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.4.4 TEE_GetPropertyAsBinaryBlock

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_GetPropertyAsBinaryBlock(
                    TEE_PropSetHandle propsetOrEnumerator,
      [instringopt] char*             name,
      [outbuf]      void*             valueBuffer, size_t* valueBufferLen );
```

Description

The function `TEE_GetPropertyAsBinaryBlock` retrieves an individual property and converts its value into a binary block.

If a property cannot be viewed as a binary block, this function SHALL return `TEE_ERROR_BAD_FORMAT`.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`.
- `valueBuffer`, `valueBufferLen`: Output buffer for the binary block

Specification Number: 10 **Function Number:** 0x204

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property cannot be retrieved as a binary block
- `TEE_ERROR_SHORT_BUFFER`: If the value buffer is not large enough to hold the whole property value

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `valueBufferLen`.

4.4.5 TEE_GetPropertyAsUUID

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetPropertyAsUUID(
                      TEE_PropSetHandle  propsetOrEnumerator,
        [instringopt] char*              name,
        [out]         TEE_UUID*          value );
```

Description

The function `TEE_GetPropertyAsUUID` retrieves an individual property and converts its value into a UUID.

If a property cannot be viewed as a UUID, this function SHALL return `TEE_ERROR_BAD_FORMAT`.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`.
- `value`: A pointer filled with the UUID. SHALL NOT be `NULL`.

Specification Number: 10 **Function Number:** 0x209

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property cannot be converted into a UUID

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.4.6 TEE_GetPropertyAsIdentity

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetPropertyAsIdentity(
                      TEE_PropSetHandle    propsetOrEnumerator,
        [instringopt] char*                name,
        [out]         TEE_Identity*        value );
```

Description

The function `TEE_GetPropertyAsIdentity` retrieves an individual property and converts its value into a `TEE_Identity`.

If a property cannot be viewed as an identity, this function SHALL return `TEE_ERROR_BAD_FORMAT`.

Parameters

- `propsetOrEnumerator`: One of the `TEE_PROPSET_XXX` pseudo-handles or a handle on a property enumerator
- `name`: A pointer to the zero-terminated string containing the name of the property to retrieve. Its content is case-sensitive and SHALL be encoded in UTF-8.
  - If `propsetOrEnumerator` is a property enumerator handle, `name` is ignored and can be `NULL`.
  - Otherwise, `name` SHALL NOT be `NULL`.
- `value`: A pointer filled with the identity. SHALL NOT be `NULL`.

Specification Number: 10 **Function Number:** 0x206

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the property is not found or if `name` is not a valid UTF-8 encoding
- `TEE_ERROR_BAD_FORMAT`: If the property value cannot be converted into an Identity

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.4.7 TEE_AllocatePropertyEnumerator

Since: TEE Internal API v1.0

```
TEE_Result TEE_AllocatePropertyEnumerator(
      [out]      TEE_PropSetHandle*  enumerator );
```

Description

The function `TEE_AllocatePropertyEnumerator` allocates a property enumerator object. Once a handle on a property enumerator has been allocated, it can be used to enumerate properties in a property set using the function `TEE_StartPropertyEnumerator`.

Parameters

- `enumerator`: A pointer filled with an opaque handle on the property enumerator on success and with `TEE_HANDLE_NULL` on error

Specification Number: 10 **Function Number:** 0x201

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OUT_OF_MEMORY`: If there are not enough resources to allocate the property enumerator

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.4.8 TEE_FreePropertyEnumerator

Since: TEE Internal API v1.0

```
void TEE_FreePropertyEnumerator(
            TEE_PropSetHandle  enumerator );
```

Description

The function `TEE_FreePropertyEnumerator` deallocates a property enumerator object.

Parameters

- `enumerator`: A handle on the enumerator to free

Specification Number: 10 **Function Number:** 0x202

Panic Reasons

- If the implementation detects any error.

4.4.9 TEE_StartPropertyEnumerator

Since: TEE Internal API v1.0

```
void TEE_StartPropertyEnumerator(
            TEE_PropSetHandle  enumerator,
            TEE_PropSetHandle  propSet );
```

Description

The function `TEE_StartPropertyEnumerator` starts to enumerate the properties in an enumerator.

Once an enumerator is attached to a property set:

- Properties can be retrieved using one of the `TEE_GetPropertyAsXXX` functions, passing the enumerator handle as the property set and `NULL` as the name.
- The function `TEE_GetPropertyName` can be used to retrieve the name of the current property in the enumerator.
- The function `TEE_GetNextProperty` can be used to advance the enumeration to the next property in the property set.

Parameters

- `enumerator`: A handle on the enumerator
- `propSet`: A pseudo-handle on the property set to enumerate. SHALL be one of the `TEE_PROPSET_XXX` pseudo-handles.

Specification Number: 10 **Function Number:** 0x20C

Panic Reasons

- If the implementation detects any error.

4.4.10 TEE_ResetPropertyEnumerator

Since: TEE Internal API v1.0

```
void TEE_ResetPropertyEnumerator(
            TEE_PropSetHandle  enumerator );
```

Description

The function `TEE_ResetPropertyEnumerator` resets a property enumerator to its state immediately after allocation. If an enumeration is currently started, it is abandoned.

Parameters

- `enumerator`: A handle on the enumerator to reset

Specification Number: 10 **Function Number:** 0x20B

Panic Reasons

- If the implementation detects any error.

4.4.11 TEE_GetPropertyName

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_GetPropertyName(
                TEE_PropSetHandle  enumerator,
    [outstring] void*              nameBuffer, size_t* nameBufferLen );
```

Description

The function `TEE_GetPropertyName` gets the name of the current property in an enumerator.

The property name SHALL be the valid UTF-8 encoding of a Unicode string containing no intermediate U+0000 code points.

Parameters

- `enumerator`: A handle on the enumerator
- `nameBuffer`, `nameBufferLen`: The buffer filled with the name

Specification Number: 10 **Function Number:** 0x20A

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If there is no current property either because the enumerator has not started or because it has reached the end of the property set
- `TEE_ERROR_SHORT_BUFFER`: If the name buffer is not large enough to contain the property name

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `nameBufferLen`.

4.4.12 TEE_GetNextProperty

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetNextProperty(
            TEE_PropSetHandle  enumerator);
```

Description

The function `TEE_GetNextProperty` advances the enumerator to the next property.

Parameters

- `enumerator`: A handle on the enumerator

Specification Number: 10 **Function Number:** 0x203

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the enumerator has reached the end of the property set or if it has not started

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

4.5 Trusted Application Configuration Properties

Each Trusted Application is associated with configuration properties that are accessible using the generic Property Access Functions and the `TEE_PROPSET_CURRENT_TA` pseudo-handle. This section defines a few standard configuration properties that affect the behavior of the implementation. Other configuration properties can be defined:

- either by the implementation to configure implementation-defined behaviors,
- or by the Trusted Application itself for its own configuration purposes.

The way properties are actually configured and attached to a Trusted Application is out of scope of this specification.

The following table defines the standard configuration properties for Trusted Applications.

Table 4-11: Trusted Application Standard Configuration Properties

Property Name	Type	Meaning
`gpd.ta.appID`	UUID	**Since:** TEE Internal API v1.0 The identifier of the Trusted Application.
`gpd.ta.singleInstance`	Boolean	**Since:** TEE Internal API v1.0 Whether the implementation SHALL create a single TA instance for all the client sessions (if `true`) or SHALL create a separate instance for each client session (if `false`).
`gpd.ta.multiSession`	Boolean	**Since:** TEE Internal API v1.0 Whether the Trusted Application instance supports multiple sessions. This property is ignored when `gpd.ta.singleinstance` is set to `false`.

Property Name	Type	Meaning
`gpd.ta.instanceKeepAlive`	Boolean	**Since:** TEE Internal API v1.0 Whether the Trusted Application instance context SHALL be preserved when there are no sessions connected to the instance. The instance context is defined as all writable data within the memory space of the Trusted Application instance, including the instance heap. This property is meaningful only when the `gpd.ta.singleInstance` is set to `true`. When this property is set to `false`, then the TA instance SHALL be created when one or more sessions are opened on the TA and it SHALL be destroyed when there are no more sessions opened on the instance. When this property is set to `true`, then the TA instance is terminated only when the TEE shuts down, which includes when the device goes through a system-wide global power cycle. Note that the TEE SHALL NOT shut down whenever the REE does not shut down and keeps a restorable state, including when it goes through transitions into lower power states (hibernation, suspend, etc.). The exact moment when a keep-alive single instance is created is implementation-defined but it SHALL be no later than the first session opening.
`gpd.ta.dataSize`	Integer	**Since:** TEE Internal API v1.0 Maximum estimated amount of dynamic data in bytes configured for the Trusted Application. The memory blocks allocated through `TEE_Malloc` are drawn from this space, as well as the task stacks. How this value precisely relates to the exact number and sizes of blocks that can be allocated is implementation-dependent.
`gpd.ta.stackSize`	Integer	**Since:** TEE Internal API v1.0 Maximum stack size in bytes available to any task in the Trusted Application at any point in time. This corresponds to the stack size used by the TA code itself and does not include stack space possibly used by the Trusted Core Framework. For example, if this property is set to "`512`", then the Framework SHALL guarantee that, at any time, the TA code can consume up to 512 bytes of stack and still be able to call any functions in the API.
`gpd.ta.version`	String	**Since:** TEE Internal Core API v1.1 Version number of this Trusted Application.
`gpd.ta.description`	String	**Since:** TEE Internal Core API v1.1 Optional description of the Trusted Application

Property Name	Type	Meaning
`gpd.ta.endian`	Integer	**Since:** TEE Internal Core API v1.2 Endianness of the current TA. Legal values are: • The value `0` indicates little-endian TA. • The value `1` indicates a big-endian TA. • Values from `2` to `0x7FFFFFFF` are reserved for future versions of this specification. • Values in the range `0x80000000` to `0xFFFFFFFF` are implementation defined.

`gpd.ta.doesNotCloseHandleOnCorruptObject`	Boolean	**Since:** TEE Internal Core API v1.3
		• If set to `false`, then all APIs returning `TEE_ERROR_CORRUPT_OBJECT` or `TEE_ERROR_CORRUPT_OBJECT_2` will behave as specified in versions prior to TEE Internal Core API v1.3.
		• If set to `true`, then:
		  o When a function returns `TEE_ERROR_CORRUPT_OBJECT` or `TEE_ERROR_CORRUPT_OBJECT_2`, the stated closure of the object handle SHALL NOT occur and the handle SHALL need to be closed using the normal methods.
		  o While the handle remains valid until closed, the underlying object SHALL immediately be deleted.

4.6 Client Properties

This section defines the standard Client Properties, accessible using the generic Property Access Functions and the `TEE_PROPSET_CURRENT_CLIENT` pseudo-handle. Other non-standard client properties can be defined by specific implementations, but they SHALL be defined outside the "`gpd.`" namespace.

Note that Client Properties can be accessed only in the context of a TA entry point associated with a client, i.e. in one of the following entry point functions: `TA_OpenSessionEntryPoint`, `TA_InvokeCommandEntryPoint`, or `TA_CloseSessionEntryPoint`.

The following table defines the standard Client Properties.

Table 4-12: Standard Client Properties

Property Name	Type	Meaning
`gpd.client.identity`	Identity	**Since:** TEE Internal API v1.0 Identity of the current client. This can be conveniently retrieved using the function `TEE_GetPropertyAsIdentity` (see section 4.4.6). A Trusted Application can use the client identity to perform access control. For example, it can refuse to open a session for a client that is not identified.
`gpd.client.endian`	Integer	**Since:** TEE Internal Core API v1.2 Endianness of the current client. Legal values are as defined for `gpd.ta.endian` in Table 4-11.

As shown in Table 4-13, the client identity and the client properties that the Trusted Application can retrieve depend on the nature of the client and the method it has used to connect. (The constant values associated with the login methods are listed in section 4.2.2.)

Table 4-13: Client Identities

Login Method	Meaning
`TEE_LOGIN_PUBLIC`	The client is in the Regular Execution Environment and is neither identified nor authenticated. The client has no identity and the UUID is the Nil UUID as defined in [RFC 4122].
`TEE_LOGIN_USER`	The Client Application has been identified by the Regular Execution Environment and the client UUID reflects the actual user that runs the calling application independently of the actual application.
`TEE_LOGIN_GROUP`	The client UUID reflects a group identity that is executing the calling application. The notion of group identity and the corresponding UUID is REE-specific.
`TEE_LOGIN_APPLICATION`	The Client Application has been identified by the Regular Execution Environment independently of the identity of the user executing the application. The nature of this identification and the corresponding UUID is REE-specific.
`TEE_LOGIN_APPLICATION_USER`	The client UUID identifies both the calling application and the user that is executing it.

Login Method	Meaning
`TEE_LOGIN_APPLICATION_GROUP`	The client UUID identifies both the calling application and a group that is executing it.
`TEE_LOGIN_TRUSTED_APP`	The client is another Trusted Application. The client identity assigned to this session is the UUID of the calling Trusted Application. The client properties are all the configuration properties of the calling Trusted Application.
The range `0x80000000-0xEFFFFFFF` is reserved for *implementation-defined* login methods.	The meaning of the Client UUID and the associated client properties are *implementation-defined*. If the Trusted Application does not support the particular implementation, it SHOULD assume that the client has minimum rights, i.e. rights equivalent to the login method `TEE_LOGIN_PUBLIC`.
Other values are reserved for GlobalPlatform use, as described in section 4.2.2.	

Client Properties are meant to be managed by either the Regular OS or the Trusted OS and these SHALL ensure that a Client cannot tamper with its own properties in the following sense:

- The property `gpd.client.identity` SHALL always be determined by the Trusted OS and the determination of whether or not it is equal to `TEE_LOGIN_TRUSTED_APP` SHALL be as trustworthy as the Trusted OS itself.
- When `gpd.client.identity` is equal to `TEE_LOGIN_TRUSTED_APP` then the Trusted OS SHALL ensure that the remaining properties are equal to the properties of the calling TA up to the same level of trustworthiness that the target TA places in the Trusted OS.
- When `gpd.client.identity` is not equal to `TEE_LOGIN_TRUSTED_APP`, then the Regular OS is responsible for ensuring that the Client Application cannot tamper with its own properties.

Note that if a Client wants to transmit a property that is not synthesized by the Regular OS or Trusted OS, such as a password, then it SHALL use a parameter to the session open operation or in subsequent commands.

4.7 Implementation Properties

The implementation properties can be retrieved by the generic Property Access Functions with the `TEE_PROPSET_TEE_IMPLEMENTATION` pseudo-handle.

The following table defines the standard implementation properties.

Table 4-14: Implementation Properties

Property Name	Type	Meaning
`gpd.tee.apiversion`	String	**Since:** TEE Internal API v1.0; deprecated in TEE Internal Core API v1.1.2 A string composed of the Major and Minor version of the specification, e.g. “1.1”. Zero values must be represented (e.g. version 3.0 is “3.0”). This string does NOT include any other parts of the version number. (This property is deprecated in favor of `gpd.tee.internalCore.version`.)
`gpd.tee.internalCore.version`	Integer	**Since:** TEE Internal Core API v1.1.2 The TEE Internal Core API Specification version number expressed as an integer. See section 4.7.1 for details of the structure of this integer field.
`gpd.tee.description`	String	**Since:** TEE Internal API v1.0 A description of the implementation. The content of this property is implementation-dependent but typically contains a version and build number of the implementation as well as other configuration information. Note that implementations are free to define their own non-standard identification property names, provided they are not in the “`gpd.`” namespace.

Property Name	Type	Meaning
`gpd.tee.deviceID`	UUID	**Since:** TEE Internal API v1.0 A device identifier that SHALL be globally unique among all GlobalPlatform TEEs whatever the manufacturer, vendor, or integration. **Since:** TEE Internal Core API v1.1.1 If there are multiple GlobalPlatform TEEs on one device, each such TEE SHALL have a unique `gpd.tee.deviceID`. **Implementer's Note** It is acceptable to derive this device identifier from statistically unique secret or public information, such as a Hardware Unique Key, die identifiers, etc. However, note that this property is intended to be public and exposed to any software running on the device, not only to Trusted Applications. The derivation SHALL therefore be carefully designed so that it does not compromise secret information.
`gpd.tee.systemTime.` `protectionLevel`	Integer	**Since:** TEE Internal API v1.0 The protection level provided by the system time implementation. See the function `TEE_GetSystemTime` in section 7.2.1 for more details.
`gpd.tee.TAPersistentTime.` `protectionLevel`	Integer	**Since:** TEE Internal API v1.0 The protection level provided for the TA Persistent Time. See the function `TEE_GetTAPersistentTime` in section 7.2.3 for more details.
`gpd.tee.arith.maxBigIntSize`	Integer	**Since:** TEE Internal API v1.0 Maximum size in bits of the big integers for all the functions in the TEE Arithmetical API specified in Chapter 8. Beyond this limit, some of the functions MAY panic due to insufficient pre-allocated resources or hardware limitations.
`gpd.tee.cryptography.ecc`	Boolean	**Since:** TEE Internal Core API v1.1; deprecated in TEE Internal Core API v1.2 If set to `true`, then the Elliptic Curve Cryptographic (ECC) algorithms shown in Table 6-2 are supported. (This property is deprecated; however, see section 6.10.3 regarding responding when this property is queried.)

Property Name	Type	Meaning
gpd.tee.cryptography.nist	Boolean	**Since:** TEE Internal Core API v1.2 If set to true, then all of the cryptographic elements defined in Table 6-14 with the Source column marked NIST are supported. If it is set to false or is absent, it does not mean that none of these cryptographic elements are supported. See TEE_IsAlgorithmSupported in section 6.2.9.
gpd.tee.cryptography.bsi-r	Boolean	**Since:** TEE Internal Core API v1.2 If set to true, then all of the cryptographic elements defined in Table 6-14 with the Source column marked BSI-R are supported. If it is set to false or is absent, it does not mean that none of these cryptographic elements are supported. See TEE_IsAlgorithmSupported in section 6.2.9.
gpd.tee.cryptography.bsi-t	Boolean	**Since:** TEE Internal Core API v1.2 If set to true, then all of the cryptographic elements defined in Table 6-14 with the Source column marked BSI-T are supported. If it is set to false or is absent, it does not mean that none of these cryptographic elements are supported. See TEE_IsAlgorithmSupported in section 6.2.9.
gpd.tee.cryptography.ietf	Boolean	**Since:** TEE Internal Core API v1.2 If set to true, then all of the cryptographic elements defined in Table 6-14 with the Source column marked IETF are supported. If it is set to false or is absent, it does not mean that none of these cryptographic elements are supported. See TEE_IsAlgorithmSupported in section 6.2.9.
gpd.tee.cryptography.octa	Boolean	**Since:** TEE Internal Core API v1.2 If set to true, then the cryptographic elements defined in Table 6-14 with the Source column marked OCTA are supported. In addition, all definitions related to SM3 and SM4 are also supported. If it is set to false or is absent, it does not mean that none of these cryptographic elements are supported. See TEE_IsAlgorithmSupported in section 6.2.9.

Property Name	Type	Meaning
`gpd.tee.trustedStorage.private.rollbackProtection` `gpd.tee.trustedStorage.perso.rollbackProtection`	Integer	**Since:** TEE Internal Core API v1.3 Indicates the level of rollback detection provided by Trusted Storage supplied by the implementation: **100:** Rollback detection mechanism for the Trusted Storage SHALL be enforced at the REE level. **1000:** Rollback detection mechanism for the Trusted Storage SHALL be based on TEE-controlled hardware. This hardware SHALL be out of reach of software attacks from the REE. **10000:** The Trusted Storage Space SHALL be implemented on TEE-controlled hardware and SHALL be immune to rollback. **All other values:** Reserved for future use External actors may be able to roll back the Trusted Storage in the case of protection levels **100** and **1000** but this SHALL be detected by the implementation. If an active TA attempts to access material held in Trusted Storage that has been rolled back, it will receive an error equivalent to a corrupted object.
`gpd.tee.trustedStorage.protected.rollbackProtection`	Integer	**Since:** TEE Internal Core API v1.3 Indicates the level of protection from rollback of Trusted Storage supplied by the implementation: **10000:** The Trusted Storage Space SHALL be implemented on TEE-controlled hardware and SHALL be immune to rollback. **All other values:** Reserved for future use

<table>
<tr><th>Property Name</th><th>Type</th><th>Meaning</th></tr>
<tr><td><code>gpd.tee.trustedStorage.
antiRollback.protectionLevel</code></td><td>Integer</td><td>Since: TEE Internal Core API v1.2; deprecated in TEE Internal Core API v1.3 – See Backward Compatibility note below.

Indicates the level of protection from rollback of Trusted Storage supplied by the implementation:
100: Anti-rollback mechanism for the Trusted Storage SHALL be enforced at the REE level.
1000: Anti-rollback mechanism for the Trusted Storage SHALL be based on TEE-controlled hardware. This hardware SHALL be out of reach of software attacks from the REE.
All other values: Reserved.
If an active TA attempts to access material held in Trusted Storage that has been rolled back, it will receive an error equivalent to a corrupted object.
External actors may still be able to roll back the Trusted Storage but this SHALL be detected by the implementation.

Backward Compatibility

Versions prior to TEE Internal Core API v1.2 allowed no anti-rollback protection to be reported. For any Trusted OS claiming compatibility to v1.2 or later of this specification, reporting no anti-rollback protection is no longer allowed, and the Trusted OS SHALL implement some form of anti-rollback protection.
If the Trusted Storage Space is implemented entirely on hardware with a protection level greater than 1000, then the implementation SHALL set this property value to 1000; otherwise the lowest protection level SHALL be reported.</td></tr>
</table>

Property Name	Type	Meaning
`gpd.tee.trustedStorage.rollbackDetection.protectionLevel`	Integer	**Since:** TEE Internal Core API v1.1; deprecated in TEE Internal Core API v1.3 – See Backward Compatibility note below. Indicates the level of protection that a Trusted Application can assume from the rollback detection mechanism of the Trusted Storage: **100:** Rollback detection mechanism for the Trusted Storage is enforced at the REE level. **1000:** Rollback detection mechanism for the Trusted Storage is based on TEE-controlled hardware. This hardware SHALL be out of reach of software attacks from the REE. Users may still be able to roll back the Trusted Storage but this SHALL be detected by the implementation. **All other values:** Reserved. **Backward Compatibility** If the Trusted Storage Space is implemented on TEE-controlled hardware immune to rollback then the implementation SHALL set this property value to **1000**.
`gpd.tee.trustedos.implementation.version`	String	**Since:** TEE Internal Core API v1.1 The detailed version number of the Trusted OS. The value of this property SHALL change whenever anything changes in the code forming the Trusted OS which provides the TEE, i.e. any patch SHALL change this string.
`gpd.tee.trustedos.implementation.binaryversion`	Binary	**Since:** TEE Internal Core API v1.1 A binary value which is equivalent to `gpd.tee.trustedos.implementation.version`. May be derived from some form of certificate indicating the software has been signed, a measurement of the image, a checksum, a direct binary conversion of `gpd.tee.trustedos.implementation.version`, or any other binary value that the TEE manufacturer chooses to provide. The Trusted OS manufacturer's documentation SHALL state the format of this value. The value of this property SHALL change whenever anything changes in the code forming the Trusted OS which provides the TEE, i.e. any patch SHALL change this binary.
`gpd.tee.trustedos.manufacturer`	String	**Since:** TEE Internal Core API v1.1 Name of the manufacturer of the Trusted OS.

Property Name	Type	Meaning
`gpd.tee.firmware.implementation.version`	String	**Since:** TEE Internal Core API v1.1 The detailed version number of the firmware which supports the Trusted OS implementation. This includes all privileged software involved in the secure booting and support of the TEE apart from the secure OS and Trusted Applications. The value of this property SHALL change whenever anything changes in this code, i.e. any patch SHALL change this string. The value of this property MAY be the empty string if there is no such software.
`gpd.tee.firmware.implementation.binaryversion`	Binary	**Since:** TEE Internal Core API v1.1 A binary value which is equivalent to `gpd.tee.firmware.implementation.version`. May be derived from some form of certificate indicating the firmware has been signed, a measurement of the image, a checksum, a direct binary conversion of `gpd.tee.firmware.implementation.version`, or any other binary value that the Trusted OS manufacturer chooses to provide. The Trusted OS manufacturer's documentation SHALL state the format of this value. The value of this property SHALL change whenever anything changes in this code, i.e. any patch SHALL change this binary. The value of this property MAY be a zero length value if there is no such firmware.
`gpd.tee.firmware.manufacturer`	String	**Since:** TEE Internal Core API v1.1 Name of the manufacturer of the firmware which supports the Trusted OS or the empty string if there is no such firmware.
`gpd.tee.event.maxSources`	Integer	**Since:** TEE Internal Core API v1.2 The maximum number of secure event sources the implementation can support.

4.7.1 Specification Version Number Property

This specification defines a TEE property containing the version number of the specification that the implementation conforms to. The property can be retrieved using the normal Property Access Functions. The property SHALL be named "`gpd.tee.internalCore.version`" and SHALL be of integer type with the interpretation given below.

The specification version number property consists of four positions: major, minor, maintenance, and RFU. These four bytes are combined into a 32-bit unsigned integer as follows:

- The major version number of the specification is placed in the most significant byte.
- The minor version number of the specification is placed in the second most significant byte.
- The maintenance version number of the specification is placed in the second least significant byte. If the version is not a maintenance version, this SHALL be zero.
- The least significant byte is reserved for future use. Currently this byte SHALL be zero.

Table 4-14b: Specification Version Number Property – 32-bit Integer Structure

Bits [24-31] (MSB)	Bits [16-23]	Bits [8-15]	Bits [0-7] (LSB)
Major version number of the specification	Minor version number of the specification	Maintenance version number of the specification	Reserved for use by GlobalPlatform. Currently SHALL be zero.

So, for example:

- Specification version 1.1 will be held as `0x01010000` (16842752 in base 10).
- Specification version 1.2 will be held as `0x01020000` (16908288 in base 10).
- Specification version 1.2.3 will be held as `0x01020300` (16909056 in base 10).
- Specification version 12.13.14 will be held as `0x0C0D0E00` (202182144 in base 10).
- Specification version 212.213.214 will be held as `0xD4D5D600` (3570783744 in base 10).

This places the following requirement on the version numbering:

- No specification can have a Major or Minor or Maintenance version number greater than 255.

4.8 Panics

4.8.1 TEE_Panic

Since: TEE Internal API v1.0

```
void TEE_Panic(TEE_Result panicCode);
```

Description

The `TEE_Panic` function 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.

When an instance panics, its clients receive the return code `TEE_ERROR_TARGET_DEAD` of origin `TEE_ORIGIN_TEE` until they close their session. This applies to Regular Execution Environment clients calling through the TEE Client API (see [Client API]) and to Trusted Execution Environment clients calling through the Internal Client API (see section 4.9).

When this routine is called, an implementation in a non-production environment, such as in a development or pre-production state, SHALL display the supplied `panicCode` using the mechanisms defined in [TEE TA Debug] (or an implementation-specific alternative) to help the developer understand the programmer error. Diagnostic information SHOULD NOT be exposed outside of a secure development environment.

Once an instance is panicked, no TA entry point is ever called again for this instance, not even `TA_DestroyEntryPoint`. The caller cannot expect that the `TEE_Panic` function will return.

Parameters

- `panicCode`: An informative Panic code defined by the TA. May be displayed in traces if traces are available.

Specification Number: 10 **Function Number:** 0x301

4.9 Internal Client API

This API allows a Trusted Application to act as a client to another Trusted Application.

4.9.1 TEE_OpenTASession

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_OpenTASession(
      [in] TEE_UUID*              destination,
           uint32_t               cancellationRequestTimeout,
           uint32_t               paramTypes,
   [inout] TEE_Param              params[4],
     [out] TEE_TASessionHandle*   session,
     [out] uint32_t*              returnOrigin);
```

Description

The function TEE_OpenTASession opens a new session with a Trusted Application.

The destination Trusted Application is identified by its UUID passed in destination. A set of four parameters can be passed during the operation. See section 4.9.4 for a detailed specification of how these parameters are passed in the paramTypes and params arguments.

The result of this function is returned both in the return code and the return origin, stored in the variable pointed to by returnOrigin:

- If the return origin is different from TEE_ORIGIN_TRUSTED_APP, then the function has failed before it could reach the target Trusted Application. The possible return codes are listed in "Return Code" below.
- If the return origin is TEE_ORIGIN_TRUSTED_APP, then the meaning of the return code depends on the protocol exposed by the target Trusted Application. However, if TEE_SUCCESS is returned, it always means that the session was successfully opened and if the function returns a code different from TEE_SUCCESS, it means that the session opening failed.

When the session is successfully opened, i.e. when the function returns TEE_SUCCESS, a valid session handle is written into *session. Otherwise, the value TEE_HANDLE_NULL is written into *session.

Parameters

- destination: A pointer to a TEE_UUID structure containing the UUID of the destination Trusted Application
- cancellationRequestTimeout: Timeout in milliseconds or the special value TEE_TIMEOUT_INFINITE if there is no timeout. After the timeout expires, the TEE SHALL act as though a cancellation request for the operation had been sent.
- paramTypes: The types of all parameters passed in the operation. See section 4.9.4 for more details.
- params: The parameters passed in the operation. See section 4.9.4 for more details. These are updated only if the returnOrigin is TEE_ORIGIN_TRUSTED_APP.

    The params parameter is defined in the prototype as an array of length 4. Implementers should be aware that the address of the start of the array is passed to the callee.

- session: A pointer to a variable that will receive the client session handle. The pointer SHALL NOT be NULL. The value is set to TEE_HANDLE_NULL upon error.

- `returnOrigin`: A pointer to a variable which will contain the return origin. This field may be `NULL` if the return origin is not needed.

Specification Number: 10 **Function Number:** 0x403

Return Code

- `TEE_SUCCESS`: In case of success; the session was successfully opened.
- Any other value: The opening failed.

  If the return origin is `TEE_ORIGIN_TRUSTED_APP`, the return code is defined by the protocol exposed by the destination Trusted Application.

  If the return origin is other than `TEE_ORIGIN_TRUSTED_APP`, one of the following return codes can be returned:

  - `TEE_ERROR_OUT_OF_MEMORY`: If not enough resources are available to open the session
  - `TEE_ERROR_ITEM_NOT_FOUND`: If no Trusted Application matches the requested destination UUID
  - `TEE_ERROR_ACCESS_DENIED`: If access to the destination Trusted Application is denied
  - `TEE_ERROR_BUSY`: If the destination Trusted Application does not allow more than one session at a time and already has a session in progress
  - `TEE_ERROR_TARGET_DEAD`: If the destination Trusted Application has panicked during the operation
  - `TEE_ERROR_CANCEL`: If the request is cancelled by anything other than the destination Trusted Application

Panic Reasons

- If the implementation detects any error that cannot be represented by any defined or implementation defined error code.
- If memory which was allocated with `TEE_MALLOC_NO_SHARE` is referenced by one of the parameters.

Backward Compatibility

The error code `TEE_CANCEL` was added in TEE Internal Core API v1.2.

4.9.2 TEE_CloseTASession

Since: TEE Internal API v1.0

```
void TEE_CloseTASession(TEE_TASessionHandle session);
```

Description

The function `TEE_CloseTASession` closes a client session.

Parameters

- `session`: An opened session handle

Specification Number: 10 **Function Number:** 0x401

Panic Reasons

- If the implementation detects any error.

4.9.3 TEE_InvokeTACommand

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_InvokeTACommand(
           TEE_TASessionHandle  session,
           uint32_t             cancellationRequestTimeout,
           uint32_t             commandID,
           uint32_t             paramTypes,
   [inout] TEE_Param            params[4],
     [out] uint32_t*            returnOrigin);
```

Description

The function `TEE_InvokeTACommand` invokes a command within a session opened between the client Trusted Application instance and a destination Trusted Application instance.

The parameter `session` SHALL reference a valid session handle opened by `TEE_OpenTASession`.

Up to four parameters can be passed during the operation. See section 4.9.4 for a detailed specification of how these parameters are passed in the `paramTypes` and `params` arguments.

The result of this function is returned both in the return code and the return origin, stored in the variable pointed to by `returnOrigin`:

If the return origin is different from `TEE_ORIGIN_TRUSTED_APP`, then the function has failed before it could reach the destination Trusted Application. The possible return codes are listed in “Return Code” below.

If the return origin is `TEE_ORIGIN_TRUSTED_APP`, then the meaning of the return code is determined by the protocol exposed by the destination Trusted Application. It is recommended that the Trusted Application developer choose `TEE_SUCCESS` (`0`) to indicate success in their protocol, as this makes it possible to determine success or failure without looking at the return origin.

Parameters

- `session`: An opened session handle
- `cancellationRequestTimeout`: Timeout in milliseconds or the special value `TEE_TIMEOUT_INFINITE` if there is no timeout. After the timeout expires, the TEE SHALL act as though a cancellation request for the operation had been sent.
- `commandID`: The identifier of the Command to invoke. The meaning of each Command Identifier SHALL be defined in the protocol exposed by the target Trusted Application.
- `paramTypes`: The types of all parameters passed in the operation. See section 4.9.4 for more details.
- `params`: The parameters passed in the operation. See section 4.9.4 for more details.

  The `params` parameter is defined in the prototype as an array of length 4. Implementers should be aware that the address of the start of the array is passed to the callee.
- `returnOrigin`: A pointer to a variable which will contain the return origin. This field may be `NULL` if the return origin is not needed.

Specification Number: 10 **Function Number:** 0x402

Return Code

- If the return origin is different from `TEE_ORIGIN_TRUSTED_APP`, one of the following return codes can be returned:
  - `TEE_SUCCESS`: In case of success.
  - `TEE_ERROR_OUT_OF_MEMORY`: If not enough resources are available to perform the operation
  - `TEE_ERROR_TARGET_DEAD`: If the destination Trusted Application has panicked during the operation
  - `TEE_ERROR_CANCEL`: If the request is cancelled by anything other than the destination Trusted Application
- If the return origin is `TEE_ORIGIN_TRUSTED_APP`, the return code is defined by the protocol exposed by the destination Trusted Application.

Panic Reasons

- If the implementation detects that the security characteristics of a memory buffer would be downgraded by the requested access rights. See Table 4-5.
- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.
- If memory which was allocated with `TEE_MALLOC_NO_SHARE` is referenced by one of the parameters.

Backward Compatibility

The error code `TEE_CANCEL` was added in TEE Internal Core API v1.2.

4.9.4 Operation Parameters in the Internal Client API

The functions `TEE_OpenTASession` and `TEE_InvokeTACommand` take `paramTypes` and `params` as arguments. The calling Trusted Application can use these arguments to pass up to four parameters.

Each of the parameters has a type, which is one of the `TEE_PARAM_TYPE_XXX` values listed in section 4.2.1. The content of `paramTypes` SHOULD be built using the macro `TEE_PARAM_TYPES` (see section 4.3.6.1).

Unless all parameter types are set to `TEE_PARAM_TYPE_NONE`, `params` SHALL NOT be `NULL` and SHALL point to an array of four `TEE_Param` elements. Each of the `params[i]` is interpreted as follows.

When the operation starts, the Framework reads the parameters as described in the following table.

Table 4-15: Interpretation of `params[i]` on Entry to Internal Client API

Parameter Type	Interpretation of `params[i]`
`TEE_PARAM_TYPE_NONE` `TEE_PARAM_TYPE_VALUE_OUTPUT`	Ignored.
`TEE_PARAM_TYPE_VALUE_INPUT` `TEE_PARAM_TYPE_VALUE_INOUT`	Contains two integers in `params[i].value.a` and `params[i].value.b`.

`TEE_PARAM_TYPE_MEMREF_INPUT`
`TEE_PARAM_TYPE_MEMREF_OUTPUT`
`TEE_PARAM_TYPE_MEMREF_INOUT`
	`params[i].memref.buffer` and `params[i].memref.size` SHALL be initialized with a memory buffer that is accessible with the access rights described in the type. The buffer can be `NULL`, in which case `size` SHALL be set to `0`.

During the operation, the destination Trusted Application can update the contents of the `OUTPUT` or `INOUT` Memory References.

When the operation completes, the Framework updates the structure `params[i]` as described in the following table.

Table 4-16: Effects of Internal Client API on `params[i]`

Parameter Type	Effects on `params[i]`

`TEE_PARAM_TYPE_NONE`
`TEE_PARAM_TYPE_VALUE_INPUT`
`TEE_PARAM_TYPE_MEMREF_INPUT`
	Unchanged.

`TEE_PARAM_TYPE_VALUE_OUTPUT` `TEE_PARAM_TYPE_VALUE_INOUT`	`params[i].value.a` and `params[i].value.b` are updated with the value sent by the destination Trusted Application.
`TEE_PARAM_TYPE_MEMREF_OUTPUT` `TEE_PARAM_TYPE_MEMREF_INOUT`	`params[i].memref.size` is updated to reflect the actual or requested size of the buffer.

The implementation SHALL enforce the following restrictions on TEE_PARAM_TYPE_MEMREF_XXX values:

- Where all or part of the referenced memory buffer was passed to the TA from the REE or from another TA, the implementation SHALL NOT result in downgrade of the security characteristics of the buffer – see Table 4-5.
- Where all or part of the referenced buffer was allocated by the TA with the TEE_MALLOC_NO_SHARE hint, the implementation SHALL raise a Panic for the TA.

4.10 Cancellation Functions

This section defines functions for Trusted Applications to handle cancellation requested by a Client where a Client is either an REE Client Application or a TA.

When a Client requests cancellation using the function `TEEC_RequestCancellation` (in the case of an REE Client using the [Client API]) or a cancellation is created through a timeout (in the case of a TA Client), the implementation SHALL do the following:

- If the operation has not reached the TA yet but has been queued in the TEE, then it SHALL be retired from the queue and fail with the return code:
  - For an REE Client, `TEEC_ERROR_CANCEL` and the origin `TEEC_ORIGIN_TEE`;
  - For a TEE Client, `TEE_ERROR_CANCEL` and the origin `TEE_ORIGIN_TEE`.
- If the operation has been transmitted to the Trusted Application, the implementation SHALL set the Cancellation Flag of the task executing the command. If the Peripheral and Event APIs are present, a `TEE_Event_ClientCancel` event shall be inserted into the event queue by the session peripheral.
- If the Trusted Application has unmasked the effects of cancellation by using the function `TEE_UnmaskCancellation`, and if the task is engaged in a cancellable function when the Cancellation Flag is set, then that cancellable function is interrupted. The Trusted Application can detect that the function has been interrupted because it returns `TEE_ERROR_CANCEL`. It can then execute cleanup code and possibly fail the current client operation, although it may well report a success.
  - Note that this version of the specification defines the following cancellable functions: `TEE_Wait` and `TEE_Event_Wait`.
  - The functions `TEE_OpenTASession` and `TEE_InvokeTACommand`, while not cancellable per se, SHALL transmit cancellation requests: If the Cancellation Flag is set and the effects of cancellation are not masked, then the Trusted Core Framework SHALL consider that the cancellation of the corresponding operation is requested.
- When the Cancellation Flag is set for a given task, the function `TEE_GetCancellationFlag` SHALL return `true`, but only in the case the cancellations are not masked. This allows the Trusted Application to poll the Cancellation Flag, for example, when it is engaged in a lengthy active computation not using cancellable functions such as `TEE_Wait`.

4.10.1 TEE_GetCancellationFlag

Since: TEE Internal API v1.0

```
bool TEE_GetCancellationFlag( void );
```

Description

The `TEE_GetCancellationFlag` function determines whether the current task's Cancellation Flag is set. If cancellations are masked, this function SHALL return `false`. This function cannot panic.

Specification Number: 10 **Function Number:** 0x501

Return Value

- `true` if the Cancellation Flag is set and cancellations are not masked
- `false` if the Cancellation Flag is not set or if cancellations are masked

4.10.2 TEE_UnmaskCancellation

Since: TEE Internal API v1.0

```
bool TEE_UnmaskCancellation( void );
```

Description

The `TEE_UnmaskCancellation` function unmasks the effects of cancellation for the current task.

When cancellation requests are unmasked, the Cancellation Flag interrupts cancellable functions such as `TEE_Wait` and requests the cancellation of operations started with `TEE_OpenTASession` or `TEE_InvokeTACommand`.

By default, tasks created to handle a TA entry point have cancellation masked, so that a TA does not have to cope with the effects of cancellation requests.

Specification Number: 10 **Function Number:** 0x503

Return Value

- `true` if cancellations were masked prior to calling this function
- `false` otherwise

Panic Reasons

- If the implementation detects any error.

4.10.3 TEE_MaskCancellation

Since: TEE Internal API v1.0

```
bool TEE_MaskCancellation( void );
```

Description

The `TEE_MaskCancellation` function masks the effects of cancellation for the current task.

When cancellation requests are masked, the Cancellation Flag does not have an effect on the cancellable functions and cannot be retrieved using `TEE_GetCancellationFlag`.

By default, tasks created to handle a TA entry point have cancellation masked, so that a TA does not have to cope with the effects of cancellation requests.

Specification Number: 10 **Function Number:** 0x502

Return Value

- `true` if cancellations were masked prior to calling this function
- `false` otherwise

Panic Reasons

- If the implementation detects any error.

4.11 Memory Management Functions

This section defines the following functions:

- A function to check the access rights of a given buffer. This can be used in particular to check if the buffer belongs to shared memory.
- Access to an instance data register, which provides a possibly more efficient alternative to using read-write C global variables
- A malloc facility
- A few utilities to copy and fill data blocks

4.11.1 TEE_CheckMemoryAccessRights

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_CheckMemoryAccessRights(
                              uint32_t accessFlags,
                    [inbuf]   void*    buffer, size_t size);
```

Description

The `TEE_CheckMemoryAccessRights` function causes the implementation to examine a buffer of memory specified in the parameters `buffer` and `size` and to determine whether the current Trusted Application instance has the access rights requested in the parameter `accessFlags`. If the characteristics of the buffer are compatible with `accessFlags`, then the function returns `TEE_SUCCESS`. Otherwise, it returns `TEE_ERROR_ACCESS_DENIED`. Note that the buffer SHOULD NOT be accessed by the function, but the implementation SHOULD check the access rights based on the address of the buffer and internal memory management information.

The parameter `accessFlags` can contain one or more of the following flags:

- `TEE_MEMORY_ACCESS_READ`: Check that the buffer is entirely readable by the current Trusted Application instance.
- `TEE_MEMORY_ACCESS_WRITE`: Check that the buffer is entirely writable by the current Trusted Application instance.
- `TEE_MEMORY_ACCESS_ANY_OWNER`:
    - If this flag is *not* set, then the function checks that the buffer is not shared, i.e. whether it can be safely passed in an *[in]* or *[out]* parameter.
    - If this flag is set, then the function does not check ownership. It returns `TEE_SUCCESS` if the Trusted Application instance has read or write access to the buffer, independently of whether the buffer resides in memory owned by a Client or not.
- All other flags are reserved for future use and SHOULD be set to `0`.

The result of this function is valid until:

- The allocated memory area containing the supplied buffer is passed to `TEE_Realloc` or `TEE_Free`.
- One of the entry points of the Trusted Application returns.
- Actors outside of the TEE change the memory access rights when the memory is shared with an outside entity.

In the first two situations, the access rights of a given buffer MAY change and the Trusted Application SHOULD call the function `TEE_CheckMemoryAccessRights` again.

When this function returns `TEE_SUCCESS`, and as long as this result is still valid, the implementation SHALL guarantee the following properties:

- For the flag `TEE_MEMORY_ACCESS_READ` and `TEE_MEMORY_ACCESS_WRITE`, the implementation SHALL guarantee that subsequent read or write accesses by the Trusted Application wherever in the buffer will succeed and will not panic.
- When the flag `TEE_MEMORY_ACCESS_ANY_OWNER` is not set, the implementation SHALL guarantee that the memory buffer is owned either by the Trusted Application instance or by a more trusted component, and cannot be controlled, modified, or observed by a less trusted component, such as the Client of the Trusted Application. This means that the Trusted Application can assume the following guarantees:
    - **Read-after-read consistency**: If the Trusted Application performs two successive read accesses to the buffer at the same address and if, between the two read accesses, it performs no write, either directly or indirectly through the API to that address, then the two reads SHALL return the same result.
    - **Read-after-write consistency**: If the Trusted Application writes some data in the buffer and subsequently reads the same address and if it performs no write, either directly or indirectly through the API to that address in between, the read SHALL return the data.
    - **Non-observability**: If the Trusted Application writes some data in the buffer, then the data SHALL NOT be observable by components less trusted than the Trusted Application itself.

Note that when true memory sharing is implemented between Clients and the Trusted Application, the Memory Reference Parameters passed to the TA entry points will typically not satisfy these requirements. In this case, the function `TEE_CheckMemoryAccessRights` SHALL return `TEE_ERROR_ACCESS_DENIED`. The code handling such buffers has to be especially careful to avoid security issues brought by this lack of guarantees. For example, it can read each byte in the buffer only once and refrain from writing temporary data in the buffer.

Additionally, the implementation SHALL guarantee that some types of memory blocks have a minimum set of access rights:

- The following blocks SHALL allow read and write accesses, SHALL be owned by the Trusted Application instance, and SHOULD NOT allow code execution:
    - All blocks returned by `TEE_Malloc` or `TEE_Realloc`
    - All the local and global non-`const` C variables
    - The `TEE_Param` structures passed to the entry points `TA_OpenSessionEntryPoint` and `TA_InvokeCommandEntryPoint`. This applies to the immediate contents of the `TEE_Param` structures, but not to the pointers contained in the fields of such structures, which can of course point to memory owned by the client. Note that this also means that these `TEE_Param` structures SHALL NOT directly point to the corresponding structures in the TEE Client API (see [Client API]) or the Internal Client API (see section 4.9). The implementation SHALL perform a copy into a safe TA-owned memory buffer before passing the structures to the entry points.
- The following blocks SHALL allow read accesses, SHALL be owned by the Trusted Application instance, and SHOULD NOT allow code execution:
    - All `const` local or global C variables
- The following blocks MAY allow read accesses, SHALL be owned by the Trusted Application instance, and SHALL allow code execution:
    - The code of the Trusted Application itself

- When a particular parameter passed in the structure `TEE_Param` to a TA entry point is a Memory Reference as specified in its parameter type, then this block, as described by the initial values of the fields `buffer` and `size` in that structure, SHALL allow read and/or write accesses as specified in the parameter type. As noted above, this buffer is not required to reside in memory owned by the TA instance.

Finally, any implementation SHALL also guarantee that the `NULL` pointer cannot be dereferenced. If a Trusted Application attempts to read one byte at the address `NULL`, it SHALL panic. This guarantee SHALL extend to a segment of addresses starting at `NULL`, but the size of this segment is implementation-dependent.

Parameters

- `accessFlags`: The access flags to check. Valid values are shown in Table 4-5.
- `buffer`, `size`: The description of the buffer to check.

Specification Number: 10 **Function Number:** 0x601

Return Code

- `TEE_SUCCESS`: If the entire buffer allows the requested accesses
- `TEE_ERROR_ACCESS_DENIED`: If at least one byte in the buffer is not accessible with the requested accesses

Panic Reasons

`TEE_CheckMemoryAccessRights` SHALL NOT panic for any reason.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `size`.

Prior to TEE Internal Core API v1.2, `TEE_CheckMemoryAccessRights` did not specify the *[inbuf]* annotation on `buffer`.

4.11.2 TEE_SetInstanceData

Since: TEE Internal API v1.0

```
void TEE_SetInstanceData(
          [ctx] void* instanceData );
```

Description

The TEE_SetInstanceData and TEE_GetInstanceData functions provide an alternative to writable global data (writable variables with global scope and writable static variables with global or function scope). While an implementation SHALL support C global variables, using these functions may be sometimes more efficient, especially if only a single instance data variable is required.

These two functions can be used to register and access an instance variable. Typically this instance variable can be used to hold a pointer to a Trusted Application-defined memory block containing any writable data that needs instance global scope, or writable static data that needs instance function scope.

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 *instanceData may be set with a pointer to a buffer allocated by the Trusted Application instance or with anything else, such as an integer, a handle, etc. The Framework will *not* automatically free *instanceData when the session is closed; the Trusted Application instance is responsible for freeing memory if required.

An equivalent session context variable for managing session global and static data exists for sessions (see TA_OpenSessionEntryPoint, TA_InvokeCommandEntryPoint, and TA_CloseSessionEntryPoint in section 4.3).

This function sets the Trusted Application instance data pointer. The data pointer can then be retrieved by the Trusted Application instance by calling the TEE_GetInstanceData function.

Parameters

- instanceData: A pointer to the global Trusted Application instance data. This pointer may be NULL.

Specification Number: 10 **Function Number:** 0x609

Panic Reasons

- If the implementation detects any error.

4.11.3 TEE_GetInstanceData

Since: TEE Internal API v1.0

```
[ctx] void* TEE_GetInstanceData( void );
```

Description

The `TEE_GetInstanceData` function retrieves the instance data pointer set by the Trusted Application using the `TEE_SetInstanceData` function.

Specification Number: 10 **Function Number:** 0x603

Return Value

The value returned is the previously set pointer to the Trusted Application instance data, or `NULL` if no instance data pointer has yet been set.

Panic Reasons

- If the implementation detects any error.

4.11.4 TEE_Malloc

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void* TEE_Malloc(
          size_t   size,
          uint32_t hint );
```

Description

The `TEE_Malloc` function allocates space for an object whose size in bytes is specified in the parameter `size`.

The pointer returned is guaranteed to be aligned such that it may be assigned as a pointer to any basic C type.

The parameter `hint` is a hint to the allocator. The valid values for the hint are defined in Table 4-17. 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.

The hint values should be treated as a mask – they can be logically 'or'd together. In Table 4-17:

- 'x' in a field means that the value of that bit or bits can be `1` or `0`.
- 'y' in a field means that the value of that bit or bits is irrelevant to the definition of that row, **UNLESS already defined in a previous row**, and can be either `1` or `0`.

Table 4-17: Valid Hint Values

Name	Bit Number				Meaning
	31	30 - 2	1	0	
TEE_MALLOC_FILL_ZERO	0	x	x	0	Memory block returned SHALL be filled with zeros. Note: `TEE_MALLOC_NO_FILL` has precedence over `TEE_MALLOC_FILL_ZERO`.
TEE_MALLOC_NO_FILL	0	x	x	1	Memory block returned may not be filled with zeros
TEE_MALLOC_NO_SHARE	0	x	1	x	The returned block of memory will not be shared with other TA instances.
Reserved	0	y			Reserved for future versions of this specification.
Implementation defined	1	y			Reserved for implementation-defined hints.

The hint SHALL be attached to the allocated block and SHALL be used when the block is reallocated with `TEE_Realloc`.

If the space cannot be allocated, given the current `hint` value (for example because the hint value is not implemented), a `NULL` pointer SHALL be returned.

`TEE_MALLOC_NO_SHARE` provides a mechanism for a TA developer to indicate that the allocation request is not to be shared with other TAs. Implementations MAY choose to use this hint to allocate memory from memory pools which are optimized for performance at the expense of sharing.

`TEE_MALLOC_NO_FILL` provides a mechanism to allow a TA to indicate that it does not assume that memory will be zero filled. It SHALL be used in conjunction with `TEE_MALLOC_NO_SHARE`.

A Trusted OS MAY use the `TEE_MALLOC_NO_FILL` hint to avoid clearing memory on allocation where it is safe to do so. When allocating to a TA, a Trusted OS SHALL zero fill memory which:

- Has previously been allocated to another TA instance;
- Has previously been allocated to internal structures of the TEE.
- Does not have the `TEE_MALLOC_NO_SHARE` hint.

Parameters

- `size`: The size of the buffer to be allocated.
- `hint`: A hint to the allocator. See Table 4-17 for valid values.

Specification Number: 10 **Function Number:** 0x604

Return Value

Upon successful completion, with size not equal to zero, the function returns a pointer to the allocated space. If the space cannot be allocated, given the current `hint` value, a `NULL` pointer is returned.

If the size of the requested space is zero:

- The value returned is undefined but guaranteed to be different from `NULL`. This non-`NULL` value ensures that the hint can be associated with the returned pointer for use by `TEE_Realloc`.
- The Trusted Application SHALL NOT access the returned pointer. The Trusted Application SHOULD panic if the memory pointed to by such a pointer is accessed for either read or write.

Panic Reasons

- If the implementation detects any error.
- If `TEE_MALLOC_NO_FILL` is used without `TEE_MALLOC_NO_SHARE`.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `size`.

The hint values `TEE_MALLOC_NO_SHARE` and `TEE_MALLOC_NO_FILL` were added in TEE Internal Core API v1.2.

4.11.5 TEE_Realloc

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void* TEE_Realloc(
            [inout]  void*    buffer,
                     size_t   newSize );
```

Description

The `TEE_Realloc` function changes the size of the memory object pointed to by `buffer` to the size specified by `newSize`.

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.

If `buffer` is `NULL`, `TEE_Realloc` is equivalent to `TEE_Malloc` for the specified size. The associated hint applied SHALL be the default value defined in `TEE_Malloc`.

It is a programmer error if `buffer` does not match a pointer previously returned by `TEE_Malloc` or `TEE_Realloc`, or if the space has previously been deallocated by a call to `TEE_Free` or `TEE_Realloc`.

If the hint initially provided when the block was allocated with `TEE_Malloc` is `0`, then the extended space is filled with zeroes. In general, the function `TEE_Realloc` SHOULD allocate the new memory buffer using exactly the same hint as for the buffer initially allocated with `TEE_Malloc`. In any case, it SHALL NOT downgrade the security or performance characteristics of the buffer.

Note that any pointer returned by `TEE_Malloc` or `TEE_Realloc` and not yet freed or reallocated can be passed to `TEE_Realloc`. This includes the special non-`NULL` pointer returned when an allocation for `0` bytes is requested.

Parameters

- `buffer`: The pointer to the object to be reallocated
- `newSize`: The new size required for the object

Specification Number: 10 **Function Number:** 0x608

Return Value

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.

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

Prior to TEE Internal Core API v1.2:

- `TEE_Realloc` used the *[in]* annotation for `buffer`.
- `TEE_Realloc` used type `uint32_t` for the `size` parameter. On a Trusted OS with natural word length greater than 32 bits this leads to operation limitations, and the size parameter was changed to a `size_t`.

A backward compatible version of `TEE_Realloc` can be selected at compile time if the version compatibility definitions (see section 3.5.1) indicate that compatibility with a version of this specification before v1.2 is required.

```
void* TEE_Realloc(
          [in]    void*       buffer,
                  uint32_t    newSize );
```

4.11.6 TEE_Free

Since: TEE Internal API v1.0

```
void TEE_Free(void *buffer);
```

Description

The `TEE_Free` function causes the space pointed to by `buffer` to be deallocated; that is, made available for further allocation.

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

Specification Number: 10 **Function Number:** 0x602

Panic Reasons

- If the implementation detects any error.

4.11.7 TEE_MemMove

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void  TEE_MemMove(
  [outbuf(size)]   void*     dest,
  [inbuf(size)]    void*     src,
                   size_t    size );
```

Description

The `TEE_MemMove` function copies `size` bytes from the buffer pointed to by `src` into the buffer pointed to by `dest`.

Copying takes place as if the `size` bytes from the buffer pointed to by `src` are first copied into a temporary array of `size` bytes that does not overlap the buffers pointed to by `dest` and `src`, and then the `size` bytes from the temporary array are copied into the buffer pointed to by `dest`.

Parameters

- `dest`: A pointer to the destination buffer
- `src`: A pointer to the source buffer
- `size`: The number of bytes to be copied

Specification Number: 10 **Function Number:** 0x607

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_MemMove` used type `uint32_t` for the size parameter. On a Trusted OS with natural word length greater than 32 bits this leads to operation limitations, and the size parameter was changed to a `size_t`.

A backward compatible version of `TEE_MemMove` can be selected at compile time if the version compatibility definitions (see section 3.5.1) indicate that compatibility with a version of this specification before v1.2 is required.

```
void TEE_MemMove(
  [inbuf(size)] void*       buffer1,
  [inbuf(size)] void*       buffer2,
                uint32_t    size);
```

4.11.8 TEE_MemCompare

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
int32_t TEE_MemCompare(
  [inbuf(size)] void*       buffer1,
  [inbuf(size)] void*       buffer2,
                size_t      size);
```

Description

The TEE_MemCompare function compares the first size bytes of the buffer pointed to by buffer1 to the first size bytes of the buffer pointed to by buffer2.

Parameters

- buffer1: A pointer to the first buffer
- buffer2: A pointer to the second buffer
- size: The number of bytes to be compared

Specification Number: 10 **Function Number:** 0x605

Return Value

The sign of a non-zero return value is determined by the sign of the difference between the values of the first pair of bytes (both interpreted as type uint8_t) that differ in the objects being compared.

- If the first byte that differs is higher in buffer1, then return an integer greater than zero.
- If the first size bytes of the two buffers are identical, then return zero.
- If the first byte that differs is higher in buffer2, then return an integer lower than zero.

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

Prior to TEE Internal Core API v1.2, TEE_MemCompare used type uint32_t for the size parameter. On a Trusted OS with natural word length greater than 32 bits this leads to operation limitations, and the size parameter was changed to a size_t.

A backward compatible version of TEE_MemCompare can be selected at compile time if the version compatibility definitions (see section 3.5.1) indicate that compatibility with a version of this specification before v1.2 is required.

```
int32_t TEE_MemCompare(
  [inbuf(size)] void*       buffer1,
  [inbuf(size)] void*       buffer2,
                uint32_t    size);
```

4.11.9 TEE_MemFill

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void  TEE_MemFill(
 [outbuf(size)] void*     buffer,
                uint8_t   x,
                size_t    size);
```

Description

The `TEE_MemFill` function writes the byte `x` into the first `size` bytes of the buffer pointed to by `buffer`.

Parameters

- `buffer`: A pointer to the destination buffer
- `x`: The value to be set
- `size`: The number of bytes to be set

Specification Number: 10 **Function Number:** 0x606

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_MemFill` used type `uint32_t` for the `x` and `size` parameters.

- The previous definition of `x` stated that the value of `x` would be cast to a `uint8_t`, which has now been made explicit.
- Using `uint32_t` for a `size` parameter can lead to limitations on some platforms, and the `size` parameter has been changed to a `size_t`.

A backward compatible version of `TEE_MemFill` can be selected at compile time if the version compatibility definitions (see section 3.5.1) indicate that compatibility with a version of this specification before v1.2 is required.

```
void  TEE_MemFill(
 [outbuf(size)] void*     buffer,
                uint32_t  x,
                uint32_t  size);
```

5 Trusted Storage API for Data and Keys

This chapter includes the following sections:

5.1 Summary of Features and Design

This section provides a summary of the features and design of the Trusted Storage API.

- Each TA has access to a set of Trusted Storage Spaces, identified by 32-bit Storage Identifiers.
  - This specification defines three Trusted Storage Spaces for each TA, which are its own private storage spaces.
    - `TEE_STORAGE_PRIVATE`
      - A storage space that SHALL be private to the TEE, but that MAY be external to the hardware supporting the TEE.
      - Tampering SHALL be detected.
      - Rollback SHALL be detected as described in section 5.2.
      - This storage space MAY NOT be available if the REE is not active.
      - This storage space SHALL be erased by a factory reset.
    - `TEE_STORAGE_PERSO` (Optional)
      - A storage space that SHALL be private to the TEE, but that MAY be external to the hardware supporting the TEE.
      - Required by TMF (see [TMF ASN.1] section 5.5).
      - Tampering SHALL be detected.
      - Rollback SHALL be detected as described in section 5.2.
      - This storage space MAY NOT be available if the REE is not active.
      - Immunity from factory reset if present in the `gpd.tee.tmf.resetpreserved.entities` property (see [TMF ASN.1] section 6.5.4).
    - `TEE_STORAGE_PROTECTED` (Optional)
      - A storage space with additional characteristics over `TEE_STORAGE_PRIVATE` including:
        - Immunity from tampering.
        - Immunity from rollback.

        - Immunity from factory reset if present in the `gpd.tee.tmf.resetpreserved.entities` property (see [TMF ASN.1] section 6.5.4).
      - This storage space MAY impose relatively low per TA storage limits and MAY impose rate limits. If storage or rate limiting is required, it SHALL be enforced by the Trusted OS.
      - This storage space MAY also be available while the REE is booting. GlobalPlatform believes that this can be implemented using a Replay Protected Memory Block (RPMB).
  - Unless explicitly overridden by other specifications, the objects in any Trusted Storage Space are accessible only to the TA that created them and SHALL NOT be visible to other TEE entities except those associated directly with implementing the Trusted Storage System.
  - Other storage identifiers may be defined in future versions of this specification or by an implementation, e.g. to refer to storage spaces shared among multiple TAs or for communicating between boot-time entities and run-time Trusted Applications.
- A Trusted Storage Space contains Persistent Objects. Each persistent object is identified by an Object Identifier, which is a variable-length binary buffer from `0` to `64` bytes. Object identifiers can contain any bytes, including bytes corresponding to non-printable characters.
- A persistent object can be a Cryptographic Key Object, a Cryptographic Key-Pair Object, or a Data Object.
- Each persistent object has a type, which precisely defines the content of the object. For example, there are object types for AES keys, RSA key-pairs, data objects, etc.
- All persistent objects have an associated Data Stream. Persistent data objects have only a data stream. Persistent cryptographic objects (that is, keys or key-pairs) have a data stream, Object Attributes, and metadata.
  - The Data Stream is entirely managed in the TA memory space. It can be loaded into a TA-allocated buffer when the object is opened or stored from a TA-allocated buffer when the object is created. It can also be accessed as a stream, so it can be used to store large amounts of data accessed by small chunks.
  - Object Attributes are used for small amounts of data (typically a few tens or hundreds of bytes). They can be stored in a memory pool that is separated from the TA instance and some attributes may be hidden from the TA itself. Attributes are used to store the key material in a structured way. For example, an RSA key-pair has an attribute for the modulus, the public exponent, the private exponent, etc. When an object is created, all mandatory Object Attributes SHALL be specified and optional attributes MAY be specified.

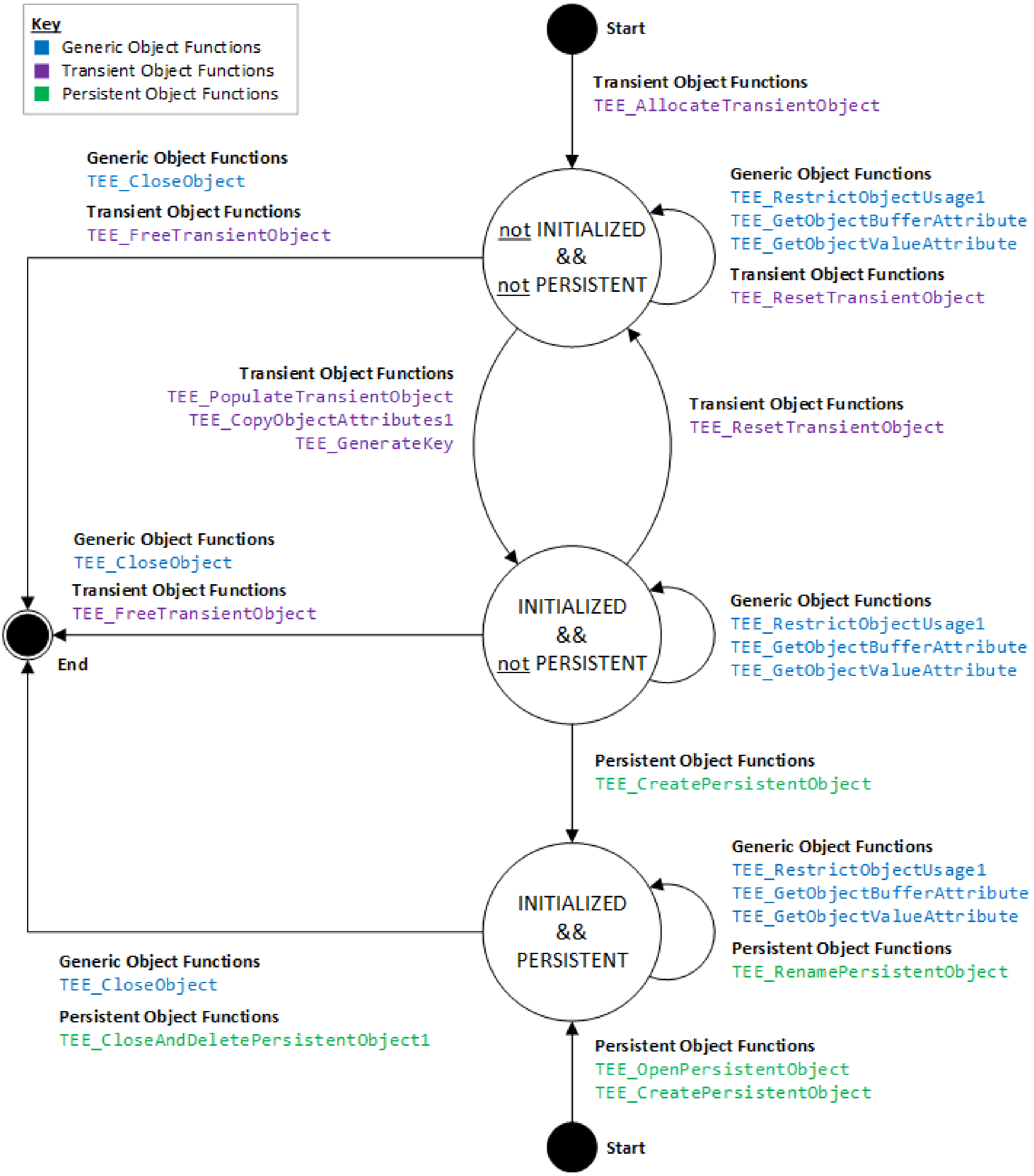
    Note that an implementation is allowed to store more information in an object than the visible attributes. For example, some data might be pre-computed and stored internally to accelerate subsequent cryptographic operations.
  - The metadata associated with each cryptographic object includes:
    - Key Size in bits. The precise meaning depends on the key algorithm. For example, AES key can have 128 bits, 192 bits, or 256 bits; RSA keys can have 1024 bits or 2048 bits or any other supported size, etc.
    - Key Usage Flags, which define the operations permitted with the key as well as whether the sensitive parts of the key material can be retrieved by the TA or not.
- A TA can also allocate Transient Objects. Compared to persistent objects:
  - Transient objects are held in memory and are automatically wiped and reclaimed when they are closed or when the TA instance is destroyed.

  - Transient objects contain only attributes and no data stream.
  - A transient object can be **uninitialized**, in which case it is an object container allocated with a certain object type and maximum size but with no attributes. A transient object becomes **initialized** when its attributes are populated. Note that persistent objects are always created initialized. This means that when the TA wants to generate or derive a persistent key, it has to first use a transient object then write the attributes of a transient object into a persistent object.
  - Transient objects have no identifier, they are only manipulated through object handles.
  - Currently, transient objects are used for cryptographic keys and key-pairs.
- Any function that accesses a persistent object handle MAY return a status of `TEE_ERROR_CORRUPT_OBJECT` or `TEE_ERROR_CORRUPT_OBJECT_2`, which indicates that corruption of the object has been detected. Before this status is returned, the implementation SHALL delete the corrupt object and MAY close the associated handle; see `gpd.ta.doesNotCloseHandleOnCorruptedObject` on page 84.
- Any function that accesses a persistent object MAY return a status of `TEE_ERROR_STORAGE_NOT_AVAILABLE` or `TEE_ERROR_STORAGE_NOT_AVAILABLE_2`, which indicates that the storage system in which the object is stored is not accessible for some reason.
- Persistent and transient objects are manipulated through opaque Object Handles.
  - Some functions accept both types of object handles. For example, a cryptographic operation can be started with either a transient key handle or a persistent key handle.
  - Some functions accept only handles on transient objects. For example, populating the attributes of an object works only with a transient object because it requires an uninitialized object and persistent objects are always fully initialized.
  - Finally, the file-like API functions to access the data stream work only with persistent objects because transient objects have no data stream.

Cryptographic operations are described in Chapter 6.

Figure 5-1 illustrates how a `TEE_ObjectHandle` is manipulated by the Trusted Storage API. The state diagram is expressed in terms of the state that is revealed in the `handleFlags` by `TEE_GetObjectInfo1`.

2238 **Figure 5-1: State Diagram for `TEE_ObjectHandle` (Informative)**



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5.2 Trusted Storage and Rollback Protection

The level of protection that a Trusted Application can assume from the rollback detection mechanism of the Trusted Storage Spaces is implementation defined. The implementation SHALL provide appropriate properties as defined in Table 4-14 in section 4.7 to indicate the level of protection provided.

```
gpd.tee.trustedStorage.private.rollbackProtection
gpd.tee.trustedStorage.perso.rollbackProtection
gpd.tee.trustedStorage.protected.rollbackProtection
```

Trusted Applications can query the implementation properties to discover the level of protection.

Table 5-1: Values of Trusted Storage Space Rollback Protection Properties *[obsolete]*

<table>
<tr><th>Property Value</th><th>Meaning</th></tr>
<tr><td colspan="2">This table existed in previous versions of the specification and was removed in v1.3.

The values of the rollback protection properties are discussed in Table 4-14: Implementation Properties. See page 90.</td></tr>
</table>

5.3 Data Types

5.3.1 TEE_Attribute

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

An array of this type is passed whenever a set of attributes is specified as argument to a function of the API.

```
typedef struct {
   uint32_t attributeID;
   union
   {
      struct
      {
         [inoutbuf] void* buffer; size_t length;
      } ref;
      struct
      {
         uint32_t a;
         uint32_t b;
      } value;
   } content;
} TEE_Attribute;
```

An attribute can be either a buffer attribute or a value attribute. This is determined by bit [29] of the attribute identifier. If this bit is set to `0`, then the attribute is a buffer attribute and the field `ref` SHALL be selected. If the bit is set to 1, then it is a value attribute and the field `value` SHALL be selected.

When an array of attributes is passed to a function, either to populate an object or to specify operation parameters, and if an attribute identifier occurs twice in the array, then only the first occurrence is used.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `length`.

Versions prior to TEE Internal Core API v1.3 used a different notation for `buffer`.

5.3.2 TEE_ObjectInfo

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
typedef struct {
   uint32_t objectType;
   uint32_t objectSize;
   uint32_t maxObjectSize;
   uint32_t objectUsage;
   size_t   dataSize;
   size_t   dataPosition;
   uint32_t handleFlags;
} TEE_ObjectInfo;
```

See the documentation of function `TEE_GetObjectInfo1` in section 5.5.1 for a description of this structure.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `dataSize` and `dataPosition` were defined as `uint32_t`. Note that `objectType` and `objectSize` have intentionally remained as `uint32_t` as they are used to define keys and similar material which can always be represented in a buffer which can be indexed by a `uint32_t`.

5.3.3 TEE_Whence

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
typedef uint32_t TEE_Whence;
```

This structure indicates the possible start offset when moving a data position in the data stream associated with a persistent object. The following table lists the legal values for `TEE_Whence`. All other values are reserved.

Table 5-1b: `TEE_Whence` Constants

Constant Name	Value
TEE_DATA_SEEK_SET	0x00000000
TEE_DATA_SEEK_CUR	0x00000001
TEE_DATA_SEEK_END	0x00000002
Reserved	0x00000003 – 0x7FFFFFFE
TEE_WHENCE_ILLEGAL_VALUE	0x7FFFFFFF
Implementation defined	0x80000000 – 0xFFFFFFFF

`TEE_WHENCE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when provided to the `TEE_SeekObjectData` function.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_Whence` was defined as an `enum`.

5.3.4 TEE_ObjectHandle

Since: TEE Internal API v1.0

```
typedef struct __TEE_ObjectHandle* TEE_ObjectHandle;
```

`TEE_ObjectHandle` is an opaque handle (as defined in section 2.4) on an object.

These handles are returned by the functions `TEE_AllocateTransientObject` (section 5.6.1), `TEE_OpenPersistentObject` (section 5.7.1), and `TEE_CreatePersistentObject` (section 5.7.2).

5.3.5 TEE_ObjectEnumHandle

Since: TEE Internal API v1.0

```
typedef struct __TEE_ObjectEnumHandle* TEE_ObjectEnumHandle;
```

`TEE_ObjectEnumHandle` is an opaque handle (as defined in section 2.4) on an object enumerator. These handles are returned by the function `TEE_AllocatePersistentObjectEnumerator` specified in section 5.8.1.

5.4 Constants

5.4.1 Constants Used in Trusted Storage API for Data and Keys

The following tables pertain to the Trusted Storage API for Data and Keys (Chapter 5).

Table 5-2: Object Storage Constants

Constant Name	Value
Reserved	0x00000000
TEE_STORAGE_PRIVATE	0x00000001
TEE_STORAGE_PERSO	0x00000002
TEE_STORAGE_PROTECTED	0x00000003
Reserved for future use	0x00000004-0x7FFFFFFE
TEE_STORAGE_ILLEGAL_VALUE	0x7FFFFFFF
Reserved for implementation defined storage	0x80000000-0xFFFFFFFF

TEE_STORAGE_ILLEGAL_VALUE is reserved for testing and validation and SHALL be treated as an undefined value when provided to the TEE_OpenPersistentObject or TEE_CreatePersistentObject function.

Table 5-3: Data Flag Constants

Constant Name	Value
TEE_DATA_FLAG_ACCESS_READ	0x00000001
TEE_DATA_FLAG_ACCESS_WRITE	0x00000002
TEE_DATA_FLAG_ACCESS_WRITE_META	0x00000004
TEE_DATA_FLAG_SHARE_READ	0x00000010
TEE_DATA_FLAG_SHARE_WRITE	0x00000020
TEE_DATA_FLAG_OVERWRITE	0x00000400
TEE_DATA_FLAG_EXCLUSIVE (deprecated, replace with TEE_DATA_FLAG_OVERWRITE)	0x00000400
Set bits reserved for use by GlobalPlatform	0x007FF800
TEE_DATA_FLAG_ILLEGAL_VALUE	0x00800000
Set bits reserved for implementation defined flags	0xFF000000

TEE_DATA_FLAG_ILLEGAL_VALUE is reserved for testing and validation and SHALL be treated as an undefined value when provided to the TEE_OpenPersistentObject or TEE_CreatePersistentObject function.

Table 5-4: Usage Constants

Constant Name	Value
TEE_USAGE_EXTRACTABLE	0x00000001
TEE_USAGE_ENCRYPT	0x00000002
TEE_USAGE_DECRYPT	0x00000004
TEE_USAGE_MAC	0x00000008
TEE_USAGE_SIGN	0x00000010
TEE_USAGE_VERIFY	0x00000020
TEE_USAGE_DERIVE	0x00000040
Set bits reserved for use by GlobalPlatform	0x007FFF80
TEE_USAGE_ILLEGAL_VALUE	0x00800000
Set bits reserved for implementation defined flags	0xFF000000

`TEE_USAGE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when provided to the `TEE_RestrictObjectUsage1` or `TEE_GetObjectInfo1` function.

Table 5-4b: Miscellaneous Constants *[formerly Table 5-8]*

Constant Name	Value
TEE_DATA_MAX_POSITION	0xFFFFFFFF
TEE_OBJECT_ID_MAX_LEN	64

5.4.2 Constants Used in Cryptographic Operations API

The following tables pertain to the Cryptographic Operations API (Chapter 6).

Table 5-5: Handle Flag Constants

Constant Name	Value
Set bits reserved for implementation defined flags	`0x0000FFFF`
`TEE_HANDLE_FLAG_PERSISTENT`	`0x00010000`
`TEE_HANDLE_FLAG_INITIALIZED`	`0x00020000`
`TEE_HANDLE_FLAG_KEY_SET`	`0x00040000`
`TEE_HANDLE_FLAG_EXPECT_TWO_KEYS`	`0x00080000`
`TEE_HANDLE_FLAG_EXTRACTING`	`0x00100000`
Set bits reserved for use by GlobalPlatform	`0xFFE00000`

Table 5-6: Operation Constants

Constant Name	Value
`TEE_OPERATION_CIPHER`	`1`
`TEE_OPERATION_MAC`	`3`
`TEE_OPERATION_AE`	`4`
`TEE_OPERATION_DIGEST`	`5`
`TEE_OPERATION_ASYMMETRIC_CIPHER`	`6`
`TEE_OPERATION_ASYMMETRIC_SIGNATURE`	`7`
`TEE_OPERATION_KEY_DERIVATION`	`8`
Reserved for future use	`0x00000009-0x7FFFFFFF`
Implementation defined	`0x80000000-0xFFFFFFFF`

Table 5-7: Operation States

Constant Name	Value
`TEE_OPERATION_STATE_INITIAL`	`0x00000000`
`TEE_OPERATION_STATE_ACTIVE`	`0x00000001`
`TEE_OPERATION_STATE_EXTRACTING`	`0x00000002`
Reserved for future use	`0x00000003-0x7FFFFFFF`
Implementation defined	`0x80000000-0xFFFFFFFF`

Table 5-8: *[moved – now Table 5-4b]*

5.5 Generic Object Functions

These functions can be called on both transient and persistent object handles.

5.5.1 TEE_GetObjectInfo1

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_GetObjectInfo1(
         TEE_ObjectHandle      object,
   [out] TEE_ObjectInfo*       objectInfo );
```

Description

This function replaces the `TEE_GetObjectInfo` function, whose use is deprecated.

The `TEE_GetObjectInfo1` function returns the characteristics of an object. It fills in the following fields in the structure `TEE_ObjectInfo` (section 5.3.2):

- `objectType`: The parameter `objectType` passed when the object was created
- `objectSize`: The current size in bits of the object as determined by its attributes. This will always be less than or equal to `maxObjectSize`. Set to `0` for uninitialized and data only objects.
- `maxObjectSize`: The maximum `objectSize` which this object can represent.
  - For a persistent object, set to `objectSize`
  - For a transient object, set to the parameter `maxObjectSize` passed to `TEE_AllocateTransientObject`
- `objectUsage`: A bit vector of the `TEE_USAGE_XXX` bits defined in Table 5-4.
- `dataSize`
  - For a persistent object, set to the current size of the data associated with the object
  - For a transient object, always set to `0`
- `dataPosition`
  - For a persistent object, set to the current position in the data for this handle. Data positions for different handles on the same object may differ.
  - For a transient object, set to `0`
- `handleFlags`: A bit vector containing one or more of the following flags:
  - `TEE_HANDLE_FLAG_PERSISTENT`: Set for a persistent object
  - `TEE_HANDLE_FLAG_INITIALIZED`
    - For a persistent object, always set
    - For a transient object, initially cleared, then set when the object becomes initialized
  - `TEE_DATA_FLAG_XXX`: Only for persistent objects, the flags used to open or create the object

Parameters

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

Specification Number: 10 **Function Number:** 0x706

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_CORRUPT_OBJECT: If the persistent object is corrupt. The object handle SHALL behave based on the gpd.ta.doesNotCloseHandleOnCorruptObject property.
- TEE_ERROR_STORAGE_NOT_AVAILABLE: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If object is not a valid opened object handle.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, the behavior associated with the return code TEE_ERROR_CORRUPT_OBJECT resulted in the object handle always being closed.

5.5.2 TEE_RestrictObjectUsage1

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_RestrictObjectUsage1(
   TEE_ObjectHandle  object,
   uint32_t          objectUsage );
```

Description

This function replaces the `TEE_RestrictObjectUsage` function, whose use is deprecated.

The `TEE_RestrictObjectUsage1` function restricts the object usage flags of an object handle to contain at most the flags passed in the `objectUsage` parameter.

For each bit in the parameter `objectUsage`:

- If the bit is set to 1, the corresponding usage flag in the object is left unchanged.
- If the bit is set to `0`, the corresponding usage flag in the object is cleared.

For example, if the usage flags of the object are set to `TEE_USAGE_ENCRYPT | TEE_USAGE_DECRYPT` and if `objectUsage` is set to `TEE_USAGE_ENCRYPT | TEE_USAGE_EXTRACTABLE`, then the only remaining usage flag in the object after calling the function `TEE_RestrictObjectUsage1` is `TEE_USAGE_ENCRYPT`.

Note that an object usage flag can only be cleared. Once it is cleared, it cannot be set to 1 again on a persistent object.

A transient object's object usage flags are reset to 1 using the `TEE_ResetTransientObject` function.

For a persistent object, setting the object usage SHALL be an atomic operation.

Parameters

- `object`: Handle on an object
- `objectUsage`: New object usage, an OR combination of one or more of the `TEE_USAGE_XXX` constants defined in Table 5-4

Specification Number: 10 **Function Number:** 0x707

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_CORRUPT_OBJECT`: If the persistent object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid opened object handle.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.5.3 TEE_GetObjectBufferAttribute

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_GetObjectBufferAttribute(
               TEE_ObjectHandle   object,
               uint32_t           attributeID,
   [outbuf]    void*              buffer, size_t* size );
```

Description

The `TEE_GetObjectBufferAttribute` function extracts one buffer attribute from an object.

The attribute is identified by the argument `attributeID`. The precise meaning of this parameter depends on the container type and size and is defined in section 6.1.1.

Bit [29] of the attribute identifier SHALL be set to `0`; i.e. it SHALL denote a buffer attribute.

There are two kinds of object attributes, which are identified by a bit in their handle value (see Table 6-17):

- Public object attributes can always be extracted whatever the status of the container.
- Protected attributes can be extracted only if the object's key usage contains the `TEE_USAGE_EXTRACTABLE` flag.

See section 6.1.1 for a definition of all available object attributes, their formats, and their level of protection.

Note: It is recommended that TA writers do not rely on implementations stripping leading zeros from bignum attributes and check actual key size using the `TEE_GetObjectInfo1` function. However, calling `TEE_GetObjectBufferAttribute` with a NULL buffer will trigger a `TEE_ERROR_SHORT_BUFFER` return value (see section 3.4.4) and is guaranteed to return a size sufficient to hold the attribute.

Parameters

- `object`: Handle of the object
- `attributeID`: Identifier of the attribute to retrieve
- `buffer`, `size`: Output buffer to get the content of the attribute

Specification Number: 10 **Function Number:** 0x702

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the attribute is not found on this object
- `TEE_ERROR_SHORT_BUFFER`: If `buffer` is `NULL` or too small to contain the key part
- `TEE_ERROR_CORRUPT_OBJECT`: If the persistent object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid opened object handle.
- If the object is not initialized.
- If Bit [29] of `attributeID` is not set to `0`, so the attribute is not a buffer attribute.

- If Bit [28] of attributeID is set to 0, denoting a protected attribute, and the object usage does not contain the TEE_USAGE_EXTRACTABLE flag.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for size.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code TEE_ERROR_CORRUPT_OBJECT resulted in the object handle always being closed.

5.5.4 TEE_GetObjectValueAttribute

Since: TEE Internal API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_GetObjectValueAttribute(
               TEE_ObjectHandle   object,
               uint32_t           attributeID,
    [outopt]   uint32_t*          a,
    [outopt]   uint32_t*          b );
```

Description

The TEE_GetObjectValueAttribute function extracts a value attribute from an object.

The attribute is identified by the argument attributeID. The precise meaning of this parameter depends on the container type and size and is defined in section 6.1.1.

Bit [29] of the attribute identifier SHALL be set to 1, i.e. it SHALL denote a value attribute.

They are two kinds of object attributes, which are identified by a bit in their handle value (see Table 6-17):

- Public object attributes can always be extracted whatever the status of the container.
- Protected attributes can be extracted only if the object's key usage contains the TEE_USAGE_EXTRACTABLE flag.

See section 6.1.1 for a definition of all available object attributes and their level of protection.

Where the format of the attribute (see Table 6-16) does not define a meaning for b, the value returned for b is implementation defined.

Parameters

- object: Handle of the object
- attributeID: Identifier of the attribute to retrieve
- a, b: Pointers on the placeholders filled with the attribute fields a and b. Each can be NULL if the corresponding field is not of interest to the caller.

Specification Number: 10 **Function Number:** 0x704

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_ITEM_NOT_FOUND: If the attribute is not found on this object
- TEE_ERROR_ACCESS_DENIED: Deprecated: Handled by a Panic
- TEE_ERROR_CORRUPT_OBJECT: If the persistent object is corrupt. The object handle SHALL behave based on the gpd.ta.doesNotCloseHandleOnCorruptObject property.
- TEE_ERROR_STORAGE_NOT_AVAILABLE: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If object is not a valid opened object handle.
- If the object is not initialized.
- If Bit [29] of attributeID is not set to 1, so the attribute is not a value attribute.

- If Bit [28] of `attributeID` is set to `0`, denoting a protected attribute, and the object usage does not contain the `TEE_USAGE_EXTRACTABLE` flag.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.5.5 TEE_CloseObject

Since: TEE Internal API v1.0

```
void TEE_CloseObject( TEE_ObjectHandle object );
```

Description

The `TEE_CloseObject` function closes an opened object handle. The object can be persistent or transient. For transient objects, `TEE_CloseObject` is equivalent to `TEE_FreeTransientObject`.

This function will operate correctly even if the object or the containing storage is corrupt.

Parameters

- `object`: Handle on the object to close. If set to `TEE_HANDLE_NULL`, does nothing.

Specification Number: 10 **Function Number:** 0x701

Panic Reasons

- If `object` is not a valid opened object handle and is not equal to `TEE_HANDLE_NULL`.
- If the implementation detects any other error.

5.6 Transient Object Functions

5.6.1 TEE_AllocateTransientObject

Since: TEE Internal API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_AllocateTransientObject(
        uint32_t          objectType,
        uint32_t          maxObjectSize,
  [out] TEE_ObjectHandle* object );
```

Description

The TEE_AllocateTransientObject function allocates an uninitialized transient object, i.e. a container for attributes. Transient objects are used to hold a cryptographic object (key or key-pair).

The object type SHALL be specified. The maximum key size SHALL also be specified with all of the object types defined in Table 5-9.

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. For backward compatibility reasons, a Trusted OS SHALL treat object types that are not defined in Table 5-9 as though they require TEE_KEYSIZE_NO_KEY.

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.

The initial value of the key usage associated with the container is 0xFFFFFFFF, which means that it contains all usage flags. You can use the function TEE_RestrictObjectUsage1 to restrict the usage of the container.

The returned handle is used to refer to the newly-created container in all subsequent functions that require an object container: key management and operation functions. The handle remains valid until the container is deallocated using the function TEE_FreeTransientObject.

As shown in Table 5-9, the object type determines the possible object size to be passed to TEE_AllocateTransientObject, which is not necessarily the size of the object to allocate. In particular, for key objects the size to be passed is one of the appropriate key sizes described in Table 5-9.

A compliant implementation SHALL implement all object types and key sizes as described in Table 5-9.

Table 5-9: TEE_AllocateTransientObject Object Types and Key Sizes[3]

Object Type	Possible Key Sizes
TEE_TYPE_AES	128, 192, or 256 bits
TEE_TYPE_DES	Always 64 bits including the parity bits. This gives an effective key size of 56 bits
TEE_TYPE_DES3	128 or 192 bits including the parity bits. This gives effective key sizes of 112 or 168 bits
TEE_TYPE_HMAC_MD5	Between 64 and 512 bits, multiple of 8 bits
TEE_TYPE_HMAC_SHA1	Between 80 and 512 bits, multiple of 8 bits

[3] WARNING: Given the increases in computing power, it is necessary to increase the strength of encryption used with time. Many of the algorithms and key sizes included are known to be weak and are included to support legacy implementations only. TA designers should regularly review the choice of cryptographic primitives and key sizes used in their applications and should refer to appropriate government guidelines.

Object Type	Possible Key Sizes	
TEE_TYPE_HMAC_SHA224	Between 112 and 512 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA256	Between 192 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA384	Between 256 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA512	Between 256 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA3_224	Between 192 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA3_256	Between 256 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA3_384	Between 256 and 1024 bits, multiple of 8 bits	
TEE_TYPE_HMAC_SHA3_512	Between 256 and 1024 bits, multiple of 8 bits	
TEE_TYPE_RSA_PUBLIC_KEY	The number of bits in the modulus. 256, 512, 768, 1024, 1536, 2048, 3072, and 4096 bit keys SHALL be supported. Support for other key sizes including bigger key sizes is implementation-dependent. Minimum key size is 256 bits.	
TEE_TYPE_RSA_KEYPAIR	Same as for RSA public key size.	
TEE_TYPE_DSA_PUBLIC_KEY	Depends on algorithm:	
	TEE_ALG_DSA_SHA1	Between 512 and 1024 bits, multiple of 64 bits
	TEE_ALG_DSA_SHA224	2048 bits
	TEE_ALG_DSA_SHA256	2048 or 3072 bits
	TEE_ALG_DSA_SHA3_224	2048 or 3072 bits
	TEE_ALG_DSA_SHA3_256	2048 or 3072 bits
	TEE_ALG_DSA_SHA3_384	2048 or 3072 bits
	TEE_ALG_DSA_SHA3_512	2048 or 3072 bits
TEE_TYPE_DSA_KEYPAIR	Same as for DSA public key size.	
TEE_TYPE_DH_KEYPAIR	From 256 to 2048 bits, multiple of 8 bits.	
TEE_TYPE_ECDSA_PUBLIC_KEY	Between 160 and 521 bits. Conditional: Available only if at least one of the ECC curves defined in Table 6-14 with "generic" equal to "Y" is supported.	
TEE_TYPE_ECDSA_KEYPAIR	Between 160 and 521 bits. Conditional: Available only if at least one of the ECC curves defined in Table 6-14 with "generic" equal to "Y" is supported. SHALL be same value as for ECDSA public key size (for values, see Table 6-14).	
TEE_TYPE_ECDH_PUBLIC_KEY	Between 160 and 521 bits. Conditional: Available only if at least one of the ECC curves defined in Table 6-14 with "generic" equal to "Y" is supported.	

Object Type	Possible Key Sizes
TEE_TYPE_ECDH_KEYPAIR	Between 160 and 521 bits. Conditional: Available only if at least one of the ECC curves defined in Table 6-14 with "generic" equal to "Y" is supported. SHALL be same value as for ECDH public key size (for values, see Table 6-14).
TEE_TYPE_ED25519_PUBLIC_KEY	256 bits. Conditional: Available only if TEE_ECC_CURVE_25519 defined in Table 6-14 is supported.
TEE_TYPE_ED25519_KEYPAIR	
TEE_TYPE_X25519_PUBLIC_KEY	
TEE_TYPE_X25519_KEYPAIR	
TEE_TYPE_ED448_PUBLIC_KEY	448 bits. Conditional: Available only if TEE_ECC_CURVE_448 defined in Table 6-14 is supported.
TEE_TYPE_ED448_KEYPAIR	
TEE_TYPE_X448_PUBLIC_KEY	
TEE_TYPE_X448_KEYPAIR	
TEE_TYPE_SM2_DSA_PUBLIC_KEY	256 bits. Conditional: Available only if TEE_ECC_CURVE_SM2 defined in Table 6-14 is supported.
TEE_TYPE_SM2_DSA_KEYPAIR	
TEE_TYPE_SM2_KEP_PUBLIC_KEY	
TEE_TYPE_SM2_KEP_KEYPAIR	
TEE_TYPE_SM2_PKE_PUBLIC_KEY	
TEE_TYPE_SM2_PKE_KEYPAIR	
TEE_TYPE_SM4	128 bits. Conditional: Available only if TEE_ECC_CURVE_SM2 is supported.
TEE_TYPE_HMAC_SM3	Between 80 and 1024 bits, multiple of 8 bits. Conditional: Available only if TEE_ECC_CURVE_SM2 is supported.
TEE_TYPE_GENERIC_SECRET	Multiple of 8 bits, up to 4096 bits. This type is intended for secret data that has been derived from a key derivation scheme.

Parameters

- `objectType`: Type of uninitialized object container to be created (see Table 6-13).
- `maxObjectSize`: Key Size of the object. Valid values depend on the object type and are defined in Table 5-9 above.
- `object`: Filled with a handle on the newly created key container

Specification Number: 10 **Function Number:** 0x801

Return Code

- `TEE_SUCCESS`: 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.

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, object type `TEE_TYPE_DATA` was included in Table 5-9, erroneously indicating that `TEE_AllocateTransientObject` could be used to allocate an object of that type.

5.6.2 TEE_FreeTransientObject

Since: TEE Internal API v1.0

```
void TEE_FreeTransientObject(
   TEE_ObjectHandle object );
```

Description

The `TEE_FreeTransientObject` function deallocates a transient object previously allocated with `TEE_AllocateTransientObject`. After this function has been called, the object handle is no longer valid and all resources associated with the transient object SHALL have been reclaimed.

If the object is initialized, the object attributes are cleared before the object is deallocated.

This function does nothing if `object` is `TEE_HANDLE_NULL`.

Parameters

- `object`: Handle on the object to free

Specification Number: 10 **Function Number:** 0x803

Panic Reasons

- If `object` is not a valid opened object handle and is not equal to `TEE_HANDLE_NULL`.
- If the implementation detects any other error.

5.6.3 TEE_ResetTransientObject

Since: TEE Internal API v1.0

```
void TEE_ResetTransientObject(
   TEE_ObjectHandle   object );
```

Description

The `TEE_ResetTransientObject` function resets a transient object to its initial state after allocation.

If the object is currently initialized, the function clears the object of all its material. The object is then uninitialized again.

In any case, the function resets the key usage of the container to `0xFFFFFFFF`.

This function does nothing if `object` is set to `TEE_HANDLE_NULL`.

Parameters

- `object`: Handle on a transient object to reset

Specification Number: 10 **Function Number:** 0x808

Panic Reasons

- If `object` is not a valid opened object handle and is not equal to `TEE_HANDLE_NULL`.
- If the implementation detects any other error.

5.6.4 TEE_PopulateTransientObject

Since: TEE Internal API v1.0

```
TEE_Result TEE_PopulateTransientObject(
        TEE_ObjectHandle      object,
   [in] TEE_Attribute*        attrs, uint32_t attrCount );
```

Description

The `TEE_PopulateTransientObject` function populates an uninitialized object container with object attributes passed by the TA in the `attrs` parameter.

When this function is called, the object SHALL be uninitialized. If the object is initialized, the caller SHALL first clear it using the function `TEE_ResetTransientObject`.

Note that if the object type is a key-pair, then this function sets both the private and public attributes of the key-pair.

As shown in the following table, the interpretation of the `attrs` parameter depends on the object type. The values of all attributes are copied into the object so that the `attrs` array and all the memory buffers it points to may be freed after this routine returns without affecting the object.

Table 5-10: `TEE_PopulateTransientObject` Supported Attributes

Object Type	Attributes
TEE_TYPE_AES	For all secret key objects, the TEE_ATTR_SECRET_VALUE SHALL be provided. For TEE_TYPE_DES and TEE_TYPE_DES3, the buffer associated with this attribute SHALL include parity bits. These object types are collectively known as the 'Simple Symmetric Key Types'.
TEE_TYPE_DES	
TEE_TYPE_DES3	
TEE_TYPE_SM4	
TEE_TYPE_HMAC_MD5	
TEE_TYPE_HMAC_SHA1	
TEE_TYPE_HMAC_SHA224	
TEE_TYPE_HMAC_SHA256	
TEE_TYPE_HMAC_SHA384	
TEE_TYPE_HMAC_SHA512	
TEE_TYPE_HMAC_SHA3_224	
TEE_TYPE_HMAC_SHA3_256	
TEE_TYPE_HMAC_SHA3_384	
TEE_TYPE_HMAC_SHA3_512	
TEE_TYPE_HMAC_SM3	
TEE_TYPE_GENERIC_SECRET	
TEE_TYPE_RSA_PUBLIC_KEY	The following attributes SHALL be provided: TEE_ATTR_RSA_MODULUS TEE_ATTR_RSA_PUBLIC_EXPONENT

Object Type	Attributes
TEE_TYPE_RSA_KEYPAIR	The following attributes SHALL be provided: TEE_ATTR_RSA_MODULUS TEE_ATTR_RSA_PUBLIC_EXPONENT TEE_ATTR_RSA_PRIVATE_EXPONENT The CRT parameters are optional. If any of these attributes is provided, then all of them SHALL be provided: TEE_ATTR_RSA_PRIME1 TEE_ATTR_RSA_PRIME2 TEE_ATTR_RSA_EXPONENT1 TEE_ATTR_RSA_EXPONENT2 TEE_ATTR_RSA_COEFFICIENT
TEE_TYPE_ECDSA_PUBLIC_KEY	Conditional: If ECC is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_CURVE
TEE_TYPE_ECDSA_KEYPAIR	Conditional: If ECC is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_CURVE
TEE_TYPE_ECDH_PUBLIC_KEY	Conditional: If ECC is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_CURVE
TEE_TYPE_ECDH_KEYPAIR	Conditional: If ECC is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_CURVE
TEE_TYPE_DSA_PUBLIC_KEY	The following attributes SHALL be provided: TEE_ATTR_DSA_PRIME TEE_ATTR_DSA_SUBPRIME TEE_ATTR_DSA_BASE TEE_ATTR_DSA_PUBLIC_VALUE

Object Type	Attributes
TEE_TYPE_DSA_KEYPAIR	The following attributes SHALL be provided: TEE_ATTR_DSA_PRIME TEE_ATTR_DSA_SUBPRIME TEE_ATTR_DSA_BASE TEE_ATTR_DSA_PRIVATE_VALUE TEE_ATTR_DSA_PUBLIC_VALUE
TEE_TYPE_DH_KEYPAIR	The following attributes SHALL be provided: TEE_ATTR_DH_PRIME TEE_ATTR_DH_BASE TEE_ATTR_DH_PUBLIC_VALUE TEE_ATTR_DH_PRIVATE_VALUE The following parameters can optionally be passed: TEE_ATTR_DH_SUBPRIME (*q*) If present, constrains the private value *x* to be in the range [2, *q*-2], and a mismatch will cause a TEE_ERROR_BAD_PARAMETERS error. TEE_ATTR_DH_X_BITS (ℓ) If present, constrains the private value *x* to have ℓ bits, and a mismatch will cause a TEE_ERROR_BAD_PARAMETERS error. If neither of these optional parts is specified, then the only constraint on *x* is that it is less than *p*-1.
TEE_TYPE_ED25519_PUBLIC_KEY	Conditional: If TEE_ECC_CURVE_25519 is supported, then the following attributes SHALL be provided: TEE_ATTR_ED25519_PUBLIC_VALUE
TEE_TYPE_ED25519_KEYPAIR	Conditional: If TEE_ECC_CURVE_25519 is supported, then the following attributes SHALL be provided: TEE_ATTR_ED25519_PUBLIC_VALUE TEE_ATTR_ED25519_PRIVATE_VALUE
TEE_TYPE_X25519_PUBLIC_KEY	Conditional: If TEE_ECC_CURVE_25519 is supported, then the following attributes SHALL be provided: TEE_ATTR_X25519_PUBLIC_VALUE
TEE_TYPE_X25519_KEYPAIR	Conditional: If TEE_ECC_CURVE_25519 is supported, then the following attributes SHALL be provided: TEE_ATTR_X25519_PUBLIC_VALUE TEE_ATTR_X25519_PRIVATE_VALUE
TEE_TYPE_ED448_PUBLIC_KEY	Conditional: If TEE_ECC_CURVE_448 is supported, then the following attributes SHALL be provided: TEE_ATTR_ED448_PUBLIC_VALUE

Object Type	Attributes
TEE_TYPE_ED448_KEYPAIR	Conditional: If TEE_ECC_CURVE_448 is supported, then the following attributes SHALL be provided: TEE_ATTR_ED448_PUBLIC_VALUE TEE_ATTR_ED448_PRIVATE_VALUE
TEE_TYPE_X448_PUBLIC_KEY	Conditional: If TEE_ECC_CURVE_448 is supported, then the following attributes SHALL be provided: TEE_ATTR_X448_PUBLIC_VALUE
TEE_TYPE_X448_KEYPAIR	Conditional: If TEE_ECC_CURVE_448 is supported, then the following attributes SHALL be provided: TEE_ATTR_X448_PUBLIC_VALUE TEE_ATTR_X448_PRIVATE_VALUE
TEE_TYPE_SM2_DSA_PUBLIC_KEY	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided (each 32 bytes): TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_DSA_KEYPAIR	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_KEP_PUBLIC_KEY	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_KEP_KEYPAIR	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_PKE_PUBLIC_KEY	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_PKE_KEYPAIR	Conditional: if TEE_ECC_CURVE_SM2 is supported, then the following attributes SHALL be provided: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y

All mandatory attributes SHALL be specified; otherwise the routine will panic.

If attribute values are larger than the maximum size specified when the object was created, the implementation SHALL panic.

The implementation can attempt to detect whether the attribute values are consistent; for example, if the numbers supposed to be prime are indeed prime. However, it is not required to do these checks fully and reliably. If it detects invalid attributes, it SHALL return the error code `TEE_ERROR_BAD_PARAMETERS` and SHALL NOT panic. If it does not detect any inconsistencies, it SHALL be able to later proceed with all operations associated with the object without error. In this case, it is not required to make sensible computations, but all computations SHALL terminate and output some result.

Only the attributes specified in Table 5-10 associated with the object's type are valid. The presence of any other attribute in the attribute list is an error and will cause the routine to panic.

Parameters

- `object`: Handle on an already created transient and uninitialized object
- `attrs`, `attrCount`: Array of object attributes

Specification Number: 10 **Function Number:** 0x807

Return Code

- `TEE_SUCCESS`: In case of success. In this case, the content of the object SHALL be initialized.
- `TEE_ERROR_BAD_PARAMETERS`: If an incorrect or inconsistent attribute value is detected. In this case, the content of the object SHALL remain uninitialized.

Panic Reasons

- If `object` is not a valid opened object handle that is transient and uninitialized.
- If some mandatory attribute is missing.
- If `attrs` includes an attribute that is not defined for the object's type.
- If an attribute value is too big to fit within the maximum object size specified when the object was created.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

5.6.5 TEE_InitRefAttribute, TEE_InitValueAttribute

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_InitRefAttribute(
   [out]   TEE_Attribute* attr,
           uint32_t       attributeID,
   [inbuf] void*          buffer, size_t length );
```

```
void  TEE_InitValueAttribute(
   [out]   TEE_Attribute* attr,
           uint32_t       attributeID,
           uint32_t       a,
           uint32_t       b );
```

Description

The `TEE_InitRefAttribute` and `TEE_InitValueAttribute` helper functions can be used to populate a single attribute either with a reference to a buffer or with integer values.

For example, the following code can be used to initialize a DH key generation:

```
TEE_Attribute attrs[3];
TEE_InitRefAttribute(&attrs[0], TEE_ATTR_DH_PRIME, &p, len);
TEE_InitRefAttribute(&attrs[1], TEE_ATTR_DH_BASE, &g, len);
TEE_InitValueAttribute(&attrs[2], TEE_ATTR_DH_X_BITS, xBits, 0);
TEE_GenerateKey(key, 1024, attrs, sizeof(attrs)/sizeof(TEE_Attribute));
```

Note that in the case of `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 (defined in section 5.3.1) to initialize
- `attributeID`: Identifier of the attribute to populate, defined in section 6.1.1
- `buffer`, `length`: Input buffer that holds the content of the attribute. Assigned to the corresponding members of the attribute structure defined in section 5.3.1.
- a: unsigned integer value to assign to the a member of the attribute structure defined in section 5.3.1
- b: unsigned integer value to assign to the b member of the attribute structure defined in section 5.3.1

`TEE_InitRefAttribute`: **Specification Number:** 10 **Function Number:** 0x805

`TEE_InitValueAttribute`: **Specification Number:** 10 **Function Number:** 0x806

Panic Reasons

- If Bit [29] of `attributeID` describing whether the attribute identifier is a value or reference (as discussed in Table 6-17) is not consistent with the function.
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `length`.

5.6.6 TEE_CopyObjectAttributes1

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_CopyObjectAttributes1(
   [out]   TEE_ObjectHandle destObject,
   [in]    TEE_ObjectHandle srcObject );
```

Description

This function replaces the `TEE_CopyObjectAttributes` function, whose use is deprecated.

The `TEE_CopyObjectAttributes1` function populates an uninitialized object handle with the attributes of another object handle; that is, it populates the attributes of `destObject` with the attributes of `srcObject`. It is most useful in the following situations:

- To extract the public key attributes from a key-pair object
- To copy the attributes from a persistent object into a transient object

`destObject` SHALL refer to an uninitialized object handle and SHALL therefore be a transient object.

The source and destination objects SHALL have compatible types and sizes in the following sense:

- The type of `destObject` SHALL be a subtype of `srcObject`, i.e. one of the conditions listed in the following table SHALL be true.

Table 5-11: `TEE_CopyObjectAttributes1` Parameter Types

Type of `srcObject`	Type of `destObject`
Any	Equal to type of `srcObject`
`TEE_TYPE_RSA_KEYPAIR`	`TEE_TYPE_RSA_PUBLIC_KEY`
`TEE_TYPE_DSA_KEYPAIR`	`TEE_TYPE_DSA_PUBLIC_KEY`
`TEE_TYPE_ECDSA_KEYPAIR` (optional)	`TEE_TYPE_ECDSA_PUBLIC_KEY` (optional)
`TEE_TYPE_ECDH_KEYPAIR` (optional)	`TEE_TYPE_ECDH_PUBLIC_KEY` (optional)
`TEE_TYPE_ED25519_KEYPAIR` (optional)	`TEE_TYPE_ED25519_PUBLIC_KEY` (optional)
`TEE_TYPE_X25519_KEYPAIR` (optional)	`TEE_TYPE_X25519_PUBLIC_KEY` (optional)
`TEE_TYPE_ED448_KEYPAIR` (optional)	`TEE_TYPE_ED448_PUBLIC_KEY` (optional)
`TEE_TYPE_X448_KEYPAIR` (optional)	`TEE_TYPE_X448_PUBLIC_KEY` (optional)
`TEE_TYPE_SM2_DSA_KEYPAIR` (optional)	`TEE_TYPE_SM2_DSA_PUBLIC_KEY` (optional)
`TEE_TYPE_SM2_KEP_KEYPAIR` (optional)	`TEE_TYPE_SM2_KEP_PUBLIC_KEY` (optional)
`TEE_TYPE_SM2_PKE_KEYPAIR` (optional)	`TEE_TYPE_SM2_PKE_PUBLIC_KEY` (optional)

- The size of `srcObject` SHALL be less than or equal to the maximum size of `destObject`.

The effect of this function on `destObject` is identical to the function `TEE_PopulateTransientObject` except that the attributes are taken from `srcObject` instead of from parameters.

The object usage of `destObject` is set to the bitwise AND of the current object usage of `destObject` and the object usage of `srcObject`.

Parameters

- `destObject`: Handle on an uninitialized transient object
- `srcObject`: Handle on an initialized object

Specification Number: 10 **Function Number:** 0x809

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_CORRUPT_OBJECT`: If the persistent object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `srcObject` is not initialized.
- If `destObject` is initialized.
- If the type and size of `srcObject` and `destObject` are not compatible.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_CopyObjectAttributes1` did not specify the *[in]* or *[out]* annotations.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.6.7 TEE_GenerateKey

Since: TEE Internal API v1.0

```
TEE_Result TEE_GenerateKey(
        TEE_ObjectHandle  object,
        uint32_t          keySize,
   [in] TEE_Attribute*    params, uint32_t paramCount );
```

Description

The `TEE_GenerateKey` function generates a random key or a key-pair and populates a transient key object with the generated key material.

The size passed in the `keySize` parameter is dependent on the operation:

- Where the key size is variable depending on the attributes provided for the object type, `keySize` SHALL be `0`. The size of the generated key SHALL be less than or equal to the maximum key size specified when the transient object was created.
- Where the key size is known for the attributes provided, the `keySize` parameter SHALL be less than or equal to the maximum key size specified when the transient object was created. The valid values for key size are defined in Table 5-9.

As shown in the following table, the generation algorithm can take parameters depending on the object type.

Table 5-12: `TEE_GenerateKey` Parameters

Object Type	Details
TEE_TYPE_AES	No parameter is necessary. The function generates the attribute `TEE_ATTR_SECRET_VALUE`. The generated value SHALL be the full key size.
TEE_TYPE_DES	
TEE_TYPE_DES3	
TEE_TYPE_SM4	
TEE_TYPE_HMAC_MD5	
TEE_TYPE_HMAC_SHA1	
TEE_TYPE_HMAC_SHA224	
TEE_TYPE_HMAC_SHA256	
TEE_TYPE_HMAC_SHA384	
TEE_TYPE_HMAC_SHA512	
TEE_TYPE_HMAC_SHA3_224	
TEE_TYPE_HMAC_SHA3_256	
TEE_TYPE_HMAC_SHA3_384	
TEE_TYPE_HMAC_SHA3_512	
TEE_TYPE_HMAC_SM3	
TEE_TYPE_GENERIC_SECRET	

Object Type	Details
TEE_TYPE_RSA_KEYPAIR	No parameter is required. The TEE_ATTR_RSA_PUBLIC_EXPONENT attribute may be specified; if omitted, the default value is 65537. Key generation SHALL follow the rules defined in [NIST SP800-56B]. The function generates and populates the following attributes: TEE_ATTR_RSA_MODULUS TEE_ATTR_RSA_PUBLIC_EXPONENT (if not specified) TEE_ATTR_RSA_PRIVATE_EXPONENT TEE_ATTR_RSA_PRIME1 TEE_ATTR_RSA_PRIME2 TEE_ATTR_RSA_EXPONENT1 TEE_ATTR_RSA_EXPONENT2 TEE_ATTR_RSA_COEFFICIENT
TEE_TYPE_DSA_KEYPAIR	The following domain parameters SHALL be passed to the function: TEE_ATTR_DSA_PRIME TEE_ATTR_DSA_SUBPRIME TEE_ATTR_DSA_BASE The function generates and populates the following attributes: TEE_ATTR_DSA_PUBLIC_VALUE TEE_ATTR_DSA_PRIVATE_VALUE
TEE_TYPE_DH_KEYPAIR	The following domain parameters SHALL be passed to the function: TEE_ATTR_DH_PRIME TEE_ATTR_DH_BASE The following parameters can optionally be passed: TEE_ATTR_DH_SUBPRIME (q): If present, constrains the private value x to be in the range [2, q-2] TEE_ATTR_DH_X_BITS (ℓ) If present, constrains the private value x to have ℓ bits If neither of these optional parts is specified, then the only constraint on x is that it is less than p-1. The function generates and populates the following attributes: TEE_ATTR_DH_PUBLIC_VALUE TEE_ATTR_DH_PRIVATE_VALUE TEE_ATTR_DH_X_BITS (number of bits in x)
TEE_TYPE_ECDSA_KEYPAIR	The following domain parameters SHALL be passed to the function: TEE_ATTR_ECC_CURVE The function generates and populates the following attributes: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_PRIVATE_VALUE

Object Type	Details
TEE_TYPE_ECDH_KEYPAIR	The following domain parameters SHALL be passed to the function: TEE_ATTR_ECC_CURVE The function generates and populates the following attributes: TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y TEE_ATTR_ECC_PRIVATE_VALUE
TEE_TYPE_ED25519_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_ED25519_PUBLIC_VALUE TEE_ATTR_ED25519_PRIVATE_VALUE
TEE_TYPE_X25519_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_X25519_PUBLIC_VALUE TEE_ATTR_X25519_PRIVATE_VALUE
TEE_TYPE_ED448_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_ED448_PUBLIC_VALUE TEE_ATTR_ED448_PRIVATE_VALUE
TEE_TYPE_X448_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_X448_PUBLIC_VALUE TEE_ATTR_X448_PRIVATE_VALUE
TEE_TYPE_SM2_DSA_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_KEP_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y
TEE_TYPE_SM2_PKE_KEYPAIR	No parameter is required The function generates and populates the following attributes: TEE_ATTR_ECC_PRIVATE_VALUE TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y

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Once the key material has been generated, the transient object is populated exactly as in the function `TEE_PopulateTransientObject` except that the key material is randomly generated internally instead of being passed by the caller.

Parameters

- `object`: Handle on an uninitialized transient key to populate with the generated key
- `keySize`: Requested key size.
- `params`, `paramCount`: Parameters for the key generation. The values of all parameters are copied into 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.

Specification Number: 10 **Function Number:** 0x804

Return Code

- `TEE_SUCCESS`: On success.
- `TEE_ERROR_BAD_PARAMETERS`: If an incorrect or inconsistent attribute is detected. The checks that are performed depend on the implementation.

Panic Reasons

- If `object` is not a valid opened object handle that is transient and uninitialized.
- If `keySize` is not supported or is too large.
- If a mandatory parameter is missing.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

5.7 Persistent Object Functions

5.7.1 TEE_OpenPersistentObject

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_OpenPersistentObject(
                        uint32_t          storageID,
  [in(objectIDLength)]  void*             objectID, size_t objectIDLen,
                        uint32_t          flags,
  [out]                 TEE_ObjectHandle* object );
```

Description

The `TEE_OpenPersistentObject` function opens a handle on an existing persistent object. It returns a handle that can be used to access the object's attributes and data stream.

The `storageID` parameter indicates which Trusted Storage Space to access. Possible values are defined in Table 5-2.

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 from the following list:

- Access control 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. This allows the Trusted Application to call the functions `TEE_WriteObjectData` and `TEE_TruncateObjectData`.
  - `TEE_DATA_FLAG_ACCESS_WRITE_META`: The object is opened with the write-meta access right. This allows the Trusted Application to call the functions `TEE_CloseAndDeletePersistentObject1 and TEE_RenamePersistentObject`.
- Sharing permission control flags:
  - `TEE_DATA_FLAG_SHARE_READ`: The caller allows another handle on the object to be created with read access.
  - `TEE_DATA_FLAG_SHARE_WRITE`: The caller allows another handle on the object to be created with write access.
- Other flags are reserved for future use and SHALL be set to `0`.

Multiple handles may be opened on the same object simultaneously, but sharing SHALL be explicitly allowed as described in section 5.7.3.

The initial data position in the data stream is set to `0`.

Every Trusted Storage implementation is expected to return `TEE_ERROR_CORRUPT_OBJECT` if a Trusted Application attempts to open an object and the TEE determines that its contents (or those of the storage itself) have been tampered with or rolled back.

Parameters

- `storageID`: The storage to use. Valid values are defined in Table 5-2.
- `objectID`, `objectIDLen`: The object identifier. Note that this buffer cannot reside in shared memory.
- `flags`: The flags which determine the settings under which the object is opened. Valid values are defined in Table 5-3.
- `object`: A pointer to the handle, which contains the opened handle upon successful completion. If this function fails for any reason, the value pointed to by `object` is set to `TEE_HANDLE_NULL`. When the object handle is no longer required, it SHALL be closed using a call to the `TEE_CloseObject` function.

Specification Number: 10 **Function Number:** 0x903

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the storage denoted by `storageID` does not exist or if the object identifier cannot be found in the storage
- `TEE_ERROR_ACCESS_CONFLICT`: If an access right conflict (see section 5.7.3) was detected while opening the object
- `TEE_ERROR_OUT_OF_MEMORY`: If there is not enough memory to complete the operation
- `TEE_ERROR_CORRUPT_OBJECT`: If the storage or object is corrupt
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible. It may be associated with the device but unplugged, busy, or inaccessible for some other reason.

Panic Reasons

- If `objectIDLen` is greater than `TEE_OBJECT_ID_MAX_LEN`.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `objectIDLen`.

5.7.2 TEE_CreatePersistentObject

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_CreatePersistentObject(
                         uint32_t          storageID,
  [in(objectIDLength)] void*             objectID, size_t objectIDLen,
                         uint32_t          flags,
                         TEE_ObjectHandle  attributes,
  [inbuf]                void*             initialData, size_t initialDataLen,
  [outopt]               TEE_ObjectHandle* object );
```

Description

The `TEE_CreatePersistentObject` function creates a persistent object with initial attributes and an initial data stream content. The `storageID` parameter indicates which Trusted Storage Space to access; possible values are defined in Table 5-2.

The `flags` parameter is a set of flags that controls the access rights, sharing permissions, and object creation mechanism with which the object handle is opened. The value of the `flags` parameter is constructed by a bitwise-inclusive OR of flags from the following list:

- Access control 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. This allows the Trusted Application to call the functions `TEE_WriteObjectData` and `TEE_TruncateObjectData`.
  - `TEE_DATA_FLAG_ACCESS_WRITE_META`: The object is opened with the write-meta access right. This allows the Trusted Application to call the functions `TEE_CloseAndDeletePersistentObject1 and TEE_RenamePersistentObject`.
- Sharing permission control flags:
  - `TEE_DATA_FLAG_SHARE_READ`: The caller allows another handle on the object to be created with read access.
  - `TEE_DATA_FLAG_SHARE_WRITE`: The caller allows another handle on the object to be created with write access.
- `TEE_DATA_FLAG_OVERWRITE`: As summarized in Table 5-13:
  - If this flag is present and the object exists, then the object is deleted and re-created as an atomic operation: that is, the TA sees either the old object or the new one.
  - If the flag is absent and the object exists, then the function SHALL return `TEE_ERROR_ACCESS_CONFLICT`.
- Other flags are reserved for future use and SHALL be set to `0`.

The attributes of the newly created persistent object are taken from `attributes`, which can be another persistent object or an initialized transient object. The object type, size, and usage are copied from `attributes`.

To create a pure data object, the `attributes` argument can also be `NULL`. If `attributes` is `NULL`, the object type SHALL be set to `TEE_TYPE_DATA` to create a pure data object.

Multiple handles may be opened on the same object simultaneously, but sharing SHALL be explicitly allowed as described in section 5.7.3.

The initial data position in the data stream is set to `0`.

To transform an initialized transient object into a persistent object, see the description of the `object` parameter following Table 5-13.

Table 5-13: Effect of `TEE_DATA_FLAG_OVERWRITE` on Behavior of `TEE_CreatePersistentObject`

`TEE_DATA_FLAG_OVERWRITE` in flags	Object Exists	Object Created?	Return Code
Absent	No	Yes	`TEE_SUCCESS`
Absent	Yes	No	`TEE_ERROR_ACCESS_CONFLICT`
Present	No	Yes	`TEE_SUCCESS`
Present	Yes	Deleted and re-created as an atomic operation	`TEE_SUCCESS`

Parameters

- `storageID`: The storage to use. Valid values are defined in Table 5-2.
- `objectID`, `objectIDLen`: The object identifier. Note that this cannot reside in shared memory.
- `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. Can be `TEE_HANDLE_NULL` if the persistent object contains no attribute; for example, if it is a pure data object.
- `initialData`, `initialDataLen`: The initial data content of the persistent object
- `object`: An optional pointer to the handle.

  When `object` is not `NULL`:

  - Contains the opened handle upon successful completion.
  - If this function fails for any reason, the value pointed to by `object` is set to `TEE_HANDLE_NULL`.
  - When the object handle is no longer required, it SHALL be closed using a call to the `TEE_CloseObject` function.

  When `object` is `NULL`:

  - If `attributes` is a handle on an initialized transient object, the initialized transient object SHALL be transformed to a persistent object.

Specification Number: 10 **Function Number:** 0x902

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If the storage denoted by `storageID` does not exist
- `TEE_ERROR_ACCESS_CONFLICT`: If an access right conflict (see section 5.7.3) was detected while opening the object

- `TEE_ERROR_OUT_OF_MEMORY`: If there is not enough memory to complete the operation
- `TEE_ERROR_STORAGE_NO_SPACE`: If insufficient space is available to create the persistent object
- `TEE_ERROR_CORRUPT_OBJECT`: If the storage is corrupt
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible. It may be associated with the device but unplugged, busy, or inaccessible for some other reason.

Panic Reasons

- If `objectIDLen` is greater than `TEE_OBJECT_ID_MAX_LEN`.
- If `attributes` is not `TEE_HANDLE_NULL` and is not a valid handle on an initialized object containing the type and attributes of the persistent object to create.
- If `attributes` is not a handle on an initialized transient object and `object` is `NULL`.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `objectIDLen` and `initialDataLen`.

Prior to TEE Internal Core API v1.3, output parameter `object` was mandatory.

5.7.3 Persistent Object Sharing Rules

Multiple handles may be opened on the same object simultaneously using the functions TEE_OpenPersistentObject or TEE_CreatePersistentObject, but sharing SHALL be explicitly allowed. More precisely, at any one time the following constraints apply: If more than one handle is opened on the same object, and if any of these object handles was opened with the flag TEE_DATA_FLAG_ACCESS_READ, then all the object handles SHALL have been opened with the flag TEE_DATA_FLAG_SHARE_READ. There is a corresponding constraint with the flags TEE_DATA_FLAG_ACCESS_WRITE and TEE_DATA_FLAG_SHARE_WRITE. Accessing an object with ACCESS_WRITE_META rights is exclusive and can never be shared.

When one of the functions TEE_OpenPersistentObject or TEE_CreatePersistentObject is called and if opening the object would violate these constraints, then the function returns the return code TEE_ERROR_ACCESS_CONFLICT.

Any bits in flags not defined in Table 5-3 of section 5.4 are reserved for future use and SHALL be set to zero.

The examples in Table 5-14 illustrate the behavior of the TEE_OpenPersistentObject function when called twice on the same object. Note that for readability, the flag names used in Table 5-14 have been abbreviated by removing the 'TEE_DATA_FLAG_' prefix from their name, and any non-TEE_SUCCESS return codes have been shortened by removing the 'TEE_ERROR_' prefix.

Table 5-14: Examples of `TEE_OpenPersistentObject` Sharing Rules

Value of `flags` for First Open/Create	Value of `flags` for Second Open/Create	Return Code of Second Open/Create	Comments
ACCESS_READ	ACCESS_READ	ACCESS_CONFLICT	The object handles have not been opened with the flag SHARE_READ. Only the first call will succeed.
ACCESS_READ | SHARE_READ	ACCESS_READ	ACCESS_CONFLICT	Not all the object handles have been opened with the flag SHARE_READ. Only the first call will succeed.
ACCESS_READ | SHARE_READ	ACCESS_READ | SHARE_READ	TEE_SUCCESS	All the object handles have been opened with the flag SHARE_READ.
ACCESS_READ	ACCESS_WRITE	ACCESS_CONFLICT	Objects are not opened with share flags. Only the first call will succeed.
ACCESS_WRITE_META	ACCESS_READ | SHARE_READ | ACCESS_WRITE | SHARE_WRITE	ACCESS_CONFLICT	The write-meta flag indicates an exclusive access to the object. Only the first Open/Create will succeed.
ACCESS_WRITE_META | (Anything)	(Anything)	ACCESS_CONFLICT	The write-meta flag indicates an exclusive access to the object. Only the first Open/Create will succeed.
ACCESS_READ | SHARE_READ | SHARE_WRITE	ACCESS_WRITE | SHARE_READ | SHARE_WRITE	TEE_SUCCESS	All the object handles have been opened with the share flags.
ACCESS_READ | SHARE_READ | ACCESS_WRITE | SHARE_WRITE	ACCESS_WRITE_META	ACCESS_CONFLICT	The write-meta flag indicates an exclusive access to the object. Only the first call will succeed.
SHARE_READ	ACCESS_WRITE | SHARE_WRITE	ACCESS_CONFLICT	An object can be opened with only share flags, which locks the access to an object against a given mode. Here the first call prevents subsequent accesses in write mode.
0	ACCESS_READ | SHARE_READ	ACCESS_CONFLICT	An object can be opened with no flag set, which completely locks all subsequent attempts to access the object. Only the first call will succeed.

5.7.4 TEE_CloseAndDeletePersistentObject1

Since: TEE Internal Core API v1.1

```
TEE_Result TEE_CloseAndDeletePersistentObject1( TEE_ObjectHandle object );
```

Description

This function replaces the `TEE_CloseAndDeletePersistentObject` function, whose use is deprecated.

The `TEE_CloseAndDeletePersistentObject1` function marks an object for deletion and closes the object handle.

The object handle SHALL have been opened with the write-meta access right, which means access to the object is exclusive.

Deleting an object is atomic; once this function returns, the object is definitely deleted and no more open handles for the object exist. This SHALL be the case even if the object or the storage containing it have become corrupted.

The only reason this routine can fail is if the storage area containing the object becomes inaccessible (e.g. the user removes the media holding the object). In this case `TEE_ERROR_STORAGE_NOT_AVAILABLE` SHALL be returned.

If `object` is `TEE_HANDLE_NULL`, the function does nothing.

Parameters

- `object`: The object handle

Specification Number: 10 **Function Number:** 0x905

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object opened with the write-meta access right.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

5.7.5 TEE_RenamePersistentObject

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_RenamePersistentObject(
                      TEE_ObjectHandle object,
 [in(newObjectIDLen)] void*            newObjectID, size_t newObjectIDLen );
```

Description

The function `TEE_RenamePersistentObject` changes the identifier of an object. The object handle SHALL have been opened with the write-meta access right, which means access to the object is exclusive.

Renaming an object is an atomic operation; either the object is renamed or nothing happens.

Parameters

- `object`: The object handle
- `newObjectID`, `newObjectIDLen`: A buffer containing the new object identifier. The identifier contains arbitrary bytes, including the zero byte. The identifier length SHALL be less than or equal to `TEE_OBJECT_ID_MAX_LEN` and can be zero. The buffer containing the new object identifier cannot reside in shared memory.

Specification Number: 10 **Function Number:** 0x904

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ACCESS_CONFLICT`: If an object with the same identifier already exists
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object that has been opened with the write-meta access right.
- If `newObjectID` resides in shared memory.
- If `newObjectIDLen` is more than `TEE_OBJECT_ID_MAX_LEN`.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `newObjectIDLen`.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.8 Persistent Object Enumeration Functions

5.8.1 TEE_AllocatePersistentObjectEnumerator

Since: TEE Internal API v1.0

```
TEE_Result TEE_AllocatePersistentObjectEnumerator(
      [out] TEE_ObjectEnumHandle* objectEnumerator );
```

Description

The `TEE_AllocatePersistentObjectEnumerator` function allocates a handle on an object enumerator. Once an object enumerator handle has been allocated, it can be reused for multiple enumerations.

Parameters

- `objectEnumerator`: A pointer filled with the newly-allocated object enumerator handle on success. Set to `TEE_HANDLE_NULL` in case of error.

Specification Number: 10 **Function Number:** 0xA01

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OUT_OF_MEMORY`: If there is not enough memory to allocate the enumerator handle

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

5.8.2 TEE_FreePersistentObjectEnumerator

Since: TEE Internal API v1.0

```
void TEE_FreePersistentObjectEnumerator(
                        TEE_ObjectEnumHandle objectEnumerator );
```

Description

The `TEE_FreePersistentObjectEnumerator` function deallocates all resources associated with an object enumerator handle. After this function is called, the handle is no longer valid.

Parameters

- `objectEnumerator`: The handle to close. If `objectEnumerator` is `TEE_HANDLE_NULL`, then this function does nothing.

Specification Number: 10 **Function Number:** 0xA02

Panic Reasons

- If `objectEnumerator` is not a valid handle on an object enumerator.
- If the implementation detects any other error.

5.8.3 TEE_ResetPersistentObjectEnumerator

Since: TEE Internal API v1.0

```
void TEE_ResetPersistentObjectEnumerator(
                        TEE_ObjectEnumHandle objectEnumerator );
```

Description

The `TEE_ResetPersistentObjectEnumerator` function resets an object enumerator handle to its initial state after allocation. If an enumeration has been started, it is stopped.

This function does nothing if `objectEnumerator` is `TEE_HANDLE_NULL`.

Parameters

- `objectEnumerator`: The handle to reset

Specification Number: 10 **Function Number:** 0xA04

Panic Reasons

- If `objectEnumerator` is not `TEE_HANDLE_NULL` and is not a valid handle on an object enumerator.
- If the implementation detects any other error.

5.8.4 TEE_StartPersistentObjectEnumerator

Since: TEE Internal API v1.0

```
TEE_Result TEE_StartPersistentObjectEnumerator(
           TEE_ObjectEnumHandle objectEnumerator,
           uint32_t             storageID );
```

Description

The TEE_StartPersistentObjectEnumerator function starts the enumeration of all the persistent objects in a given Trusted Storage. The object information can be retrieved by calling the function TEE_GetNextPersistentObject repeatedly.

The enumeration does not necessarily reflect a given consistent state of the storage: During the enumeration, other TAs or other instances of the TA may create, delete, or rename objects. It is not guaranteed that all objects will be returned if objects are created or destroyed while the enumeration is in progress.

To stop an enumeration, the TA can call the function TEE_ResetPersistentObjectEnumerator, which detaches the enumerator from the Trusted Storage. The TA can call the function TEE_FreePersistentObjectEnumerator to completely deallocate the object enumerator.

If this function is called on an enumerator that has already been started, the enumeration is first reset then started.

Parameters

- objectEnumerator: A valid handle on an object enumerator
- storageID: The identifier of the storage in which the objects SHALL be enumerated. Possible values are defined in Table 5-2.

Specification Number: 10 **Function Number:** 0xA05

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_ITEM_NOT_FOUND: If the storage does not exist or if there is no object in the specified storage
- TEE_ERROR_CORRUPT_OBJECT: If the storage is corrupt
- TEE_ERROR_STORAGE_NOT_AVAILABLE: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If objectEnumerator is not a valid handle on an object enumerator.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

5.8.5 TEE_GetNextPersistentObject

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_GetNextPersistentObject(
                                  TEE_ObjectEnumHandle      objectEnumerator,
    [out]                         TEE_ObjectInfo*           objectInfo,
    [out]                         void*                     objectID,
    [out]                         size_t*                   objectIDLen );
```

Description

The `TEE_GetNextPersistentObject` function gets the next object in an enumeration and returns information about the object: type, size, identifier, etc.

If there are no more objects in the enumeration or if there is no enumeration started, then the function returns `TEE_ERROR_ITEM_NOT_FOUND`.

If while enumerating objects a corrupt object is detected, then its object ID SHALL be returned in `objectID`, `objectInfo` SHALL be zeroed, and the function SHALL return `TEE_ERROR_CORRUPT_OBJECT`.

If the set of available objects changes while an enumeration is taking place, then objects may be reported more than once, or not at all.

Parameters

- `objectEnumerator`: A handle on the object enumeration
- `objectInfo`: A pointer to a `TEE_ObjectInfo` filled with the object information as specified in the function `TEE_GetObjectInfo1` in section 5.5.1. It may be `NULL`.
- `objectID`: Pointer to an array able to hold at least `TEE_OBJECT_ID_MAX_LEN` bytes. On return, the object identifier is written to this location
- `objectIDLen`: Filled with the size of the object identifier (from `0` to `TEE_OBJECT_ID_MAX_LEN`)

Specification Number: 10 **Function Number:** 0xA03

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_ITEM_NOT_FOUND`: If there are no more elements in the object enumeration or if no enumeration is started on this handle
- `TEE_ERROR_CORRUPT_OBJECT`: If the storage or returned object is corrupt
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `objectEnumerator` is not a valid handle on an object enumerator.
- If `objectID` is `NULL`.
- If `objectIDLen` is `NULL`.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `objectIDLen`.

5.9 Data Stream Access Functions

These functions can be used to access the data stream of persistent objects. They work like a file API.

5.9.1 TEE_ReadObjectData

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_ReadObjectData(
             TEE_ObjectHandle  object,
       [out] void*             buffer,
             size_t            size,
       [out] size_t*           count );
```

Description

The `TEE_ReadObjectData` function attempts to read `size` bytes from the data stream associated with the object `object` into the buffer pointed to by `buffer`.

The object handle SHALL have been opened with the read access right.

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-of-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`.

No data transfer can occur past the current end of stream. If an attempt is made to read past the end-of-stream, the `TEE_ReadObjectData` function stops reading data at the end-of-stream and returns the data read up to that point. This is still a success. The position indicator is then set at the end-of-stream. If the position is at, or past, the end of the data when this function is called, then no bytes are copied to `*buffer` and `*count` is set to `0`.

Parameters

- `object`: The object handle
- `buffer`: A pointer to the memory which, upon successful completion, contains the bytes read
- `size`: The number of bytes to read
- `count`: A pointer to the variable which upon successful completion contains the number of bytes read

Specification Number: 10 **Function Number:** 0xB01

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object opened with the read access right.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `size`.

Prior to TEE Internal Core API v1.2, `TEE_ReadObjectData` used a different type for `count`.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.9.2 TEE_WriteObjectData

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_WriteObjectData(
            TEE_ObjectHandle   object,
    [inbuf] void*              buffer, size_t size );
```

Description

The `TEE_WriteObjectData` function writes `size` bytes from the buffer pointed to by `buffer` to the data stream associated with the open object handle `object`.

The object handle SHALL have been opened with the write access permission.

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. Thus, the size of the data stream can be increased as a result of this operation.

If the operation would move the data position indicator to beyond its maximum possible value, then `TEE_ERROR_OVERFLOW` is returned and the operation fails.

The data position indicator is advanced by `size`. The data position indicators of other object handles opened on the same object are not changed.

Writing in a data stream is atomic; either the entire operation completes successfully or no write is done.

Parameters

- `object`: The object handle
- `buffer`: The buffer containing the data to be written
- `size`: The number of bytes to write

Specification Number: 10 **Function Number:** 0xB04

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_STORAGE_NO_SPACE`: If insufficient storage space is available
- `TEE_ERROR_OVERFLOW`: If the value of the data position indicator resulting from this operation would be greater than `TEE_DATA_MAX_POSITION`
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object opened with the write access right.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `size`.

Prior to TEE Internal Core API v1.3:

- `TEE_WriteObjectData` defined `buffer` as an *[in]*.
- The behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.9.3 TEE_TruncateObjectData

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_TruncateObjectData(
           TEE_ObjectHandle object,
           size_t           size );
```

Description

The function `TEE_TruncateObjectData` changes the size of a data stream. If `size` is less than the current size of the data stream then all bytes beyond `size` are removed. If `size` is greater than the current size of the data stream then the data stream is extended by adding zero bytes at the end of the stream.

The object handle SHALL have been opened with the write access permission.

This operation does not change the data position of any handle opened on the object. Note that if the current data position of such a handle is beyond `size`, the data position will point beyond the object data's end after truncation.

Truncating a data stream is atomic; either the data stream is successfully truncated or nothing happens.

Parameters

- `object`: The object handle
- `size`: The new size of the data stream

Specification Number: 10 **Function Number:** 0xB03

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_STORAGE_NO_SPACE`: If insufficient storage space is available to perform the operation
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object opened with the write access right.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.2, a different type was used for `size`.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

5.9.4 TEE_SeekObjectData

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_SeekObjectData(
           TEE_ObjectHandle object,
           intmax_t         offset,
           TEE_Whence       whence );
```

Description

The `TEE_SeekObjectData` function sets the data position indicator associated with the object handle.

The parameter `whence` controls the meaning of `offset`:

- If `whence` is `TEE_DATA_SEEK_SET`, the data position is set to `offset` bytes from the beginning of the data stream.
- If `whence` is `TEE_DATA_SEEK_CUR`, the data position is set to its current position plus `offset`.
- If `whence` is `TEE_DATA_SEEK_END`, the data position is set to the size of the object data plus `offset`.

The `TEE_SeekObjectData` function may be used to set the data position beyond the end of stream; this does not constitute an error. However, the data position indicator does have a maximum value which is `TEE_DATA_MAX_POSITION`. If the value of the data position indicator resulting from this operation would be greater than `TEE_DATA_MAX_POSITION`, the error `TEE_ERROR_OVERFLOW` is returned.

If an attempt is made to move the data position before the beginning of the data stream, the data position is set at the beginning of the stream. This does not constitute an error.

Parameters

- `object`: The object handle
- `offset`: The number of bytes to move the data position. A positive value moves the data position forward; a negative value moves the data position backward.
- `whence`: The position in the data stream from which to calculate the new position

Specification Number: 10 **Function Number:** 0xB02

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OVERFLOW`: If the value of the data position indicator resulting from this operation would be greater than `TEE_DATA_MAX_POSITION`
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `object` is not a valid handle on a persistent object.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3:

- A different type was used for `offset`.
- The behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

6 Cryptographic Operations API

This part of the Cryptographic API defines how to actually perform cryptographic operations:

- Cryptographic operations can be pre-allocated for a given operation type, algorithm, and key size. Resulting Cryptographic Operation Handles can be reused for multiple operations.
- When required by the operation, the Cryptographic Operation Key can be set up independently and reused for multiple operations. Note that some cryptographic algorithms, such as AES-XTS, require two keys.
- An operation may be in three states: **initial** state where nothing is going on, **active** state where an operation is in progress, and **extracting** state where a digest extraction operation is in progress.
- The cryptographic algorithms listed in the following table are supported in this specification.

Table 6-1: Supported Cryptographic Algorithms[4]

Algorithm Type	Supported Algorithm
Digests	MD5 SHA-256 SHA3-224 SHAKE128 SHA-1 SHA-224 SHA3-256 SHAKE256 SHA-384 SHA3-384 SHA-512 SHA3-512 SM3-256
Symmetric ciphers	DES Triple-DES with double-length and triple-length keys AES SM4
Message Authentication Codes (MACs)	DES-MAC AES-MAC AES-CMAC HMAC with one of the supported digests
Authenticated Encryption (AE)	AES-CCM with support for Additional Authenticated Data (AAD) AES-GCM with support for Additional Authenticated Data (AAD)
Asymmetric Encryption Schemes	RSA PKCS1-V1.5 RSA OAEP
Asymmetric Signature Schemes	DSA RSA PKCS1-V1.5 RSA PSS
Key Exchange Algorithms	Diffie-Hellman

[4] WARNING: Given the increases in computing power, it is necessary to increase the strength of encryption used with time. Many of the algorithms and key sizes included are known to be weak and are included to support legacy implementations only. TA designers should regularly review the choice of cryptographic primitives and key sizes used in their applications and should refer to appropriate government guidelines.

- A number of cryptographic algorithms are optional in this specification. Optional algorithms if implemented SHALL be supported as defined in the following table.

Table 6-2: Optional Cryptographic Algorithms

Algorithm Type	Optional Supported Algorithm	
Asymmetric Signature Schemes on generic curve types	ECDSA	Required if supporting any curve for which "Generic" in Table 6-14 is Y
Key Exchange Algorithms on generic curve types	ECDH	Required if supporting any curve for which "Generic" in Table 6-14 is Y
Asymmetric Signature on Edwards Curves	ED25519	Required if any Edwards curve is supported
Key Exchange Algorithms on Edwards Curves	X25519	Required if any Edwards curve is supported
Asymmetric Signature on Edwards Curves	ED448	Required if Edwards curve 448 is supported
Key Exchange Algorithms on Edwards Curves	X448	Required if Edwards curve 448 is supported
Various asymmetric Elliptic Curve-based cryptographic schemes using the SM2 curve	SM2	Requires support for SM3 and SM4
Various signature and HMAC schemes based on the SM3 hash function	SM3	
Various symmetric encryption-based schemes based on SM4 symmetric encryption	SM4	

- Digest, symmetric ciphers, MACs, and AE operations are always multi-stage, i.e. data can be provided in successive chunks to the API. On the other hand, asymmetric operations are always single stage.
- Operation states can be copied from one operation handle into an uninitialized operation handle. This allows the TA to duplicate or fork a multi-stage operation, for example.

6.1 Data Types

6.1.1 TEE_OperationMode

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

The `TEE_OperationMode` type is used to specify one of the available cryptographic operations. Table 6-3 defines the legal values of `TEE_OperationMode`.

```
typedef uint32_t TEE_OperationMode;
```

Table 6-3: Possible `TEE_OperationMode` Values

Constant Name	Value	Comment
TEE_MODE_ENCRYPT	0x00000000	Encryption mode
TEE_MODE_DECRYPT	0x00000001	Decryption mode
TEE_MODE_SIGN	0x00000002	Signature generation mode
TEE_MODE_VERIFY	0x00000003	Signature verification mode
TEE_MODE_MAC	0x00000004	MAC mode
TEE_MODE_DIGEST	0x00000005	Digest mode
TEE_MODE_DERIVE	0x00000006	Key derivation mode
Reserved for future GlobalPlatform specifications	0x00000007 – 0x7FFFFFFE	
TEE_MODE_ILLEGAL_VALUE	0x7FFFFFFF	
Implementation defined	0x80000000 – 0xFFFFFFFF	

`TEE_MODE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when provided to a cryptographic operation function.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_OperationMode` was defined as an enum.

6.1.2 TEE_OperationInfo

Since: TEE Internal API v1.0

```
typedef struct {
   uint32_t algorithm;
   uint32_t operationClass;
   uint32_t mode;
   uint32_t digestLength;
   uint32_t maxKeySize;
   uint32_t keySize;
   uint32_t requiredKeyUsage;
   uint32_t handleState;
} TEE_OperationInfo;
```

See the documentation of function `TEE_GetOperationInfo` in section 6.2.3 for a description of this structure.

6.1.3 TEE_OperationInfoMultiple

Since: TEE Internal Core API v1.1

```
typedef struct {
   uint32_t keySize;
   uint32_t requiredKeyUsage;
} TEE_OperationInfoKey;

typedef struct {
   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[];
} TEE_OperationInfoMultiple;
```

See the documentation of function `TEE_GetOperationInfoMultiple` in section 6.2.4 for a description of this structure.

The buffer size to allocate to hold details of N keys is given by

```
sizeof(TEE_OperationInfoMultiple) + N * sizeof(TEE_OperationInfoKey)
```

6.1.4 TEE_OperationHandle

Since: TEE Internal API v1.0

```
typedef struct __TEE_OperationHandle* TEE_OperationHandle;
```

`TEE_OperationHandle` is an opaque handle (as defined in section 2.4) on a cryptographic operation. These handles are returned by the function `TEE_AllocateOperation` specified in section 6.2.1.

6.2 Generic Operation Functions

Except where otherwise indicated, the functions in this subsection are common to all types of cryptographic operation. These functions support the following types of cryptographic operations:

- Message Digests; see section 6.3
- Symmetric Ciphers; see section 6.4
- MACs; see section 6.5
- Authenticated Encryptions; see section 6.6
- Asymmetric Operations; see section 6.7
- Key Derivations; see section 6.8

6.2.1 TEE_AllocateOperation

Since: TEE Internal API v1.0

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

Description

The `TEE_AllocateOperation` function 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, 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.

The parameter `algorithm` SHALL be one of the constants defined in section 6.10.1.

The parameter `mode` SHALL be one of the constants defined in section 6.1.1. It SHALL be compatible with the algorithm as defined by Table 6-4.

The parameter `maxKeySize` SHALL be a valid value as defined in Table 5-9 for the algorithm, for algorithms referenced in Table 5-9. For all other algorithms, the `maxKeySize` parameter may have any value.

The operation is placed in **initial** state.

Table 6-4: `TEE_AllocateOperation` Algorithms Allowed per Mode and Object Type

Algorithm	Object Type	Modes
TEE_ALG_AES_CBC_NOPAD TEE_ALG_AES_CCM TEE_ALG_AES_CTR TEE_ALG_AES_CTS TEE_ALG_AES_ECB_NOPAD TEE_ALG_AES_GCM TEE_ALG_AES_XTS	TEE_TYPE_AES	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_DES_CBC_NOPAD TEE_ALG_DES_ECB_NOPAD	TEE_TYPE_DES	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_DES3_CBC_NOPAD TEE_ALG_DES3_ECB_NOPAD	TEE_TYPE_DES3	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_SM4_CBC_NOPAD TEE_ALG_SM4_CBC_PKCS5 TEE_ALG_SM4_CTR TEE_ALG_SM4_ECB_NOPAD TEE_ALG_SM4_ECB_PKCS5	TEE_TYPE_SM4	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_RSA_NOPAD TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA1 TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA224 TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA256 TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA384 TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA512 TEE_ALG_RSAES_PKCS1_V1_5	TEE_TYPE_RSA_KEYPAIR TEE_TYPE_RSA_PUBLIC_KEY	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_SM2_PKE	TEE_TYPE_SM2_PKE_KEYPAIR TEE_TYPE_SM2_PKE_PUBLIC_KEY	TEE_MODE_ENCRYPT TEE_MODE_DECRYPT
TEE_ALG_AES_CBC_MAC_NOPAD TEE_ALG_AES_CBC_MAC_PKCS5 TEE_ALG_AES_CMAC	TEE_TYPE_AES	TEE_MODE_MAC
TEE_ALG_DES_CBC_MAC_NOPAD TEE_ALG_DES_CBC_MAC_PKCS5	TEE_TYPE_DES	TEE_MODE_MAC
TEE_ALG_DES3_CBC_MAC_NOPAD TEE_ALG_DES3_CBC_MAC_PKCS5	TEE_TYPE_DES3	TEE_MODE_MAC
TEE_ALG_HMAC_MD5	TEE_TYPE_HMAC_MD5	TEE_MODE_MAC
TEE_ALG_HMAC_SHA1	TEE_TYPE_HMAC_SHA1	TEE_MODE_MAC
TEE_ALG_HMAC_SHA224	TEE_TYPE_HMAC_SHA224	TEE_MODE_MAC
TEE_ALG_HMAC_SHA256	TEE_TYPE_HMAC_SHA256	TEE_MODE_MAC
TEE_ALG_HMAC_SHA384	TEE_TYPE_HMAC_SHA384	TEE_MODE_MAC
TEE_ALG_HMAC_SHA512	TEE_TYPE_HMAC_SHA512	TEE_MODE_MAC

Algorithm	Object Type	Modes
TEE_ALG_HMAC_SHA3_224	TEE_TYPE_HMAC_SHA3_224	TEE_MODE_MAC
TEE_ALG_HMAC_SHA3_256	TEE_TYPE_HMAC_SHA3_256	TEE_MODE_MAC
TEE_ALG_HMAC_SHA3_384	TEE_TYPE_HMAC_SHA3_384	TEE_MODE_MAC
TEE_ALG_HMAC_SHA3_512	TEE_TYPE_HMAC_SHA3_512	TEE_MODE_MAC
TEE_ALG_HMAC_SM3	TEE_TYPE_HMAC_SM3	TEE_MODE_MAC
TEE_ALG_MD5 TEE_ALG_SHA1 TEE_ALG_SHA224 TEE_ALG_SHA256 TEE_ALG_SHA384 TEE_ALG_SHA3_224 TEE_ALG_SHA3_256 TEE_ALG_SHA3_384 TEE_ALG_SHA3_512 TEE_ALG_SHAKE128 TEE_ALG_SHAKE256 TEE_ALG_SM3	No associated object type	TEE_MODE_DIGEST
TEE_ALG_DSA_SHA1 TEE_ALG_DSA_SHA224 TEE_ALG_DSA_SHA256 TEE_ALG_DSA_SHA3_224 TEE_ALG_DSA_SHA3_256 TEE_ALG_DSA_SHA3_384 TEE_ALG_DSA_SHA3_512	TEE_TYPE_DSA_KEYPAIR TEE_TYPE_DSA_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY
TEE_ALG_ECDSA_SHA1 TEE_ALG_ECDSA_SHA224 TEE_ALG_ECDSA_SHA256 TEE_ALG_ECDSA_SHA384 TEE_ALG_ECDSA_SHA512 TEE_ALG_ECDSA_SHA3_224 TEE_ALG_ECDSA_SHA3_256 TEE_ALG_ECDSA_SHA3_384 TEE_ALG_ECDSA_SHA3_512	TEE_TYPE_ECDSA_KEYPAIR TEE_TYPE_ECDSA_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY
TEE_ALG_ED25519	TEE_TYPE_ED25519_KEYPAIR TEE_TYPE_ED25519_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY
TEE_ALG_ED448	TEE_TYPE_ED448_KEYPAIR TEE_TYPE_ED448_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY

Algorithm	Object Type	Modes
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA1 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA224 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA256 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA384 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA512 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_224 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_256 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_384 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_512 TEE_ALG_RSASSA_PKCS1_V1_5_MD5 TEE_ALG_RSASSA_PKCS1_V1_5_SHA1 TEE_ALG_RSASSA_PKCS1_V1_5_SHA224 TEE_ALG_RSASSA_PKCS1_V1_5_SHA256 TEE_ALG_RSASSA_PKCS1_V1_5_SHA384 TEE_ALG_RSASSA_PKCS1_V1_5_SHA512 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_224 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_256 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_384 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_512	TEE_TYPE_RSA_KEYPAIR TEE_TYPE_RSA_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY
TEE_ALG_SM2_DSA_SM3	TEE_TYPE_SM2_DSA_KEYPAIR TEE_TYPE_SM2_DSA_PUBLIC_KEY	TEE_MODE_SIGN TEE_MODE_VERIFY
TEE_ALG_DH_DERIVE_SHARED_SECRET	TEE_TYPE_DH_KEYPAIR	TEE_MODE_DERIVE
TEE_ALG_ECDH_DERIVE_SHARED_SECRET	TEE_TYPE_ECDH_KEYPAIR	TEE_MODE_DERIVE
TEE_ALG_X25519	TEE_TYPE_X25519_KEYPAIR	TEE_MODE_DERIVE
TEE_ALG_X448	TEE_TYPE_X448_KEYPAIR	TEE_MODE_DERIVE
TEE_ALG_SM2_KEP	TEE_TYPE_SM2_KEP_KEYPAIR	TEE_MODE_DERIVE
TEE_ALG_HKDF	TEE_TYPE_HKDF	TEE_MODE_DERIVE

Note that all algorithms listed in Table 6-4 SHALL be supported by any compliant implementation (except the elliptic curve algorithms, which are optional; Table 6-11 identifies those algorithms explicitly). However, a particular implementation may also support more implementation-defined algorithms, modes, or key sizes.

Parameters

- `operation`: Reference to generated operation handle
- `algorithm`: One of the cipher algorithms listed in section 6.10.1
- `mode`: The operation mode
- `maxKeySize`: Maximum key size in bits for the operation – must be a valid value for the algorithm as defined in Table 5-9.

Specification Number: 10 **Function Number:** 0xC01

Return Code

- `TEE_SUCCESS`: 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.

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

6.2.2 TEE_FreeOperation

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_FreeOperation( TEE_OperationHandle operation );
```

Description

The `TEE_FreeOperation` 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

Specification Number: 10 **Function Number:** 0xC03

Panic Reasons

- If `operation` is not a valid handle on an operation and is not equal to `TEE_HANDLE_NULL`.
- If the implementation detects any other error.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_FreeOperation` MAY panic if `operation` is `TEE_HANDLE_NULL`.

6.2.3 TEE_GetOperationInfo

Since: TEE Internal API v1.0

```
void TEE_GetOperationInfo(
         TEE_OperationHandle operation,
   [out] TEE_OperationInfo*  operationInfo );
```

Description

The `TEE_GetOperationInfo` function returns information about an operation handle. It fills the following fields in the structure `operationInfo` (defined in section 6.2.1):

- `algorithm`, `mode`, `maxKeySize`: The parameters passed to the function `TEE_AllocateOperation`
- `operationClass`: One of the constants from Table 5-6, describing the kind of operation.
- `keySize`:
  - For an operation that makes no use of keys, `0`.
  - For an operation that uses a single key, the actual size of this key.
  - For an operation that uses multiple keys, `0`.
    - The actual value of `keySize` can be obtained by calling the `TEE_GetOperationInfoMultiple` routine defined in section 6.2.4.
- `requiredKeyUsage`:
  - For an operation that makes no use of keys, `0`.
  - For an operation that uses a single key, a bit vector that describes the necessary bits in the object usage for `TEE_SetOperationKey` to succeed without panicking.
  - For an operation that uses multiple keys, `0`.
    - The actual value of `requiredKeyUsage` can be obtained by calling the `TEE_GetOperationInfoMultiple` routine defined in section 6.2.4.
- `digestLength`:
  - For non-XOF MAC, AE, or Digest, describes the number of bytes in the digest or tag.
  - For XOF operations, `0`.
  - For all other operations, this value is undefined.
- `handleState`: A bit vector describing the current state of the operation. Contains one or more of the following flags:
  - `TEE_HANDLE_FLAG_EXPECT_TWO_KEYS`: Set if the algorithm expects two keys to be set, using `TEE_SetOperationKey2`.
  - `TEE_HANDLE_FLAG_KEY_SET`: Set if the required operation key has been set. Always set for digest operations.
  - `TEE_HANDLE_FLAG_INITIALIZED`: For multi-stage operations, this flag is set using one of the `TEE_XXXInit` functions, and reset (set back to zero) using one of the `TEE_XXXFinal` functions or the `TEE_ResetOperation` function. This flag is always set for Digest operations.
  - `TEE_HANDLE_FLAG_EXTRACTING`: Set for Digest operations when the operation is in the **extracting** state.

Parameters

- `operation`: Handle on the operation
- `operationInfo`: Pointer to a structure filled with the operation information

Specification Number: 10 **Function Number:** 0xC04

Panic Reasons

- If `operation` is not a valid opened operation handle.
- If the implementation detects any other error.

6.2.4 TEE_GetOperationInfoMultiple

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_GetOperationInfoMultiple(
           TEE_OperationHandle         operation,
  [outbuf] TEE_OperationInfoMultiple*  operationInfoMultiple, size_t*
                                                              operationSize );
```

Description

The `TEE_GetOperationInfoMultiple` function returns information about an operation handle. It fills the following fields in the structure `operationInfoMultiple` (defined in section 6.1.3):

- `algorithm`, `mode`, `maxKeySize`: The parameters passed to the function `TEE_AllocateOperation`.
- `operationClass`: One of the constants from Table 5-6, describing the kind of operation.
- `digestLength`: For a MAC, AE, or Digest, describes the number of bytes in the digest or tag. For other kinds of operation, or when the digest length is unknown, this value SHALL be zero.
- `handleState`: A bit vector describing the current state of the operation. Contains one or more of the following flags:
  - `TEE_HANDLE_FLAG_EXPECT_TWO_KEYS`: Set if the algorithm expects two keys to be set, using `TEE_SetOperationKey2`.
  - `TEE_HANDLE_FLAG_KEY_SET`: Set if all required operation keys have been set. Always set for digest operations.
  - `TEE_HANDLE_FLAG_INITIALIZED`: For multi-stage operations, this flag is set using one of the `TEE_XXXInit` functions, and reset (set back to zero) using one of the `TEE_XXXFinal` functions or the `TEE_ResetOperation` function. This flag is always set for Digest operations.
  - `TEE_HANDLE_FLAG_EXTRACTING`: Set for Digest operations when the operation is in the **extracting** state.
- `operationState`: One of the values from Table 5-7. This is set to `TEE_OPERATION_STATE_ACTIVE` if the operation is in **active** state, to `TEE_OPERATION_STATE_INITIAL` if the operation is in the **initial** state, and to `TEE_OPERATION_STATE_EXTRACTING` if the operation is in the **extracting** state.
- `numberOfKeys`: This is set to the number of keys required by this operation. It indicates the number of `TEE_OperationInfoKey` structures which follow. May be `0` for an operation which requires no keys.
- `keyInformation`: This array contains `numberOfKeys` entries, each of which defines the details for one key used by the operation, in the order they are defined. If the buffer is larger than required to support `numberOfKeys` entries, the additional space is not initialized or modified. For each element:
  - `keySize`: If a key is programmed in the operation, the actual size of this key; otherwise `0`.
  - `requiredKeyUsage`: A bit vector that describes the necessary bits in the object usage for `TEE_SetOperationKey` or `TEE_SetOperationKey2` to succeed without panicking.

Parameters

- `operation`: Handle on the operation
- `operationInfoMultiple`, `operationSize`: Buffer filled with the operation information. The number of keys which can be contained is given by:

```
(*operationSize-
sizeof(TEE_OperationInfoMultiple))/sizeof(TEE_OperationInfoKey)+1
```

Specification Number: 10 **Function Number:** 0xC08

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_SHORT_BUFFER`: If the `operationInfo` buffer is not large enough to hold a `TEE_OperationInfoMultiple` (defined in section 6.1.3) structure containing the number of keys required by a `TEE_Operation` of the type supplied. Table C-1 points to the normative references which define this information.

Panic Reasons

- If `operation` is not a valid opened operation handle.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `operationSize`.

TEE Internal Core API v1.2 clarified the legal values for `digestLength`.

6.2.5 TEE_ResetOperation

Since: TEE Internal API v1.0

```
void TEE_ResetOperation( TEE_OperationHandle operation );
```

Description

For a multi-stage operation, the `TEE_ResetOperation` function resets the `TEE_OperationHandle` to the state after the initial `TEE_AllocateOperation` call with the addition of any keys which were configured subsequent to this so that the `TEE_OperationHandle` can be reused with the same keys.

This function can be called on any operation and at any time after the key is set, but is meaningful only for the multi-stage operations, i.e. symmetric ciphers, MACs, AEs, and digests.

When such a multi-stage operation is active, i.e. when it has been initialized but not yet successfully finalized, then the operation is reset to **initial** state. The operation key(s) are not cleared.

Parameters

- `operation`: Handle on the operation

Specification Number: 10 **Function Number:** 0xC05

Panic Reasons

- If `operation` is not a valid opened operation handle.
- If the key has not been set yet.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

6.2.6 TEE_SetOperationKey

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_SetOperationKey(
           TEE_OperationHandle operation,
   [in]    TEE_ObjectHandle    key );
```

Description

The `TEE_SetOperationKey` function 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.

This function accepts handles on both transient key objects and persistent key objects.

The operation SHALL be in **initial** state before the operation and remains in **initial** state afterwards.

Key object types referenced in Table 5-9 SHALL be sized as defined in the table; otherwise the key object size may have any value up to the maximum key size compatible with the operation. The operation mode SHALL be compatible with key usage:

- In general, the operation mode SHALL be allowed in the object usage.
- For the `TEE_ALG_RSA_NOPAD` algorithm:
  - The only supported modes are `TEE_MODE_ENCRYPT` and `TEE_MODE_DECRYPT`.
  - For `TEE_MODE_ENCRYPT`, the object usage SHALL contain both the `TEE_USAGE_ENCRYPT` and `TEE_USAGE_VERIFY` flags.
  - For `TEE_MODE_DECRYPT`, the object usage SHALL contain both the `TEE_USAGE_DECRYPT` and `TEE_USAGE_SIGN` flags.
- For a public key object, the allowed operation modes depend on the type of key and are specified in the following table.

Table 6-5: Public Key Allowed Modes

Key Type	Allowed Operation Modes
`TEE_TYPE_RSA_PUBLIC_KEY`	`TEE_MODE_VERIFY` or `TEE_MODE_ENCRYPT`
`TEE_TYPE_DSA_PUBLIC_KEY`	`TEE_MODE_VERIFY`
`TEE_TYPE_ECDSA_PUBLIC_KEY` (optional) `TEE_TYPE_ED25519_PUBLIC_KEY` (optional) `TEE_TYPE_ED448_PUBLIC_KEY` (optional)	`TEE_MODE_VERIFY`
`TEE_TYPE_ECDH_PUBLIC_KEY` (optional) `TEE_TYPE_X25519_PUBLIC_KEY` (optional) `TEE_TYPE_X448_PUBLIC_KEY` (optional)	`TEE_MODE_DERIVE`
`TEE_TYPE_SM2_DSA_PUBLIC_KEY` (optional)	`TEE_MODE_VERIFY`
`TEE_TYPE_SM2_KEP_PUBLIC_KEY` (optional)	`TEE_MODE_DERIVE`

Key Type	Allowed Operation Modes
`TEE_TYPE_SM2_PKE_PUBLIC_KEY` (optional)	`TEE_MODE_ENCRYPT` or `TEE_MODE_DECRYPT`

- If the object is a key-pair then the key parts used in the operation depend on the operation mode as defined in the following table.

Table 6-6: Key-Pair Parts for Operation Modes

Operation Mode	Key Parts Used
`TEE_MODE_VERIFY`	Public
`TEE_MODE_SIGN`	Private
`TEE_MODE_ENCRYPT`	Public
`TEE_MODE_DECRYPT`	Private
`TEE_MODE_DERIVE`	Public and Private

If `key` is set to `TEE_HANDLE_NULL`, then the operation key is cleared.

If a key is present in the operation, then it is cleared and all key material copied into the operation is destroyed before the new key is inserted.

Parameters

- `operation`: Operation handle
- `key`: A handle on a key object

Specification Number: 10 **Function Number:** 0xC06

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_CORRUPT_OBJECT`: If the object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the persistent object is stored in a storage area which is currently inaccessible.

Panic Reasons

- If `operation` is not a valid opened operation handle.
- If `key` is not `TEE_HANDLE_NULL` and is not a valid handle on a key object.
- If `key` is not initialized.
- If the type, size, or usage of `key` is not compatible with the algorithm, mode, or size of the `operation`.
- If `operation` is not in **initial** state.
- If the flag `TEE_HANDLE_FLAG_INITIALIZED` is set on the operation.
- Hardware or cryptographic algorithm failure

- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_SetOperationKey` did not specify the *[in]* annotation on `key`.

Prior to TEE Internal Core API v1.3, the behavior associated with the return code `TEE_ERROR_CORRUPT_OBJECT` resulted in the object handle always being closed.

6.2.7 TEE_SetOperationKey2

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_SetOperationKey2(
           TEE_OperationHandle operation,
   [in]    TEE_ObjectHandle    key1,
   [in]    TEE_ObjectHandle    key2 );
```

Description

The `TEE_SetOperationKey2` function initializes an existing operation with two keys. This is used only for the algorithms `TEE_ALG_AES_XTS` and `TEE_ALG_SM2_KEP`.

This function works like `TEE_SetOperationKey` except that two keys are set instead of a single key.

`key1` and `key2` SHALL both be non-`NULL` or both `NULL`. `key1` and `key2` SHALL NOT refer to keys with bitwise identical `TEE_ATTR_SECRET_VALUE` attributes.

- For `TEE_ALG_SM2_KEP`, `key1` is the handle to the key object that contains the long-term key, and `key2` is the handle to the key object that contains the ephemeral key.
- For `TEE_ALG_AES_XTS`, `key1` and `key2` SHALL support key sizes of 128 and 256 bits.

Parameters

- `operation`: Operation handle
- `key1`: A handle on a key object
- `key2`: A handle on a key object

Specification Number: 10 **Function Number:** 0xC07

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_CORRUPT_OBJECT`: If the `key1` object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_CORRUPT_OBJECT_2`: If the `key2` object is corrupt. The object handle SHALL behave based on the `gpd.ta.doesNotCloseHandleOnCorruptObject` property.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE`: If the `key1` object is stored in a storage area which is currently inaccessible.
- `TEE_ERROR_STORAGE_NOT_AVAILABLE_2`: If the `key2` object is stored in a storage area which is currently inaccessible.
- `TEE_ERROR_SECURITY`: If the `key1` object and the `key2` object are the same.

Panic Reasons

- If `operation` is not a valid opened operation handle.
- If `key1` and `key2` are not both `TEE_HANDLE_NULL` and `key1` or `key2` or both are not valid handles on a key object.
- If `key1` and/or `key2` are not initialized.

- If the type, size, or usage of `key1` or `key2` is not compatible with the algorithm, mode, or size of the `operation`.
- If `operation` is not in **initial** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.2:

- `TEE_SetOperationKey2` did not include the `TEE_ERROR_SECURITY` return code.
- `TEE_SetOperationKey2` did not specify the *[in]* annotation.

If a TA indicates backward compatibility with a version of this specification before v1.2, the implementation MAY allow `key1` and `key2` to be the same.

Prior to TEE Internal Core API v1.3, the behavior associated with the return codes `TEE_ERROR_CORRUPT_OBJECT` and `TEE_ERROR_CORRUPT_OBJECT_2` resulted in the object handle always being closed.

6.2.8 TEE_CopyOperation

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_CopyOperation(
   [out]   TEE_OperationHandle dstOperation,
   [in]    TEE_OperationHandle srcOperation );
```

Description

The `TEE_CopyOperation` function copies an operation state from one operation handle into another operation handle. This also copies the key material associated with the source operation.

The state of `srcOperation` including the key material currently set up is copied into `dstOperation`.

This function is useful in the following use cases:

- “Forking” a digest operation after feeding some amount of initial data
- Computing intermediate digests

The algorithm and mode of `dstOperation` SHALL be equal to the algorithm and mode of `srcOperation`.

The state of `srcOperation` (**initial/active/extracting**) is copied to `dstOperation`.

If `srcOperation` has no key programmed, then the key in `dstOperation` is cleared. If there is a key programmed in `srcOperation`, then the maximum key size of `dstOperation` SHALL be greater than or equal to the actual key size of `srcOperation`.

Parameters

- `dstOperation`: Handle on the destination operation
- `srcOperation`: Handle on the source operation

Specification Number: 10 **Function Number:** 0xC02

Panic Reasons

- If `dstOperation` or `srcOperation` is not a valid opened operation handle.
- If the algorithm or mode differ in `dstOperation` and `srcOperation`.
- If `srcOperation` has a key and its size is greater than the maximum key size of `dstOperation`.
- Hardware or cryptographic algorithm failure.
- If the implementation detects any other error.

Backward Compatibility

Prior to TEE Internal Core API v1.2, `TEE_CopyOperation` did not specify the *[in]* or *[out]* annotations.

6.2.9 TEE_IsAlgorithmSupported

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_IsAlgorithmSupported(
    [in]    uint32_t algId
    [in]    uint32_t element );
```

Description

The `TEE_IsAlgorithmSupported` function can be used to determine whether a combination of `algId` and `element` is supported. Implementations SHALL return `TEE_ERROR_NOT_SUPPORTED` for any value of `algId` or `element` which is reserved for future use.

Parameters

- `algId`: An algorithm identifier from Table 6-11
- `element`: A cryptographic element from Table 6-14. Where `algId` fully defines the required support, the special value `TEE_OPTIONAL_ELEMENT_NONE` SHOULD be used.

Specification Number: 10 **Function Number:** 0xC09

Return Code

- `TEE_SUCCESS`: The requested combination of `algId` and `element` is supported.
- `TEE_ERROR_NOT_SUPPORTED`: The requested combination of `algId` and `element` is not supported.

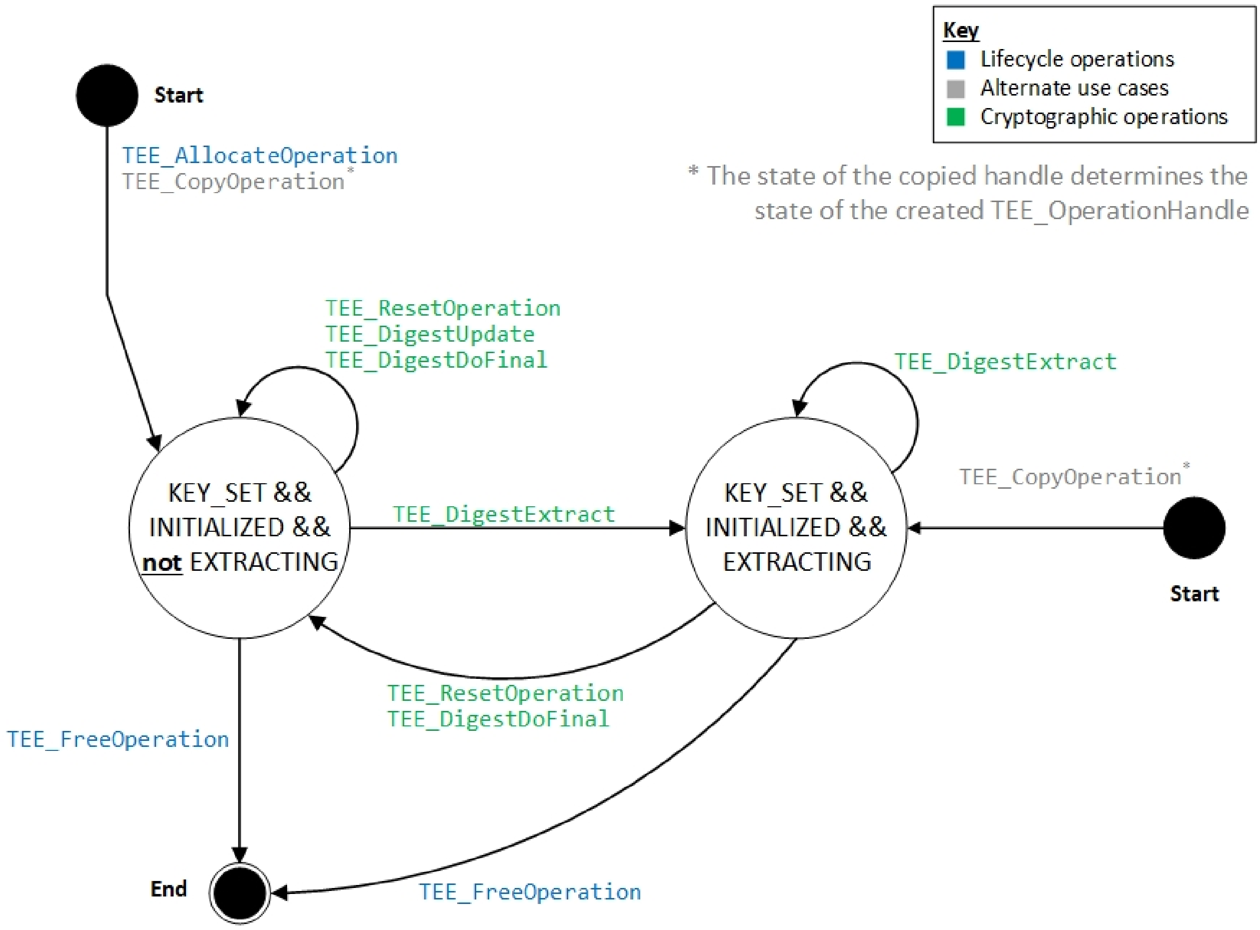
Panic Reasons

`TEE_IsAlgorithmSupported` SHALL NOT panic.

6.3 Message Digest Functions

Figure 6-1 illustrates how a `TEE_OperationHandle` is manipulated by the Message Digest functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-1: State Diagram for `TEE_OperationHandle` for Message Digest Functions (Informative)



6.3.1 TEE_DigestUpdate

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_DigestUpdate(
           TEE_OperationHandle  operation,
   [inbuf] void*                chunk, size_t chunkSize );
```

Description

The `TEE_DigestUpdate` function accumulates message data for hashing. 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`, `chunkSize`: Chunk of data to be hashed

Specification Number: 10 **Function Number:** 0xD02

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_DIGEST`.
- If input data exceeds maximum length for algorithm.
- Hardware or cryptographic algorithm failure.
- It is illegal to call `TEE_DigestUpdate` when in the **extracting** state.
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `chunkSize`.

6.3.2 TEE_DigestDoFinal

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_DigestDoFinal(
            TEE_OperationHandle   operation,
   [inbuf]  void*                 chunk, size_t chunkLen,
   [outbuf] void*                 hash,  size_t *hashLen );
```

Description

The `TEE_DigestDoFinal` 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.

The input operation may be in either **initial**, **active**, or **extracting** state and becomes **initial**.

If `TEE_DigestExtract` has returned some or all of a digest, then `TEE_DigestDoFinal` will only return the remaining part, which may be zero in length.

If you are using an XOF function, `hashLen` bytes will be returned.

Parameters

- `operation`: Handle of a running Message Digest operation
- `chunk`, `chunkLen`: Last chunk of data to be hashed
- `hash`, `hashLen`: Output buffer filled with the message hash

Specification Number: 10 **Function Number:** 0xD01

Return Code

- `TEE_SUCCESS`: On success.
- `TEE_ERROR_SHORT_BUFFER`: Only returned in the case of a non-XOF operation. Returned if the output buffer is too small. In this case, the operation is not finalized.

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_DIGEST`.
- If input data exceeds maximum length for algorithm.
- Hardware or cryptographic algorithm failure.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.
- It is illegal to call `TEE_DigestDoFinal` with `chunklen > 0` when in the **extracting** state.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `chunkLen and hashLen`.

6.3.3 TEE_DigestExtract

Since: TEE Internal Core API v1.3

```
TEE_Result TEE_DigestExtract(
           TEE_OperationHandle  operation,
  [outbuf] void*                hash,
           size_t              *hashLen );
```

Description

The `TEE_DigestExtract` function extracts some or all of the digest depending on the size of the hash buffer.

The operation may be in either **initial**, **active**, or **extracting** state and the state becomes **extracting**. Subsequent calls to this function are possible.

If called with a non-XOF DIGEST operation handle (e.g. SHA-3), then `TEE_DigestExtract` will attempt to return the digest material from that digest function. Depending on whether there is still digest material to return, a subsequent call to `TEE_DigestExtract` or `TEE_DigestDoFinal` may return no data.

Parameters

- `operation`: Handle of a running Message Digest operation
- `hash`: Filled with the unreported part of the digest
- `hashLen`: Length of the unreported part of the digest

Specification Number: 10 **Function Number:** 0xD03

Return Code

- `TEE_SUCCESS`: On success.

Panic Reasons

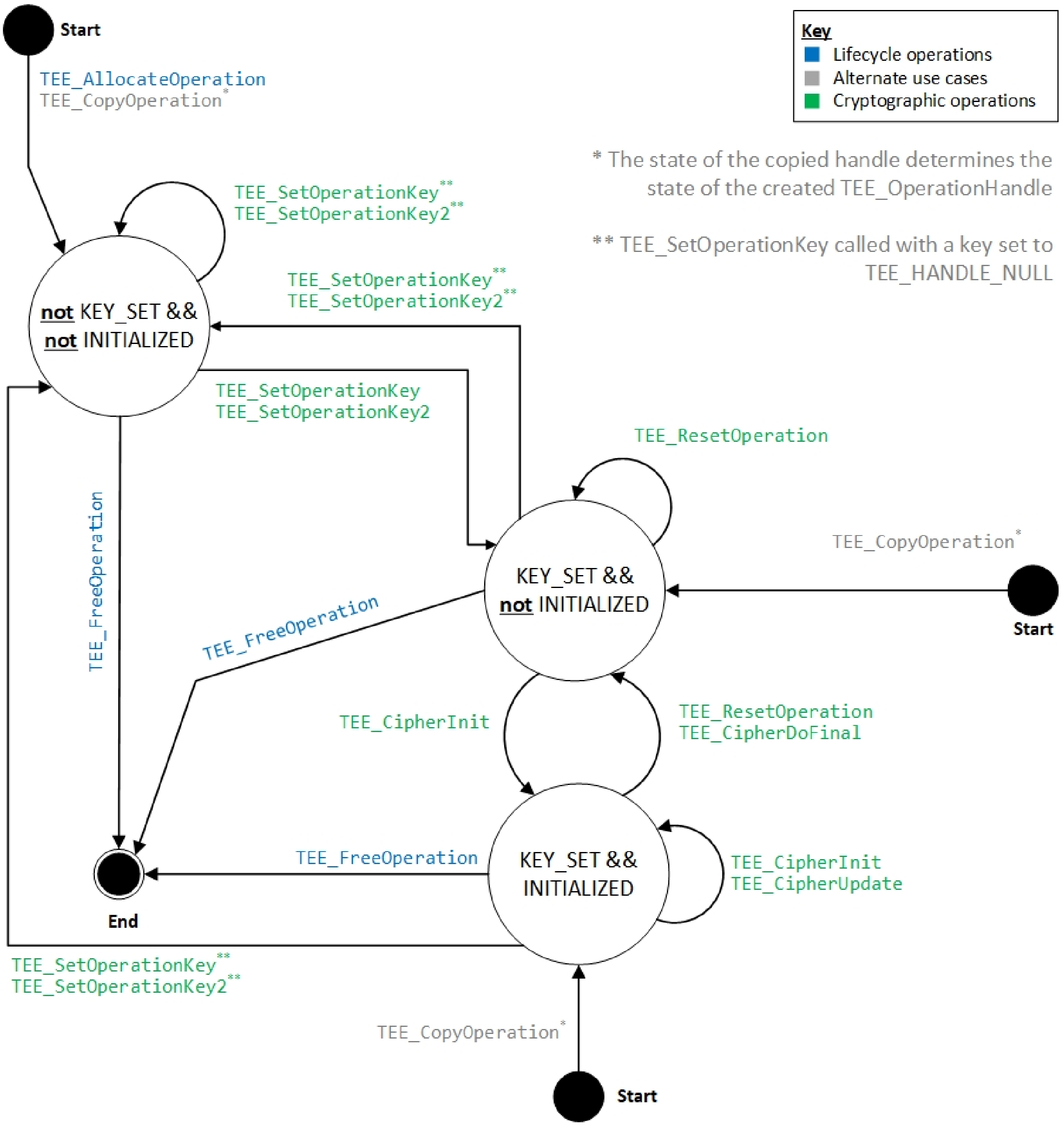
- If `operation` is not a valid operation handle of class `TEE_OPERATION_DIGEST`.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

6.4 Symmetric Cipher Functions

These functions define the way to perform symmetric cipher operations, such as AES. They cover both block ciphers and stream ciphers.

Figure 6-2 illustrates how a `TEE_OperationHandle` is manipulated by the Symmetric Cipher functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-2: State Diagram for `TEE_OperationHandle` for Symmetric Cipher Functions (Informative)



6.4.1 TEE_CipherInit

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_CipherInit(
            TEE_OperationHandle operation,
   [inbuf]  void*               IV, size_t IVLen );
```

Description

The TEE_CipherInit function 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.

The counter for algorithm TEE_ALG_AES_CTR or TEE_ALG_SM4_CTR SHALL be encoded as a 16-byte buffer in big-endian form. Between two consecutive blocks, the counter SHALL be incremented by 1. If it reaches the limit of all 128 bits set to 1, it SHALL wrap around to 0.

Parameters

- operation: A handle on an opened cipher operation setup with a key
- IV, IVLen: Buffer containing the operation Initialization Vector as appropriate (as indicated in the following table).

Table 6-6b: Symmetric Encrypt/Decrypt Operation Parameters

Algorithm	IV Required	Meaning of IV
`TEE_ALG_AES_CBC_NOPAD`	Yes	
`TEE_ALG_AES_CCM`	Yes	Nonce value
`TEE_ALG_AES_CTR`	Yes	Initial Counter Value
`TEE_ALG_AES_CTS`	Yes	
`TEE_ALG_AES_ECB_NOPAD`	No	
`TEE_ALG_AES_GCM`	Yes	Nonce value
`TEE_ALG_AES_XTS`	Yes	Tweak value
`TEE_ALG_DES_CBC_NOPAD`	Yes	
`TEE_ALG_DES_ECB_NOPAD`	No	
`TEE_ALG_DES3_CBC_NOPAD`	Yes	
`TEE_ALG_DES3_ECB_NOPAD`	No	
`TEE_ALG_SM4_CBC_NOPAD`	Yes	IV SHOULD be randomly generated. This is the responsibility of the caller.
`TEE_ALG_SM4_CBC_PKCS5`	Yes	IV SHOULD be randomly generated. This is the responsibility of the caller.
`TEE_ALG_SM4_CTR`	Yes	Initial Counter Value
`TEE_ALG_SM4_ECB_NOPAD`	No	
`TEE_ALG_SM4_ECB_PKCS5`	No	

Specification Number: 10 **Function Number:** 0xE02

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_CIPHER`.
- If no key is programmed in the `operation`.
- If the Initialization Vector does not have the length required by the algorithm.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `IVLen`.

6.4.2 TEE_CipherUpdate

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_CipherUpdate(
            TEE_OperationHandle operation,
   [inbuf]  void*               srcData,  size_t srcLen,
   [outbuf] void*               destData, size_t *destLen );
```

Description

The `TEE_CipherUpdate` function 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`, `srcLen`: Input data buffer to be encrypted or decrypted
- `destData`, `destLen`: Output buffer

Specification Number: 10 **Function Number:** 0xE03

Return Code

- `TEE_SUCCESS`: In case of success.
- `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.

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_CIPHER`.
- If the operation has not been started yet with `TEE_CipherInit` or has already been finalized.
- If `operation` is not in **active** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `srcLen and destLen`.

6.4.3 TEE_CipherDoFinal

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_CipherDoFinal(
              TEE_OperationHandle operation,
   [inbuf]     void*              srcData,  size_t srcLen,
   [outbufopt] void*              destData, size_t *destLen );
```

Description

The TEE_CipherDoFinal function finalizes the cipher operation, processing data that has not been processed by previous calls to TEE_CipherUpdate as well as data supplied in srcData. 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. If the result is not TEE_ERROR_SHORT_BUFFER, the operation enters **initial** state afterwards.

Parameters

- operation: Handle of a running Cipher operation
- srcData, srcLen: Reference to final chunk of input data to be encrypted or decrypted
- destData, destLen: Output buffer. Can be omitted if the output is to be discarded, e.g. because it is known to be empty.

Specification Number: 10 **Function Number:** 0xE01

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_SHORT_BUFFER: If the output buffer is not large enough to contain the output

Panic Reasons

- If operation is not a valid operation handle of class TEE_OPERATION_CIPHER.
- If the operation has not been started yet with TEE_CipherInit or has already been finalized.
- If the total length of the input is not a multiple of a block size when the algorithm of the operation is a symmetric block cipher which does not specify padding.
- If operation is not in **active** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for srcLen and destLen.

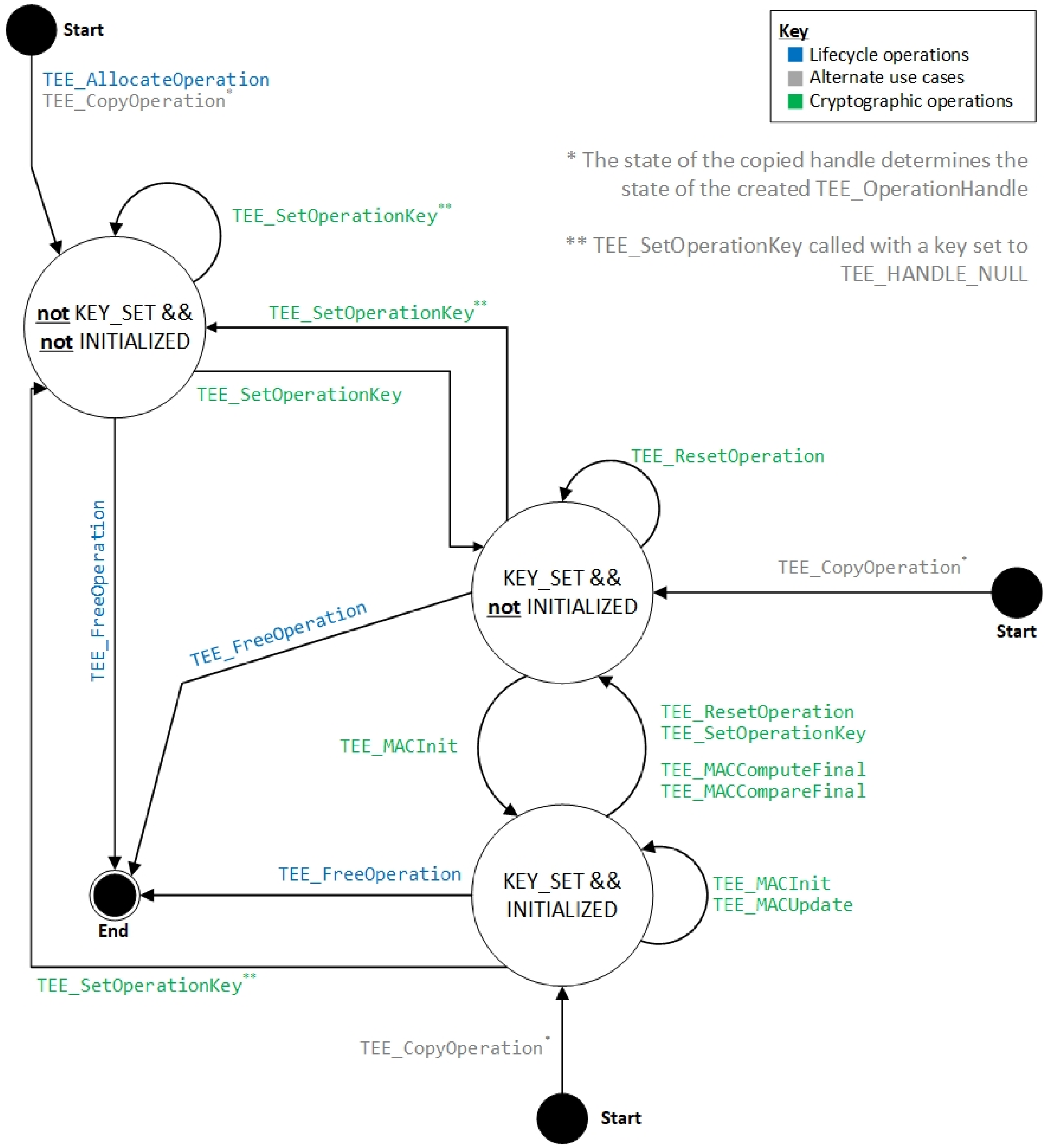
6.5 MAC Functions

These functions are used to perform MAC (Message Authentication Code) operations, such as HMAC or AES-CMAC operations.

These functions are not used for Authenticated Encryption algorithms, which SHALL use the functions defined in section 6.6.

Figure 6-3 illustrates how a `TEE_OperationHandle` is manipulated by the MAC functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-3: State Diagram for `TEE_OperationHandle` for MAC Functions (Informative)



6.5.1 TEE_MACInit

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_MACInit(
            TEE_OperationHandle operation,
   [inbuf]  void*               IV, size_t IVLen );
```

Description

The `TEE_MACInit` function initializes a MAC 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 moves to **active** state.

If the MAC algorithm does not require an IV, the parameters `IV`, `IVLen` are ignored.

Parameters

- `operation`: Operation handle
- `IV`, `IVLen`: Input buffer containing the operation Initialization Vector, if applicable

Specification Number: 10 **Function Number:** 0xF03

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_MAC`.
- If no key is programmed in the `operation`.
- If the Initialization Vector does not have the length required by the algorithm.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `IVLen`.

6.5.2 TEE_MACUpdate

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_MACUpdate(
          TEE_OperationHandle operation,
   [inbuf] void*              chunk, size_t chunkSize );
```

Description

The `TEE_MACUpdate` function accumulates data for a MAC calculation.

Input data does not have to be a multiple of the block size. Subsequent calls to this function are possible. `TEE_MACComputeFinal` or `TEE_MACCompareFinal` are called to complete the MAC operation.

The operation SHALL be in **active** state.

Parameters

- `operation`: Handle of a running MAC operation
- `chunk`, `chunkSize`: Chunk of the message to be MACed

Specification Number: 10 **Function Number:** 0xF04

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_MAC`.
- If the operation has not been started yet with `TEE_MACInit` or has already been finalized.
- If input data exceeds maximum length for algorithm.
- If `operation` is not in **active** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `chunkSize`.

6.5.3 TEE_MACComputeFinal

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_MACComputeFinal(
            TEE_OperationHandle operation,
   [inbuf]  void*               message, size_t messageLen,
   [outbuf] void*               mac, size_t *macLen );
```

Description

The `TEE_MACComputeFinal` function finalizes the MAC operation with a last chunk of message, and computes the MAC. Afterwards the operation handle can be reused or re-initialized with a new key.

The operation SHALL be in **active** state. If the result is not `TEE_ERROR_SHORT_BUFFER`, the operation enters **initial** state afterwards.

Parameters

- `operation`: Handle of a MAC operation
- `message`, `messageLen`: Input buffer containing a last message chunk to MAC
- `mac`, `macLen`: Output buffer filled with the computed MAC

Specification Number: 10 **Function Number:** 0xF02

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is not large enough to contain the computed MAC

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_MAC`.
- If the operation has not been started yet with `TEE_MACInit` or has already been finalized.
- If input data exceeds maximum length for algorithm.
- If `operation` is not in **active** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `messageLen` and `macLen`.

6.5.4 TEE_MACCompareFinal

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_MACCompareFinal(
            TEE_OperationHandle operation,
   [inbuf]  void*               message, size_t messageLen,
   [inbuf]  void*               mac, size_t macLen );
```

Description

The `TEE_MACCompareFinal` function finalizes the MAC operation and compares the MAC with the buffer passed to the function. Afterwards the operation handle can be reused and initialized with a new key.

The operation SHALL be in **active** state and moves to **initial** state afterwards.

Parameters

- `operation`: Handle of a MAC operation
- `message`, `messageLen`: Input buffer containing the last message chunk to MAC
- `mac`, `macLen`: Input buffer containing the MAC to check

Specification Number: 10 **Function Number:** 0xF01

Return Code

- `TEE_SUCCESS`: If the computed MAC corresponds to the MAC passed in the parameter `mac`.
- `TEE_ERROR_MAC_INVALID`: If the computed MAC does not correspond to the value passed in the parameter `mac`. This is regarded as a successful conclusion to the operation, and the operation moves to the initial state.

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_MAC`.
- If the operation has not been started yet with `TEE_MACInit` or has already been finalized.
- If input data exceeds maximum length for algorithm.
- If `operation` is not in **active** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

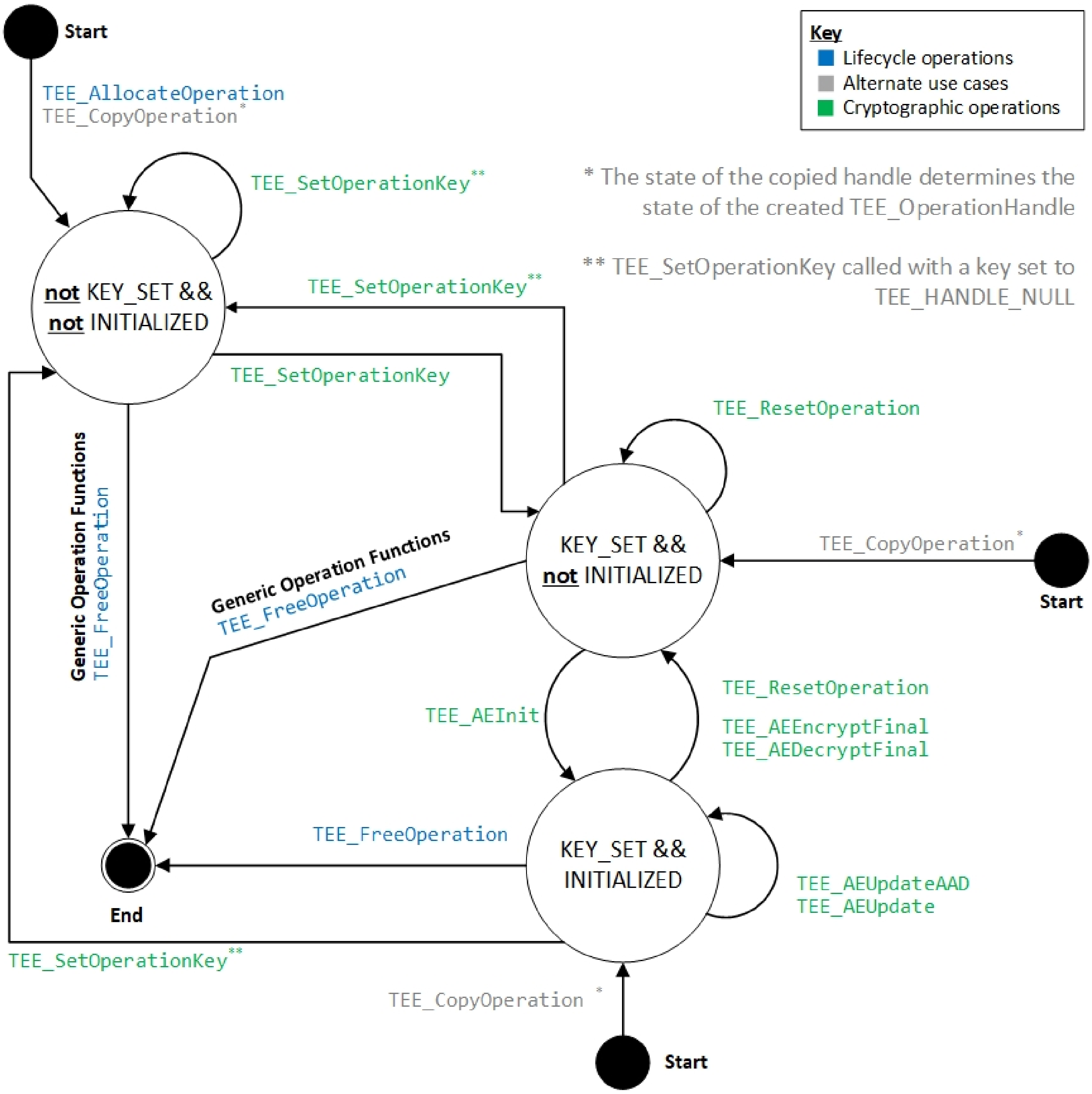
TEE Internal Core API v1.1 used a different type for `messageLen` and `macLen`.

6.6 Authenticated Encryption Functions

These functions are used for Authenticated Encryption operations, i.e. the `TEE_ALG_AES_CCM` and `TEE_ALG_AES_GCM` algorithms.

Figure 6-4 illustrates how a `TEE_OperationHandle` is manipulated by the Authenticated Encryption functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-4: State Diagram for `TEE_OperationHandle` for Authenticated Encryption Functions (Informative)



6.6.1 TEE_AEInit

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_AEInit(
           TEE_OperationHandle operation,
   [inbuf] void*               nonce, size_t nonceLen,
           uint32_t            tagLen,
           size_t              AADLen,
           size_t              payloadLen );
```

Description

The `TEE_AEInit` function initializes an Authentication Encryption operation.

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

Parameters

- `operation`: A handle on the operation
- `nonce`, `nonceLen`: The operation nonce or IV
- `tagLen`: Size in bits of the tag
    - For AES-GCM, SHALL be 128, 120, 112, 104, or 96
    - For AES-CCM, SHALL be 128, 112, 96, 80, 64, 48, or 32
- `AADLen`: Length in bytes of the AAD
    - Used only for AES-CCM; otherwise ignored.
- `payloadLen`: Length in bytes of the payload
    - Used only for AES-CCM; otherwise ignored.

Specification Number: 10 **Function Number:** 0x1003

Return Code

- `TEE_SUCCESS`: On success.
- `TEE_ERROR_NOT_SUPPORTED`: If the tag length is not supported by the algorithm

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_AE`.
- If no key is programmed in the operation.
- If the nonce length is not compatible with the length required by the algorithm.
- If `operation` is not in **initial** state.
- Hardware or cryptographic algorithm failure.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used type `uint32_t` for `nonceLen`.

Prior to TEE Internal Core API v1.2, `AADLen` and `payloadLen` used type `uint32_t`.

6.6.2 TEE_AEUpdateAAD

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_AEUpdateAAD(
          TEE_OperationHandle operation,
   [inbuf] void*              AADdata, size_t AADdataLen );
```

Description

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 operation SHALL be in **initial** state and remains in **initial** state afterwards.

Parameters

- `operation`: Handle on the AE operation
- `AADdata`, `AADdataLen`: Input buffer containing the chunk of AAD

Specification Number: 10 **Function Number:** 0x1005

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_AE`.
- If the operation has not been started yet using `TEE_AEInit`, or has already been finalized.
- If the AAD length would exceed the length permitted by the algorithm.
- If `operation` is not in **initial** state.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `AADdataLen`.

Versions of `TEE_AEUpdateAAD` prior to TEE Internal Core API v1.2 can be called in **any** state and enter **active** state on return.

6.6.3 TEE_AEUpdate

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_AEUpdate(
            TEE_OperationHandle operation,
   [inbuf]  void*               srcData,  size_t srcLen,
   [outbuf] void*               destData, size_t *destLen );
```

Description

The TEE_AEUpdate function accumulates data for an Authentication Encryption operation.

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 buffers srcData and destData SHALL be either completely disjoint or equal in their starting positions.

Warning: 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.

The operation may be in either **initial** or **active** state. If the result is not TEE_ERROR_SHORT_BUFFER and if srcLen != 0, then the operation will be in **active** state afterwards.

Parameters

- operation: Handle of a running AE operation
- srcData, srcLen: Input data buffer to be encrypted or decrypted
- destData, destLen: Output buffer

Specification Number: 10 **Function Number:** 0x1004

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_SHORT_BUFFER: If the output buffer is not large enough to contain the output

Panic Reasons

- If operation is not a valid operation handle of class TEE_OPERATION_AE.
- If the operation has not been started yet using TEE_AEInit, or has already been finalized.
- If the AAD length required by the algorithm has not been provided yet.
- If the maximum payload length for the algorithm would be exceeded.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for srcLen and destLen.

Prior to TEE Internal Core API v1.2, TEE_AEUpdate could be called in **any** state and could enter **active** state on return regardless of the value of srcLen.

6.6.4 TEE_AEEncryptFinal

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_AEEncryptFinal(
               TEE_OperationHandle operation,
   [inbuf]     void*               srcData,  size_t   srcLen,
   [outbufopt] void*               destData, size_t*  destLen,
   [outbuf]    void*               tag,      size_t*  tagLen );
```

Description

The TEE_AEEncryptFinal function processes data that has not been processed by previous calls to TEE_AEUpdate as well as data supplied in srcData. It 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. If the result is not TEE_ERROR_SHORT_BUFFER, the operation enters **initial** state afterwards.

Parameters

- operation: Handle of a running AE operation
- srcData, srcLen: Reference to final chunk of input data to be encrypted
- destData, destLen: Output buffer. Can be omitted if the output is to be discarded, e.g. because it is known to be empty, as described in section 3.4.5.
- tag, tagLen: Output buffer filled with the computed tag

Specification Number: 10 **Function Number:** 0x1002

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_SHORT_BUFFER: If the output or tag buffer is not large enough to contain the output

Panic Reasons

- If operation is not a valid operation handle of class TEE_OPERATION_AE.
- If the operation has not been started yet using TEE_AEInit, or has already been finalized.
- If the required payload or AAD length is known but has not been provided.
- Hardware or cryptographic algorithm failure.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for srcLen, destLen, and tagLen.

Prior to TEE Internal Core API v1.2, a valid destData buffer was always required.

6.6.5 TEE_AEDecryptFinal

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_AEDecryptFinal(
                TEE_OperationHandle operation,
   [inbuf]      void*               srcData, size_t srcLen,
   [outbuf]     void*               destData, size_t *destLen,
   [in]         void*               tag, size_t tagLen );
```

Description

The `TEE_AEDecryptFinal` function processes data that has not been processed by previous calls to `TEE_AEUpdate` as well as data supplied in `srcData`. It 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. If the result is not `TEE_ERROR_SHORT_BUFFER`, the operation enters **initial** state afterwards.

Parameters

- `operation`: Handle of a running AE operation
- `srcData`, `srcLen`: Reference to final chunk of input data to be decrypted
- `destData`, `destLen`: Output buffer. Can be omitted if the output is to be discarded, e.g. because it is known to be empty.
- `tag`, `tagLen`: Input buffer containing the tag to compare

Specification Number: 10 **Function Number:** 0x1001

Return Code

- `TEE_SUCCESS`: In case of 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. This is regarded as a successful conclusion to the operation, and the operation moves to the initial state.

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_AE`.
- If the operation has not been started yet using `TEE_AEInit`, or has already been finalized.
- If the required payload or AAD length is known but has not been provided.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `srcLen`, `destLen`, and `tagLen`.

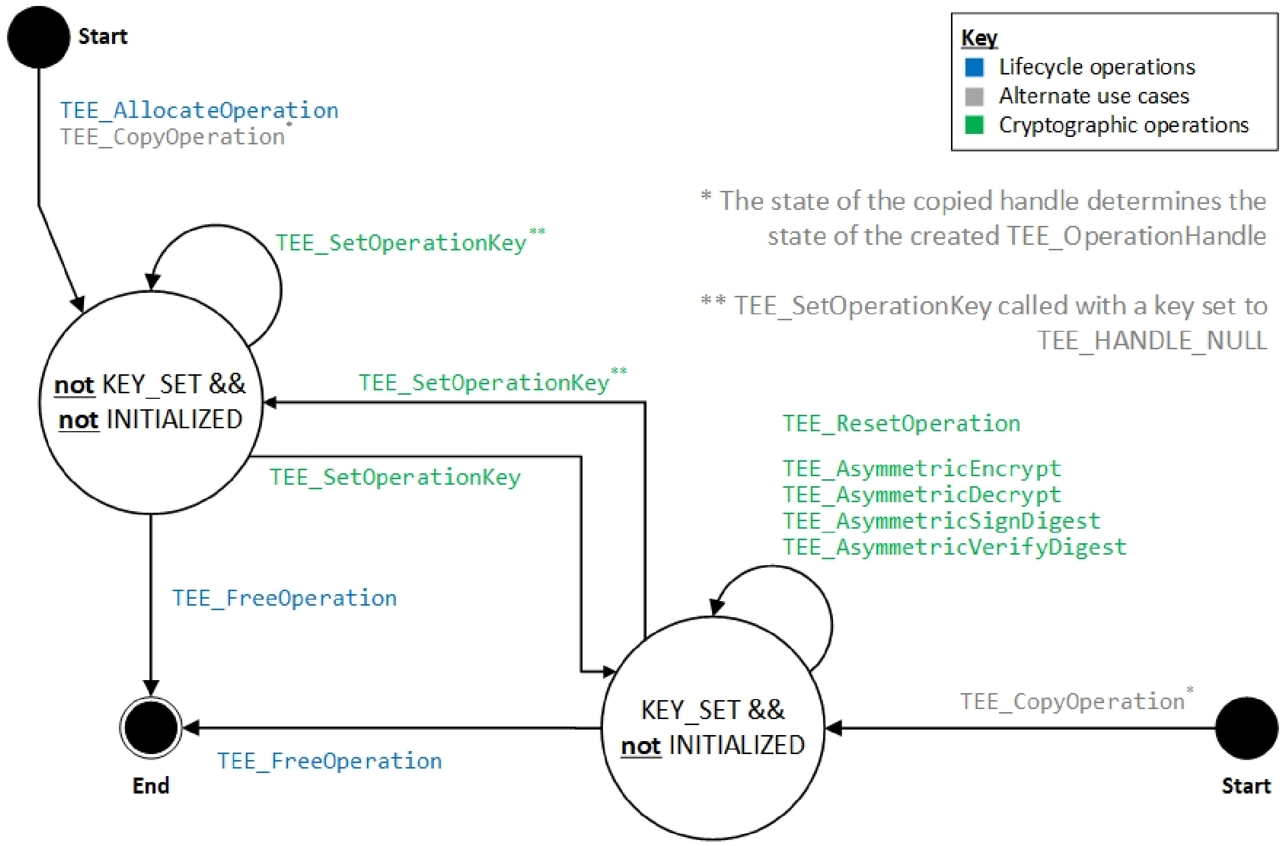
6.7 Asymmetric Functions

These functions allow the encryption and decryption of data using asymmetric algorithms, signatures of digests, and verification of signatures.

Note that asymmetric encryption is always “single-stage”, which differs from symmetric ciphers which are always “multi-stage”.

Figure 6-5 illustrates how a `TEE_OperationHandle` is manipulated by the Asymmetric functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-5: State Diagram for `TEE_OperationHandle` for Asymmetric Functions (Informative)



6.7.1 TEE_AsymmetricEncrypt, TEE_AsymmetricDecrypt

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
TEE_Result TEE_AsymmetricEncrypt(
               TEE_OperationHandle operation,
   [in]        TEE_Attribute*      params,    uint32_t paramCount,
   [inbuf]     void*               srcData,   size_t   srcLen,
   [outbuf]    void*               destData,  size_t   *destLen );

TEE_Result TEE_AsymmetricDecrypt(
               TEE_OperationHandle operation,
   [in]        TEE_Attribute*      params,    uint32_t paramCount,
   [inbuf]     void*               srcData,   size_t   srcLen,
   [outbuf]    void*               destData,  size_t   *destLen );
```

Description

The `TEE_AsymmetricEncrypt` function encrypts a message within an asymmetric operation, and the `TEE_AsymmetricDecrypt` function decrypts the result.

These functions can be called only with an operation of certain algorithms. Table 6-4 on page 182 lists the algorithms that are supported for various modes; see the asymmetric algorithms listed for modes `TEE_MODE_ENCRYPT` and `TEE_MODE_DECRYPT`.

The parameters `params`, `paramCount` contain the operation parameters listed in the following table.

Table 6-7: Asymmetric Encrypt/Decrypt Operation Parameters

Algorithm	Possible Operation Parameters
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_XXX	TEE_ATTR_RSA_OAEP_LABEL: This parameter is optional. If not present, an empty label is assumed.

Parameters

- `operation`: Handle on the operation, which SHALL have been suitably set up with an operation key
- `params`, `paramCount`: Optional operation parameters
- `srcData`, `srcLen`: Input buffer
- `destData`, `destLen`: Output buffer

`TEE_AsymmetricDecrypt`: Specification Number: 10 **Function Number:** 0x1101

`TEE_AsymmetricEncrypt`: Specification Number: 10 **Function Number:** 0x1102

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is not large enough to hold the result
- `TEE_ERROR_BAD_PARAMETERS`
  - If the length of the input buffer is not consistent with the algorithm or key size. Refer to Table 5-9 for algorithm references and supported sizes.

  - If an incorrect or inconsistent attribute is detected. The checks that are performed depend on the implementation.
- `TEE_ERROR_CIPHERTEXT_INVALID`: If the ciphertext is invalid for the given key, for example because of invalid padding.

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_ASYMMETRIC_CIPHER`.
- If no key is programmed in the operation.
- If the mode is not compatible with the function.
- Hardware or cryptographic algorithm failure
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `srcLen` and `destLen` of both functions.

Versions prior to TEE Internal Core API v1.2 did not define `TEE_ERROR_CIPHERTEXT_INVALID`.

6.7.2 TEE_AsymmetricSignDigest

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_AsymmetricSignDigest(
               TEE_OperationHandle operation,
   [in]        TEE_Attribute*      params,     uint32_t paramCount,
   [inbuf]     void*               digest,     size_t   digestLen,
   [outbuf]    void*               signature,  size_t   *signatureLen
);
```

Description

The `TEE_AsymmetricSignDigest` function signs a message digest within an asymmetric operation.

Note that only an already hashed message can be signed, with the exception of `TEE_ALG_ED25519` and `TEE_ALG_ED448` for which `digest` and `digestLen` refer to the message to be signed.

This function can be called only with an operation of an algorithm listed for modes `TEE_MODE_SIGN` and `TEE_MODE_VERIFY` in Table 6-4 on page 182.

The parameters `params`, `paramCount` contain the operation parameters listed in Table 6-8.

Table 6-8: Asymmetric Sign/Verify Operation Parameters

Algorithm	Possible Operation Parameters
`TEE_ALG_RSASSA_ PKCS1_PSS_MGF1_XXX`	`TEE_ATTR_RSA_PSS_SALT_LENGTH`: Number of bytes in the salt. This parameter is optional. If not present, the salt length is equal to the hash length.
`TEE_ALG_ED25519`	**Since:** TEE Internal Core API v1.3 – See Backward Compatibility note at end of section. `TEE_ATTR_EDDSA_PREHASH:` Optional `a` and `b` `uint32_t`, default `0,0`. ○ If `a=1` and `b=0`, then: ▪ The algorithm selected is Ed25519ph ([Ed25519]). ▪ The `digest` parameter is the pre-hashed message. ▪ If `TEE_ATTR_EDDSA_CTX` is not present, then the context string is assumed to be empty. ○ If `a=0` and `b=0`, then: ▪ The `digest` parameter is the message in full. ▪ If `TEE_ATTR_EDDSA_CTX` is present, then the algorithm selected is Ed25519ctx; otherwise it is Ed25519. ○ `a = 0x7FFF FFFF` should be treated as an illegal value in this context. ○ Values of `a` from `0x0000 0000` to `0x7FFF FFFE` are reserved for GlobalPlatform, and may have been defined above. When `a` is in this range, the value of `b` will be defined by GlobalPlatform. ○ Values of `a` from `0x8000 0000` to `0xFFFF FFFF` are reserved for implementers. When `a` is in this range, the value of `b` will be defined by the implementer. `TEE_ATTR_EDDSA_CTX`: Optional buffer, maximum length 255. ○ If present, `TEE_ATTR_EDDSA_CTX` is the context string.

Algorithm	Possible Operation Parameters
TEE_ALG_ED448	TEE_ATTR_EDDSA_PREHASH: Optional a and b uint32_t, default 0,0. ○ If a=1 and b=0, then: ▪ The algorithm selected is Ed448ph ([Ed25519]). ▪ The digest parameter is the pre-hashed message. ○ If a=0 and b=0, then the digest parameter is the message in full. ○ a = 0x7FFF FFFF is a GlobalPlatform reserved value and should be treated as an illegal value in this context. ○ Values of a from 0x0000 0002 to 0x7FFF FFFE are reserved for GlobalPlatform. When a is in this range, the value of b will be defined by GlobalPlatform. ○ Values of a from 0x8000 0000 to 0xFFFF FFFF are reserved for implementers. When a is in this range, the value of b will be defined by the implementer. TEE_ATTR_EDDSA_CTX: Optional buffer, maximum length 255. ○ If present, TEE_ATTR_EDDSA_CTX is the context string; otherwise the context string is assumed to be empty.

Where a hash algorithm is specified in the algorithm, digestLen SHALL be equal to the digest length of this hash algorithm. For TEE_ALG_ED25519 and TEE_ALG_ED448, if the TEE_ATTR_EDDSA_PREHASH attribute has a=1 , b=0, then the implementation SHALL accept a digestLen of 64, and MAY accept other values.

Parameters

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

Specification Number: 10 **Function Number:** 0x1103

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_SHORT_BUFFER: If the signature buffer is not large enough to hold the result

Panic Reasons

- If operation is not a valid operation handle of class TEE_OPERATION_ASYMMETRIC_SIGNATURE.
- If no key is programmed in the operation.
- If the operation mode is not TEE_MODE_SIGN.
- If digestLen is not equal to the hash size of the algorithm in non-XOF functions
- Hardware or cryptographic algorithm failure
- If an optional algorithm which is not supported by the Trusted OS is passed in TEE_OperationHandle.
- If an illegal value is passed as an operation parameter.

- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `digestLen` and `signatureLen`.

TEE Internal Core API v1.3:

Renamed `TEE_ATTR_ED25519_CTX` to `TEE_ATTR_EDDSA_CTX`.

Deprecated use of `TEE_ATTR_ED25519_PH`, replacing it with the generic `TEE_ATTR_EDDSA_PREHASH`. Note that these two operation parameters are not identical when used with Ed25519 because the earlier version didn’t cover the full spectrum of Ed25519 options.

6.7.3 TEE_AsymmetricVerifyDigest

Since: TEE Internal Core API v1.3 – See Backward Compatibility note below.

```
TEE_Result TEE_AsymmetricVerifyDigest(
                TEE_OperationHandle operation,
   [in]         TEE_Attribute*      params,    uint32_t paramCount,
   [inbuf]      void*               digest,    size_t   digestLen,
   [inbuf]      void*               signature, size_t   signatureLen );
```

Description

The `TEE_AsymmetricVerifyDigest` function verifies a message digest signature within an asymmetric operation.

This function can be called only with an operation of an algorithm listed for modes `TEE_MODE_SIGN` and `TEE_MODE_VERIFY` in Table 6-4 on page 182.

The parameters `params`, `paramCount` contain the operation parameters listed in Table 6-8 on page 223.

Table 6-9: Asymmetric Verify Operation Parameters *[obsolete]*

Algorithm	Possible Operation Parameters
This table existed in previous versions of the specification and was removed in v1.3. The information previously in this table has been merged into Table 6-8.	

Where a hash algorithm is specified in the algorithm, `digestLen` SHALL be equal to the digest length of this hash algorithm. For `TEE_ALG_ED25519` and `TEE_ALG_ED448`, if the `TEE_ATTR_EDDSA_PREHASH` attribute has `a=1` , `b=0`, then the implementation SHALL accept a `digestLen` of `64`, and MAY accept other values.

Parameters

- `operation`: Handle on the operation, which SHALL have been suitably set up with an operation key
- `params`, `paramCount`: Optional operation parameters
- `digest`, `digestLen`: Input buffer containing the input message digest
- `signature`, `signatureLen`: Input buffer containing the signature to verify

Specification Number: 10 **Function Number:** 0x1104

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_SIGNATURE_INVALID`: If the signature is invalid

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_ASYMMETRIC_SIGNATURE`.
- If no key is programmed in the operation.
- If the operation mode is not `TEE_MODE_VERIFY`.
- If `digestLen` is not equal to the hash size of the algorithm

- Hardware or cryptographic algorithm failure
- If an optional algorithm which is not supported by the Trusted OS is passed in `TEE_OperationHandle`.
- If an illegal value is passed as an operation parameter.
- If the implementation detects any other error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `digestLen` and `signatureLen`.

TEE Internal Core API v1.3:

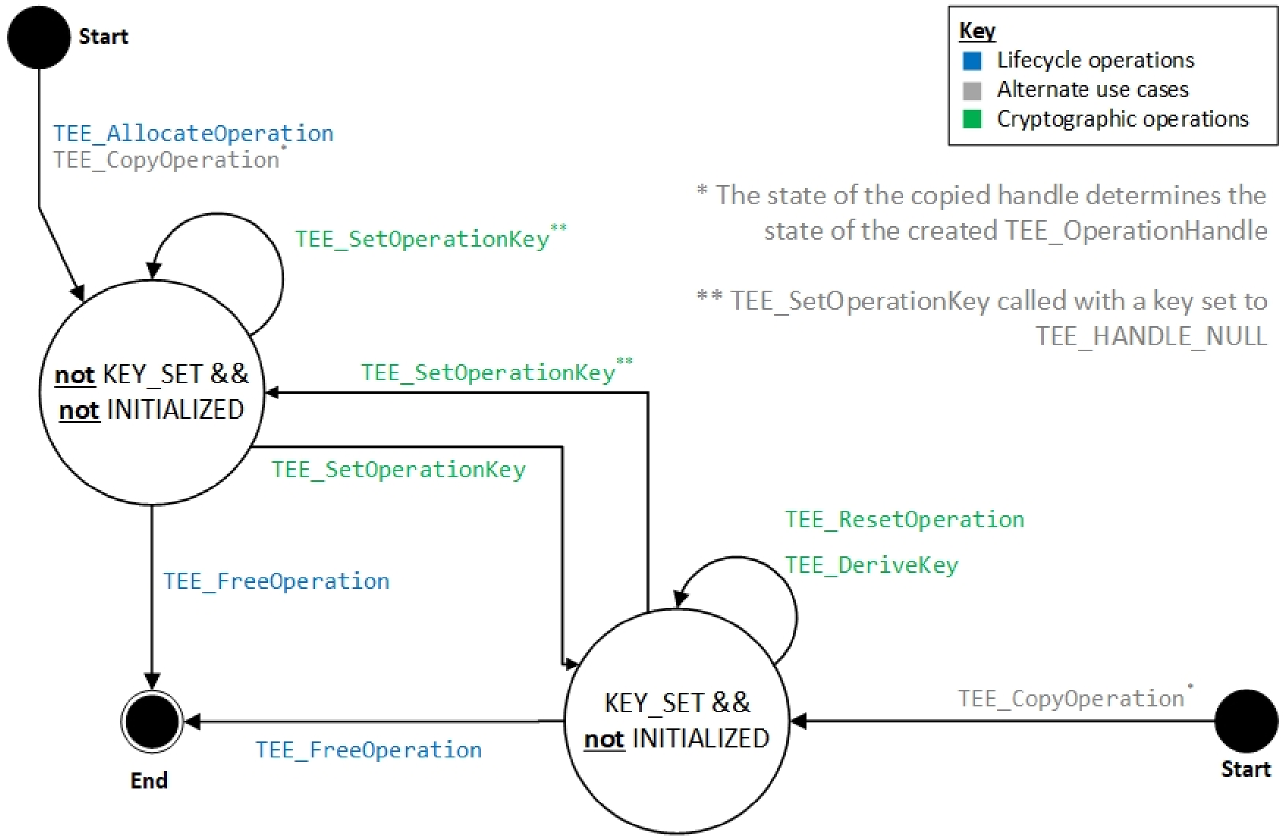
Renamed `TEE_ATTR_ED25519_CTX` to `TEE_ATTR_EDDSA_CTX`.

Deprecated use of `TEE_ATTR_ED25519_PH`, and replaced it with the generic `TEE_ATTR_EDDSA_PREHASH`. Note that these two operation parameters are not identical when used with Ed25519 because the earlier version didn't cover the full spectrum of Ed25519 options.

6.8 Key Derivation Functions

Figure 6-6 illustrates how a `TEE_OperationHandle` is manipulated by the Key Derivation functions. The state diagram is expressed in terms of the state that is revealed in the `handleState` flags by `TEE_GetOperationInfo` and `TEE_GetOperationInfoMultiple`.

Figure 6-6: State Diagram for `TEE_OperationHandle` for Key Derivation Functions (Informative)



6.8.1 TEE_DeriveKey

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_DeriveKey(
            TEE_OperationHandle operation,
   [inout]  TEE_Attribute*      params, uint32_t paramCount,
            TEE_ObjectHandle    derivedKey );
```

Description

The `TEE_DeriveKey` function takes one of the Key Derivation Operation Parameters in Table 6-10 as input, and outputs a key object.

The `TEE_DeriveKey` function can only be used with algorithms defined in Table 6-10.

The parameters `params`, `paramCount` contain the operation parameters listed in Table 6-10.

4407 **Table 6-10: Key Derivation Operation Parameters**

Algorithm	Possible Operation Parameters	Output Key Type
TEE_ALG_DH_DERIVE_ SHARED_SECRET	TEE_ATTR_DH_PUBLIC_VALUE Public key of the other party. This parameter is mandatory.	TEE_TYPE_GENERIC_SECRET
TEE_ALG_ECDH_DERIVE_ SHARED_SECRET	TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y Public key of the other party. These parameters are mandatory.	TEE_TYPE_GENERIC_SECRET
TEE_ALG_X25519	TEE_ATTR_X25519_PUBLIC_VALUE Public key of the other party. This parameter is mandatory.	TEE_TYPE_GENERIC_SECRET
TEE_ALG_X448	TEE_ATTR_X448_PUBLIC_VALUE Public key of the other party. This parameter is mandatory.	TEE_TYPE_GENERIC_SECRET
TEE_ALG_SM2_KEP	**Mandatory parameters:** TEE_ATTR_ECC_PUBLIC_VALUE_X TEE_ATTR_ECC_PUBLIC_VALUE_Y Public key of the other party. TEE_ATTR_SM2_KEP_USER Value specifying the role of the user. Value 0 means initiator and non-zero means responder. TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_X TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_Y Ephemeral public key of the other party. TEE_ATTR_SM2_ID_INITIATOR Identifier of initiator. TEE_ATTR_SM2_ID_RESPONDER Identifier of responder. **Optional parameters:** If peers want to confirm key agreement, they can provide: TEE_ATTR_SM2_KEP_CONFIRMATION_IN Confirmation value from the other peer (optional). TEE_ATTR_SM2_KEP_CONFIRMATION_OUT Confirmation value of the caller (optional).	TEE_TYPE_GENERIC_SECRET, TEE_TYPE_SM3, or TEE_TYPE_SM4

Algorithm	Possible Operation Parameters	Output Key Type
TEE_ALG_HKDF	**Optional parameters:** TEE_ATTR_HKDF_SALT If present, TEE_ATTR_HKDF_SALT is the salt value; otherwise the salt is set to hashLen zero octets. (hashLen denotes the length of the hash function output in octets.) TEE_ATTR_HKDF_INFO If present, TEE_ATTR_HKDF_INFO is the info value; otherwise the info value is set to a zero length string. TEE_ATTR_HKDF_HASH_ALGORITHM If present, TEE_ATTR_HKDF_HASH_ALGORITHM SHALL be TEE_ALG_SHA256; otherwise TEE_ALG_SHA256 is used. TEE_ATTR_KDF_KEY_SIZE If present, TEE_ATTR_KDF_KEY_SIZE is the desired output length in octets; otherwise the maximum length of the derived key object converted to octets is used.	Any Simple Symmetric Key Type (see Table 5-10)

The derivedKey handle SHALL refer to an object with one of the types listed in Table 6-10 as an Output Key Type for the algorithm to be used.

The caller SHALL have set the private part of the operation DH key using the TEE_SetOperationKey function.

The caller SHALL pass the other party's public key as a parameter of the TEE_DeriveKey function.

On completion the derived key is placed into the TEE_ATTR_SECRET_VALUE attribute of the derivedKey handle.

In the case of TEE_ALG_SM2_KEP, the caller SHALL have set the long-term and ephemeral private key of the caller by using TEE_SetOperationKey2. The caller must provide additional attributes specifying role, ephemeral public key of other peer, and identifiers of both peers. Two roles exist, initiator and responder; one or both of the parties may confirm the Key Agreement result. The function computes and populates the TEE_ATTR_SM2_KEP_CONFIRMATION_OUT parameter, which the other peer will use as the TEE_ATTR_SM2_KEP_CONFIRMATION_IN parameter.

Note that in the case of TEE_ATTR_SM2_KEP_CONFIRMATION_OUT, the attribute structure maintains a pointer back to the caller-supplied buffer. It is the responsibility of the TA author to ensure that buffer is correctly sized and that the buffer pointed to remains valid until the attributes array is no longer in use.

Parameters

- operation: Handle on the operation, which SHALL have been suitably set up with an operation key
- params, paramCount: Operation parameters
- derivedKey: Handle on an uninitialized transient object to be filled with the derived key

Specification Number: 10 **Function Number:** 0x1201

Panic Reasons

- If `operation` is not a valid operation handle of class `TEE_OPERATION_KEY_DERIVATION`.
- If the object `derivedKey` is too small for the generated value.
- If no key is programmed in the operation.
- If a mandatory parameter is missing.
- If the operation mode is not `TEE_MODE_DERIVE`.
- Hardware or cryptographic algorithm failure
- If an optional algorithm which is not supported by the Trusted OS is passed in `TEE_OperationHandle`.
- If attribute `TEE_ATTR_SM2_KEP_CONFIRMATION_OUT` is present and is too small.
- If the implementation detects any other error.

Backward Compatibility

Versions of `TEE_DeriveKey` prior to TEE Internal Core API v1.2 used a different parameter annotation for `TEE_Attribute`.

Backward compatibility with a previous version of the Internal Core API can be selected at compile time (see section 3.5.1).

```
void TEE_DeriveKey(
        TEE_OperationHandle operation,
   [in] TEE_Attribute*      params, uint32_t paramCount,
        TEE_ObjectHandle    derivedKey );
```

6.9 Random Data Generation Function

6.9.1 TEE_GenerateRandom

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_GenerateRandom(
   [out] void*       randomBuffer,
         size_t      randomBufferLen );
```

Description

The `TEE_GenerateRandom` function generates random data.

Parameters

- `randomBuffer`: Reference to generated random data
- `randomBufferLen`: Byte length of requested random data

Specification Number: 10 **Function Number:** 0x1301

Panic Reasons

- Hardware or cryptographic algorithm failure
- If the implementation detects any other error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `randomBufferLen`.

6.10 Cryptographic Algorithms Specification

This section specifies the cryptographic algorithms, key types, and key parts supported in the Cryptographic Operations API.

Note that for the "NOPAD" symmetric algorithms, it is the responsibility of the TA to do the padding.

6.10.1 List of Algorithm Identifiers

Table 6-11 provides an exhaustive list of all algorithm identifiers specified in the Cryptographic Operations API. Normative references for the algorithms may be found in Annex C.

Implementations MAY define their own algorithms. Such algorithms SHALL have implementation-defined algorithm identifiers and these identifiers SHALL use `0xF0` as the most significant byte (i.e. they fall in the range `0xF0000000-0xF0FFFFFF`).

Note: Previous versions of this specification used bit-fields to construct the algorithm identifier values. Beginning with TEE Internal Core API v1.2, this is no longer the case and no special significance is given to the bit positions within algorithm identifier values.

Table 6-11: List of Algorithm Identifiers

Algorithm Identifier	Value
TEE_ALG_AES_ECB_NOPAD	0x10000010
TEE_ALG_AES_CBC_NOPAD	0x10000110
TEE_ALG_AES_CTR	0x10000210
TEE_ALG_AES_CTS	0x10000310
TEE_ALG_AES_XTS	0x10000410
TEE_ALG_AES_CBC_MAC_NOPAD	0x30000110
TEE_ALG_AES_CBC_MAC_PKCS5	0x30000510
TEE_ALG_AES_CMAC	0x30000610
TEE_ALG_AES_CCM	0x40000710
TEE_ALG_AES_GCM	0x40000810
TEE_ALG_DES_ECB_NOPAD	0x10000011
TEE_ALG_DES_CBC_NOPAD	0x10000111
TEE_ALG_DES_CBC_MAC_NOPAD	0x30000111
TEE_ALG_DES_CBC_MAC_PKCS5	0x30000511
TEE_ALG_DES3_ECB_NOPAD [5]	0x10000013
TEE_ALG_DES3_CBC_NOPAD	0x10000113
TEE_ALG_DES3_CBC_MAC_NOPAD	0x30000113
TEE_ALG_DES3_CBC_MAC_PKCS5	0x30000513
TEE_ALG_RSASSA_PKCS1_V1_5_MD5	0x70001830

[5] Triple DES SHALL be understood as Encrypt-Decrypt-Encrypt mode with two or three keys.

Algorithm Identifier	Value
TEE_ALG_RSASSA_PKCS1_V1_5_SHA1	0x70002830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA224	0x70003830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA256	0x70004830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA384	0x70005830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA512	0x70006830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_224	0x70007830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_256	0x70008830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_384	0x70009830
TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_512	0x7000A830
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA1	0x7020B930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA224	0x70313930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA256	0x70414930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA384	0x70515930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA512	0x70616930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_224	0x70818930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_256	0x70919930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_384	0x70A1A930
TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_512	0x70B1B930
TEE_ALG_RSAES_PKCS1_V1_5	0x60000130
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA1	0x60210230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA224	0x60310230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA256	0x60410230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA384	0x60510230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA512	0x60610230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA3_224	0x60810230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA3_256	0x60910230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA3_384	0x60A10230
TEE_ALG_RSAES_PKCS1_OAEP_MGF1_SHA3_512	0x60B10230
TEE_ALG_RSA_NOPAD	0x60000030
TEE_ALG_DSA_SHA1	0x70002131
TEE_ALG_DSA_SHA224	0x70003131
TEE_ALG_DSA_SHA256	0x70004131
TEE_ALG_DSA_SHA3_224	0x70008131
TEE_ALG_DSA_SHA3_256	0x70009131
TEE_ALG_DSA_SHA3_384	0x7000A131

Algorithm Identifier	Value
TEE_ALG_DSA_SHA3_512	0x7000B131
TEE_ALG_DH_DERIVE_SHARED_SECRET	0x80000032
TEE_ALG_MD5	0x50000001
TEE_ALG_SHA1	0x50000002
TEE_ALG_SHA224	0x50000003
TEE_ALG_SHA256	0x50000004
TEE_ALG_SHA384	0x50000005
TEE_ALG_SHA512	0x50000006
TEE_ALG_SHA3_224	0x50000008
TEE_ALG_SHA3_256	0x50000009
TEE_ALG_SHA3_384	0x5000000A
TEE_ALG_SHA3_512	0x5000000B
TEE_ALG_HMAC_MD5	0x30000001
TEE_ALG_HMAC_SHA1	0x30000002
TEE_ALG_HMAC_SHA224	0x30000003
TEE_ALG_HMAC_SHA256	0x30000004
TEE_ALG_HMAC_SHA384	0x30000005
TEE_ALG_HMAC_SHA512	0x30000006
TEE_ALG_HMAC_SM3 *	0x30000007
TEE_ALG_HMAC_SHA3_224	0x30000008
TEE_ALG_HMAC_SHA3_256	0x30000009
TEE_ALG_HMAC_SHA3_384	0x3000000A
TEE_ALG_HMAC_SHA3_512	0x3000000B
TEE_ALG_ECDSA_SHA1 *	0x70001042
TEE_ALG_ECDSA_SHA224 *	0x70002042
TEE_ALG_ECDSA_SHA256 *	0x70003042
TEE_ALG_ECDSA_SHA384 *	0x70004042
TEE_ALG_ECDSA_SHA512 *	0x70005042
TEE_ALG_ECDSA_SHA3_224 *	0x70006042
TEE_ALG_ECDSA_SHA3_256 *	0x70007042
TEE_ALG_ECDSA_SHA3_384 *	0x70008042
TEE_ALG_ECDSA_SHA3_512 *	0x70009042
TEE_ALG_ED25519 *	0x70006043
TEE_ALG_ED448 *	0x70006044
TEE_ALG_ECDH_DERIVE_SHARED_SECRET *	0x80000042

Algorithm Identifier	Value
TEE_ALG_X25519 *	0x80000044
TEE_ALG_X448 *	0x80000045
TEE_ALG_SM2_DSA_SM3 *	0x70006045
TEE_ALG_SM2_KEP *	0x60000045
TEE_ALG_SM2_PKE *	0x80000046
TEE_ALG_HKDF	0x80000047
TEE_ALG_SM3 *	0x50000007
TEE_ALG_SM4_ECB_NOPAD *	0x10000014
TEE_ALG_SM4_ECB_PKCS5 *	0x10000015
TEE_ALG_SM4_CBC_NOPAD *	0x10000114
TEE_ALG_SM4_CBC_PKCS5 *	0x10000115
TEE_ALG_SM4_CTR *	0x10000214
TEE_ALG_SHAKE128	0x50000101
TEE_ALG_SHAKE256	0x50000102
TEE_ALG_ILLEGAL_VALUE	0xEFFFFFFF
Reserved for implementation-defined algorithm identifiers	0xF0000000 – 0xF0FFFFFF
All other values are reserved.	

Algorithms flagged " * " are required in limited circumstances, as discussed in Table 6-2. For all other algorithms listed in Table 6-11, support is mandatory.

`TEE_ALG_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when provided to a cryptographic operation function.

Table 6-12: Structure of Algorithm Identifier or Object Type Identifier *[obsolete]*

Bits	Function	Values
This table existed in previous versions of the specification and was removed in v1.2.		

Table 6-12b: Algorithm Subtype Identifier *[obsolete]*

Value	Subtype
This table existed in previous versions of the specification and was removed in v1.2.	

6.10.2 Object Types

Object handles are a special class of algorithm handle.

Implementations MAY define their own object handles. Such handles SHALL have implementation-defined object type identifiers and these identifiers SHALL use `0xF0` as the most significant byte (i.e. they fall in the range `0xF0000000-0xF0FFFFFF`).

Note: Previous versions of this specification used bit-fields to construct the object type values. Beginning with TEE Internal Core API v1.2, this is no longer the case and no special significance is given to the bit positions within algorithm identifier values.

Table 6-13: List of Object Types

Name	Identifier
TEE_TYPE_AES	0xA0000010
TEE_TYPE_DES	0xA0000011
TEE_TYPE_DES3	0xA0000013
TEE_TYPE_HMAC_MD5	0xA0000001
TEE_TYPE_HMAC_SHA1	0xA0000002
TEE_TYPE_HMAC_SHA224	0xA0000003
TEE_TYPE_HMAC_SHA256	0xA0000004
TEE_TYPE_HMAC_SHA384	0xA0000005
TEE_TYPE_HMAC_SHA512	0xA0000006
TEE_TYPE_HMAC_SM3	0xA0000007
TEE_TYPE_HMAC_SHA3_224	0xA0000020
TEE_TYPE_HMAC_SHA3_256	0xA0000021
TEE_TYPE_HMAC_SHA3_384	0xA0000022
TEE_TYPE_HMAC_SHA3_512	0xA0000023
TEE_TYPE_RSA_PUBLIC_KEY	0xA0000030
TEE_TYPE_RSA_KEYPAIR	0xA1000030
TEE_TYPE_DSA_PUBLIC_KEY	0xA0000031
TEE_TYPE_DSA_KEYPAIR	0xA1000031
TEE_TYPE_DH_KEYPAIR	0xA1000032
TEE_TYPE_ECDSA_PUBLIC_KEY	0xA0000041
TEE_TYPE_ECDSA_KEYPAIR	0xA1000041
TEE_TYPE_ECDH_PUBLIC_KEY	0xA0000042
TEE_TYPE_ECDH_KEYPAIR	0xA1000042
TEE_TYPE_ED25519_PUBLIC_KEY	0xA0000043
TEE_TYPE_ED25519_KEYPAIR	0xA1000043
TEE_TYPE_X25519_PUBLIC_KEY	0xA0000044

Name	Identifier
TEE_TYPE_X25519_KEYPAIR	0xA1000044
TEE_TYPE_ED448_PUBLIC_KEY	0xA0000048
TEE_TYPE_ED448_KEYPAIR	0xA1000048
TEE_TYPE_X448_PUBLIC_KEY	0xA0000049
TEE_TYPE_X448_KEYPAIR	0xA1000049
TEE_TYPE_SM2_DSA_PUBLIC_KEY	0xA0000045
TEE_TYPE_SM2_DSA_KEYPAIR	0xA1000045
TEE_TYPE_SM2_KEP_PUBLIC_KEY	0xA0000046
TEE_TYPE_SM2_KEP_KEYPAIR	0xA1000046
TEE_TYPE_SM2_PKE_PUBLIC_KEY	0xA0000047
TEE_TYPE_SM2_PKE_KEYPAIR	0xA1000047
TEE_TYPE_SM4	0xA0000014
TEE_TYPE_HKDF	0xA000004A
TEE_TYPE_GENERIC_SECRET	0xA0000000
TEE_TYPE_CORRUPTED_OBJECT (deprecated)	0xA00000BE
TEE_TYPE_DATA	0xA00000BF
TEE_TYPE_ILLEGAL_VALUE	0xEFFFFFFF
Reserved for implementation-defined object handles	0xF0000000-0xF0FFFFFF
Reserved	All values not defined above.

Object types using implementation-specific algorithms are defined by the implementation.

TEE_TYPE_CORRUPTED_OBJECT is used solely in the deprecated TEE_GetObjectInfo function to indicate that the object on which it is being invoked has been corrupted in some way.

TEE_TYPE_DATA is used to represent objects which have no cryptographic attributes, just a data stream.

TEE_TYPE_ILLEGAL_VALUE is reserved for testing and validation and SHALL be treated as an undefined value when provided to a cryptographic operation function.

6.10.3 Optional Cryptographic Elements

This specification defines support for optional cryptographic elements as follows:

- NIST ECC curve definitions from [NIST Re Cur]
- BSI ECC curve definitions from [BSI TR 03111]
- Edwards ECC curve definitions from [X25519]
- SM2 curve definition from [SM2]

Identifiers that SHALL be used to identify optional cryptographic elements are listed in Table 6-14.

`TEE_CRYPTO_ELEMENT_NONE` is a special identifier which can be used when a function requires a value from Table 6-14, but no specific cryptographic element needs to be provided. The size parameter is not applicable for `TEE_CRYPTO_ELEMENT_NONE`.

For all elliptic curve elements, the size parameter represents the length, in bits, of the base field.

In this version of the specification, a conforming implementation can support none, some, or all of the cryptographic elements listed in Table 6-14. The `TEE_IsAlgorithmSupported` function (see section 6.2.9) is provided to enable applications to determine whether a specific curve definition is supported.

Table 6-14: List of Optional Cryptographic Elements

Name	Source	Generic	Identifier	Size
TEE_CRYPTO_ELEMENT_NONE	-	Y	0x00000000	-
TEE_ECC_CURVE_NIST_P192	NIST	Y	0x00000001	192 bits
TEE_ECC_CURVE_NIST_P224	NIST	Y	0x00000002	224 bits
TEE_ECC_CURVE_NIST_P256	NIST	Y	0x00000003	256 bits
TEE_ECC_CURVE_NIST_P384	NIST	Y	0x00000004	384 bits
TEE_ECC_CURVE_NIST_P521	NIST	Y	0x00000005	521 bits
Reserved for future NIST curves		–	0x00000006 – 0x000000FF	
TEE_ECC_CURVE_BSI_P160r1	BSI-R	Y	0x00000101	160 bits
TEE_ECC_CURVE_BSI_P192r1	BSI-R	Y	0x00000102	192 bits
TEE_ECC_CURVE_BSI_P224r1	BSI-R	Y	0x00000103	224 bits
TEE_ECC_CURVE_BSI_P256r1	BSI-R	Y	0x00000104	256 bits
TEE_ECC_CURVE_BSI_P320r1	BSI-R	Y	0x00000105	320 bits
TEE_ECC_CURVE_BSI_P384r1	BSI-R	Y	0x00000106	384 bits
TEE_ECC_CURVE_BSI_P512r1	BSI-R	Y	0x00000107	512 bits
Reserved for future BSI (R) curves		–	0x00000108 – 0x000001FF	
TEE_ECC_CURVE_BSI_P160t1	BSI-T	Y	0x00000201	160 bits
TEE_ECC_CURVE_BSI_P192t1	BSI-T	Y	0x00000202	192 bits
TEE_ECC_CURVE_BSI_P224t1	BSI-T	Y	0x00000203	224 bits
TEE_ECC_CURVE_BSI_P256t1	BSI-T	Y	0x00000204	256 bits
TEE_ECC_CURVE_BSI_P320t1	BSI-T	Y	0x00000205	320 bits

Name	Source	Generic	Identifier	Size
TEE_ECC_CURVE_BSI_P384t1	BSI-T	Y	0x00000206	384 bits
TEE_ECC_CURVE_BSI_P512t1	BSI-T	Y	0x00000207	512 bits
Reserved for future BSI (T) curves		–	0x00000208 – 0x000002FF	
TEE_ECC_CURVE_25519	IETF	N	0x00000300	256 bits
TEE_ECC_CURVE_448	IETF	N	0x00000301	448 bits
Reserved for future IETF curves		–	0x00000302 – 0x000003FF	
TEE_ECC_CURVE_SM2	OCTA	N	0x00000400	256 bits
Reserved for future curves defined by OCTA		–	0x00000401 – 0x000004FF	
Reserved for future use		–	0x00000500 – 0x7FFFFFFF	
Implementation defined		–	0x80000000 – 0xFFFFFFFF	

Backward Compatibility

If a Trusted OS supports **all** of the NIST curves defined in Table 6-14, the implementation SHALL return `true` to queries of the deprecated property `gpd.tee.cryptography.ecc` (see section B.4); otherwise it SHALL return `false` to such queries.

In TEE Internal Core API v1.2 and v1.2.1, `TEE_ECC_CURVE_25519` and `TEE_ECC_CURVE_SM2` were incorrectly assigned the same identifier.

6.11 Object or Operation Attributes

Table 6-15: Object or Operation Attributes

Name	Value	Protection	Type	Format (Table 6-16)	Comment
TEE_ATTR_SECRET_VALUE	0xC0000000	Protected	Ref	binary	Used for all secret keys for symmetric ciphers, MACs, and HMACs
TEE_ATTR_RSA_MODULUS	0xD0000130	Public	Ref	bignum	
TEE_ATTR_RSA_PUBLIC_EXPONENT	0xD0000230	Public	Ref	bignum	
TEE_ATTR_RSA_PRIVATE_EXPONENT	0xC0000330	Protected	Ref	bignum	
TEE_ATTR_RSA_PRIME1	0xC0000430	Protected	Ref	bignum	Usually referred to as *p*.
TEE_ATTR_RSA_PRIME2	0xC0000530	Protected	Ref	bignum	*q*
TEE_ATTR_RSA_EXPONENT1	0xC0000630	Protected	Ref	bignum	*dp*
TEE_ATTR_RSA_EXPONENT2	0xC0000730	Protected	Ref	bignum	*dq*
TEE_ATTR_RSA_COEFFICIENT	0xC0000830	Protected	Ref	bignum	*iq*
TEE_ATTR_DSA_PRIME	0xD0001031	Public	Ref	bignum	*p*
TEE_ATTR_DSA_SUBPRIME	0xD0001131	Public	Ref	bignum	*q*
TEE_ATTR_DSA_BASE	0xD0001231	Public	Ref	bignum	*g*
TEE_ATTR_DSA_PUBLIC_VALUE	0xD0000131	Public	Ref	bignum	*y*
TEE_ATTR_DSA_PRIVATE_VALUE	0xC0000231	Protected	Ref	bignum	*x*
TEE_ATTR_DH_PRIME	0xD0001032	Public	Ref	bignum	*p*
TEE_ATTR_DH_SUBPRIME	0xD0001132	Public	Ref	bignum	*q*
TEE_ATTR_DH_BASE	0xD0001232	Public	Ref	bignum	*g*
TEE_ATTR_DH_X_BITS	0xF0001332	Public	Value	int	ℓ
TEE_ATTR_DH_PUBLIC_VALUE	0xD0000132	Public	Ref	bignum	*y*
TEE_ATTR_DH_PRIVATE_VALUE	0xC0000232	Protected	Ref	bignum	*x*
TEE_ATTR_RSA_OAEP_LABEL	0xD0000930	Public	Ref	binary	
TEE_ATTR_RSA_PSS_SALT_LENGTH	0xF0000A30	Public	Value	int	
TEE_ATTR_ECC_PUBLIC_VALUE_X	0xD0000141	Public	Ref	bignum	
TEE_ATTR_ECC_PUBLIC_VALUE_Y	0xD0000241	Public	Ref	bignum	
TEE_ATTR_ECC_PRIVATE_VALUE	0xC0000341	Protected	Ref	bignum	d
TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_X	0xD0000146	Public	Ref	bignum	

Name	Value	Protection	Type	Format (Table 6-16)	Comment
TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_Y	0xD0000246	Public	Ref	bignum	
TEE_ATTR_ECC_CURVE	0xF0000441	Public	Value	int	Identifier value from Table 6-14
Since: TEE Internal Core API v1.3 – See Backward Compatibility note at end of section. TEE_ATTR_EDDSA_CTX	0xD0000643	Public	Ref	binary	Octet string, per algorithm definition in [Ed25519]
TEE_ATTR_ED25519_PUBLIC_VALUE	0xD0000743	Public	Ref	binary	
TEE_ATTR_ED25519_PRIVATE_VALUE	0xC0000843	Protected	Ref	binary	
TEE_ATTR_X25519_PUBLIC_VALUE	0xD0000944	Public	Ref	binary	Octet string, per algorithm definition in [X25519]
TEE_ATTR_X25519_PRIVATE_VALUE	0xC0000A44	Protected	Ref	binary	
TEE_ATTR_ED448_PUBLIC_VALUE	0xD0000002	Public	Ref	binary	Octet string, per algorithm definition in [Ed25519]
TEE_ATTR_ED448_PRIVATE_VALUE	0xC0000003	Protected	Ref	binary	
TEE_ATTR_EDDSA_PREHASH	0xF0000004	Public	Value	int	
TEE_ATTR_X448_PUBLIC_VALUE	0xD0000A45	Public	Ref	binary	Octet string, per algorithm definition in [X25519]
TEE_ATTR_X448_PRIVATE_VALUE	0xC0000A46	Protected	Ref	binary	
TEE_ATTR_SM2_ID_INITIATOR	0xD0000446	Public	Ref	binary	Octet string containing identifier of initiator
TEE_ATTR_SM2_ID_RESPONDER	0xD0000546	Public	Ref	binary	Octet string containing identifier of responder
TEE_ATTR_SM2_KEP_USER	0xF0000646	Public	value	int	zero means initiator role, non-zero means responder
TEE_ATTR_SM2_KEP_CONFIRMATION_IN	0xD0000746	Public	Ref	binary	Octet string containing value from other peer

Name	Value	Protection	Type	Format (Table 6-16)	Comment
TEE_ATTR_SM2_KEP_ CONFIRMATION_OUT	0xD0000846	Public	Ref	binary	Octet string containing value from the caller
TEE_ATTR_HKDF_SALT	0xD0000946	Public	Ref	binary	
TEE_ATTR_HKDF_INFO	0xD0000A46	Public	Ref	binary	
TEE_ATTR_HKDF_HASH_ALGORITHM	0xF0000B46	Public	Value	int	
TEE_ATTR_KDF_KEY_SIZE	0xF0000C46	Public	Value	int	
Implementation defined protected object or operation attribute	0xC0010000 - 0xC001FFFF	Protected	Ref		
Implementation defined public object or operation attribute	0xD0010000 - 0xD001FFFF	Public	Ref		
Implementation defined value attribute	0xF0010000 - 0xF001FFFF	Public	Value		
TEE_ATTR_ILLEGAL_PRIVATE_REF	0xCEFFFFFF	Protected	Ref		See note following table.
TEE_ATTR_ILLEGAL_PUBLIC_REF	0xDEFFFFFF	Public	Ref		
TEE_ATTR_ILLEGAL_VALUE	0xFEFFFFFF	Public	Value		
Reserved	All values not defined above.				

TEE_ATTR_ILLEGAL_PRIVATE_REF, TEE_ATTR_ILLEGAL_PUBLIC_REF, and TEE_ATTR_ILLEGAL_VALUE are reserved for testing and validation and each SHALL be treated as an undefined value when provided to a cryptographic operation function.

Table 6-16: Attribute Format Definitions

Format	Description
binary	An array of unsigned octets
bignum	An unsigned bignum in big-endian binary format. Leading zero bytes are allowed.
int	Values attributes represented in a single integer returned/read from argument a.

Additional attributes may be defined for use with implementation defined algorithms.

Implementer's Notes

Selected bits of the attribute identifiers are explained in the following table.

Table 6-17: Partial Structure of Attribute Identifier

Bit	Function	Values
Bit [29]	Defines whether the attribute is a buffer or value attribute	`0`: buffer attribute 1: value attribute
Bit [28]	Defines whether the attribute is protected or public	`0`: protected attribute 1: public attribute

A protected attribute cannot be extracted unless the object has the `TEE_USAGE_EXTRACTABLE` flag.

The following table defines constants that reflect setting bit [29] and bit [28], respectively, intended to help decode attribute identifiers.

Table 6-18: Attribute Identifier Flags

Name	Value
`TEE_ATTR_FLAG_VALUE`	`0x20000000`
`TEE_ATTR_FLAG_PUBLIC`	`0x10000000`

Backward Compatibility

TEE Internal Core API v1.3 deprecated redundant values that TEE Internal Core API v1.2 had assigned to selected attributes.

> The correct values of `TEE_ATTR_ECC_PUBLIC_VALUE_X`, `TEE_ATTR_ECC_PUBLIC_VALUE_Y`, and `TEE_ATTR_ECC_PRIVATE_VALUE` are shown in Table 6-15; the deprecated values are listed in Table B-4.

TEE Internal Core API v1.3 deprecated `TEE_ATTR_ED25519_PH`.

TEE Internal Core API v1.3 renamed `TEE_ATTR_ED25519_CTX` to `TEE_ATTR_EDDSA_CTX`.

7 Time API

This API provides access to three sources of time:

- ***System Time***
  - The origin of this system time is arbitrary and implementation-dependent. Different TA instances may even have different system times. The only guarantee is that the system time is not reset or rolled back during the life of a given TA instance, so it can be used to compute time differences and operation deadlines, for example. The system time SHALL NOT be affected by transitions through low power states.
  - System time is related to the function `TEE_Wait`, which waits for a given timeout or cancellation.
  - The level of trust that a Trusted Application can put on the system time is implementation defined but can be discovered programmatically by querying the implementation property `gpd.tee.systemTime.protectionLevel`. Typically, an implementation may rely on the REE timer (protection level 100) or on a dedicated secure timer hardware (protection level 1000).
  - System time SHALL advance within plus or minus15% of the passage of real time in the outside world including while the device is in low power states, to ensure that appropriate security levels are maintained when, for example, system time is used to implement dictionary attack protection. This accuracy also applies to timeout values where they are specified in individual routines.
- ***TA Persistent Time***, a real-time source of time
  - The origin of this time is set individually by each Trusted Application and SHALL persist across reboots.
  - The level of trust on the TA Persistent Time can be queried through the property `gpd.tee.TAPersistentTime.protectionLevel`.
- ***REE Time***
  - This is as trusted as the REE itself and may also be tampered by the user.

All time functions use a millisecond resolution and split the time in the two fields of the structure `TEE_Time`: one field for the seconds and one field for the milliseconds within this second.

7.1 Data Types

7.1.1 TEE_Time

Since: TEE Internal API v1.0

```
typedef struct
{
   uint32_t seconds;
   uint32_t millis;
} TEE_Time;
```

When used to return a time value, this structure can represent times up to 06:28:15 UTC on Sun, 7 February 2106.

7.2 Time Functions

7.2.1 TEE_GetSystemTime

Since: TEE Internal API v1.0

```
void TEE_GetSystemTime(
   [out] TEE_Time* time );
```

Description

The `TEE_GetSystemTime` function retrieves the current system time.

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.

Implementations are allowed to use the REE timers to implement this function but may also better protect the system time. A TA can discover the level of protection implementation by querying the implementation property `gpd.tee.systemTime.protectionLevel`. Possible values are listed in the following table.

Table 7-1: Values of the `gpd.tee.systemTime.protectionLevel` Property

Value	Meaning
`100`	System time based on REE-controlled timers. Can be tampered by the REE. The implementation SHALL still guarantee that the system time is monotonic, i.e. successive calls to `TEE_GetSystemTime` SHALL return increasing values of the system time.
`1000`	System time based on a TEE-controlled secure timer. The REE cannot interfere with the system time. It may still interfere with the scheduling of TEE tasks, but is not able to hide delays from a TA calling `TEE_GetSystemTime`.

Parameters

- `time`: Filled with the number of seconds and milliseconds since midnight on January 1, 1970, UTC

Specification Number: 10 **Function Number:** 0x1402

Panic Reasons

- If the implementation detects any error.

7.2.2 TEE_Wait

Since: TEE Internal API v1.0

```
TEE_Result TEE_Wait( uint32_t timeout );
```

Description

The `TEE_Wait` function waits for the specified number of milliseconds or waits forever if `timeout` equals `TEE_TIMEOUT_INFINITE` (`0xFFFFFFFF`).

When this function returns success, the implementation SHALL guarantee that the difference between two calls to `TEE_GetSystemTime` before and after the call to `TEE_Wait` is greater than or equal to the requested timeout. However, there may be additional implementation-dependent delays due to the scheduling of TEE tasks.

This function is cancellable, i.e. if the current task's cancelled flag is set and the TA has unmasked the effects of cancellation, then this function returns earlier than the requested timeout with the return code `TEE_ERROR_CANCEL`. See section 4.10 for more details about cancellations.

Parameters

- `timeout`: The number of milliseconds to wait, or `TEE_TIMEOUT_INFINITE`

Specification Number: 10 **Function Number:** 0x1405

Return Code

- `TEE_SUCCESS`: On success.
- `TEE_ERROR_CANCEL`: If the wait has been cancelled.

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

7.2.3 TEE_GetTAPersistentTime

Since: TEE Internal API v1.0

```
TEE_Result TEE_GetTAPersistentTime(
      [out] TEE_Time* time );
```

Description

The `TEE_GetTAPersistentTime` function retrieves the persistent time of the Trusted Application, expressed as a number of seconds and milliseconds since the arbitrary origin set by calling `TEE_SetTAPersistentTime`.

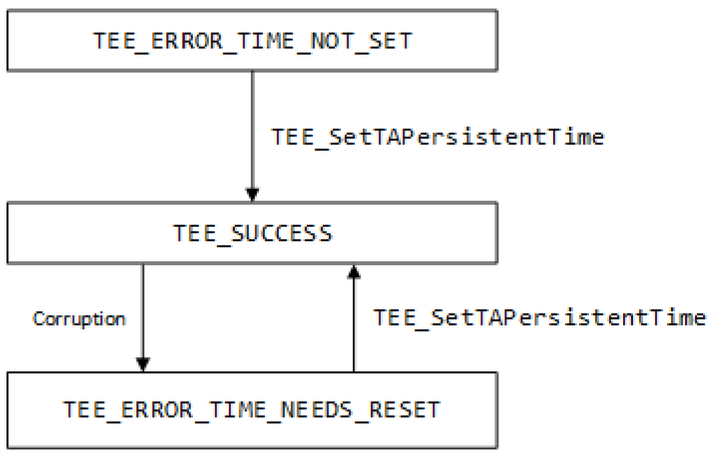
This function can return the following statuses (as well as other status values discussed in "Return Code"):

- `TEE_SUCCESS` means the persistent time is correctly set and has been retrieved into the parameter `time`.
- `TEE_ERROR_TIME_NOT_SET` is the initial status and means the persistent time has not been set. The Trusted Application SHALL set its persistent time by calling the function `TEE_SetTAPersistentTime`.
- `TEE_ERROR_TIME_NEEDS_RESET` means the persistent time has been set but may have been corrupted and SHALL no longer be trusted. In such a case it is recommended that the Trusted Application resynchronize the persistent time by calling the function `TEE_SetTAPersistentTime`. Until the persistent time has been reset, the status `TEE_ERROR_TIME_NEEDS_RESET` will always be returned.

Initially the time status is `TEE_ERROR_TIME_NOT_SET`. Once a Trusted Application has synchronized its persistent time by calling `TEE_SetTAPersistentTime`, the status can be `TEE_SUCCESS` or `TEE_ERROR_TIME_NEEDS_RESET`. Once the status has become `TEE_ERROR_TIME_NEEDS_RESET`, it will keep this status until the persistent time is re-synchronized by calling `TEE_SetTAPersistentTime`.

The following figure shows the state machine of the persistent time status.

Figure 7-1: Persistent Time Status State Machine



The meaning of the status `TEE_ERROR_TIME_NEEDS_RESET` depends on the protection level provided by the hardware implementation and the underlying real-time clock (RTC). This protection level can be queried by retrieving the implementation property `gpd.tee.TAPersistentTime.protectionLevel`, which can have one of the values listed in the following table.

Table 7-2: Values of the `gpd.tee.TAPersistentTime.protectionLevel` Property

Value	Meaning
`100`	Persistent time based on an REE-controlled real-time clock and on the TEE Trusted Storage for the storage of origins. The implementation SHALL guarantee that rollback of persistent time is detected to the fullest extent allowed by the Trusted Storage.
`1000`	Persistent time based on a TEE-controlled real-time clock and the TEE Trusted Storage. The real-time clock SHALL be out of reach of software attacks from the REE. Users may still be able to provoke a reset of the real-time clock but this SHALL be detected by the implementation.

The number of seconds in the TA Persistent Time may exceed the range of the `uint32_t` integer type. In this case, the function SHALL return the error `TEE_ERROR_OVERFLOW`, but still computes the TA Persistent Time as specified above, except that the number of seconds is truncated to 32 bits before being written to `time->seconds`. For example, if the Trusted Application sets its persistent time to 2^{32}-100 seconds, then after 100 seconds, the TA Persistent Time is 2^{32}, which is not representable with a `uint32_t`. In this case, the function `TEE_GetTAPersistentTime` SHALL return `TEE_ERROR_OVERFLOW` and set `time->seconds` to `0` (which is 2^{32} truncated to 32 bits).

Parameters

- `time`: A pointer to the `TEE_Time` structure to be set to the current TA Persistent Time. If an error other than `TEE_ERROR_OVERFLOW` is returned, this structure is filled with zeroes.

Specification Number: 10 **Function Number:** 0x1403

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_TIME_NOT_SET`
- `TEE_ERROR_TIME_NEEDS_RESET`
- `TEE_ERROR_OVERFLOW`: The number of seconds in the TA Persistent Time overflows the range of a `uint32_t`. The field `time->seconds` is still set to the TA Persistent Time truncated to 32 bits (i.e. modulo 2^{32}).
- `TEE_ERROR_OUT_OF_MEMORY`: If not enough memory is available to complete the operation

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

7.2.4 TEE_SetTAPersistentTime

Since: TEE Internal API v1.0

```
TEE_Result TEE_SetTAPersistentTime(
      [in] TEE_Time* time );
```

Description

The `TEE_SetTAPersistentTime` function sets the persistent time of the current Trusted Application.

Only the persistent time for the current Trusted Application is modified, not the persistent time of other Trusted Applications. This will affect all instances of the current Trusted Application. The modification is atomic and persistent across device reboots.

Parameters

- `time`: Filled with the persistent time of the current TA

Specification Number: 10 **Function Number:** 0x1404

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OUT_OF_MEMORY`: If not enough memory is available to complete the operation
- `TEE_ERROR_STORAGE_NO_SPACE`: If insufficient storage space is available to complete the operation

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

7.2.5 TEE_GetREETime

Since: TEE Internal API v1.0

```
void TEE_GetREETime(
   [out] TEE_Time* time );
```

Description

The `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, expressed in the number of seconds since midnight on January 1, 1970, UTC.

In normal operation, the value returned SHOULD correspond to the real time, but it SHOULD NOT be considered as trusted, as it may be tampered by the user or the REE software.

Parameters

- `time`: Filled with the number of seconds and milliseconds since midnight on January 1, 1970, UTC

Specification Number: 10 **Function Number:** 0x1401

Panic Reasons

- If the implementation detects any error.

8 TEE Arithmetical API

8.1 Introduction

All asymmetric cryptographic functions are implemented by using arithmetical functions, where operands are typically elements of finite fields or in mathematical structures containing finite field elements. The Cryptographic Operations API hides the complexity of the mathematics that is behind these operations. A developer who needs some cryptographic service does not need to know anything about the internal implementation.

However, in practice a developer may face the following difficulties: The API does not support the desired algorithm; or the API supports the algorithm, but with the wrong encodings, options, etc. The purpose of the TEE Arithmetical API is to provide building blocks so that the developer can implement missing asymmetric algorithms. In other words, the arithmetical API can be used to implement a plug-in into the Cryptographic Operations API. To ease the design of speed efficient algorithms, the arithmetical API also gives access to a Fast Modular Multiplication primitive, referred to as FMM.

This specification mandates that all functions within the TEE Arithmetical API SHALL work when input and output `TEE_BigInt` values are within the interval $[-2^M + 1, 2^M - 1]$ (limits included), where M is an implementation-defined number of bits. Every implementation SHALL ensure that M is at least 2048. The exact value of M can be retrieved as the implementation property `gpd.tee.arith.maxBigIntSize`.

Throughout this chapter:

- The notation “n-bit integer” refers to an integer that can take values in the range $[-2^n + 1, 2^n - 1]$, including limits.
- The notation “`magnitude(src)`” denotes the minimum number of required bits to represent the absolute value of the big integer `src` in a natural binary representation. The developer may query the magnitude of a big integer by using the function `TEE_BigIntGetBitCount(src)`, as described in section 8.7.5.

8.2 Error Handling and Parameter Checking

This low level arithmetical API performs very few checks on the parameters given to the functions. Most functions will return undefined results when called inappropriately but will not generate any error return codes.

Some functions in the API MAY work for inputs larger than indicated by the implementation property `gpd.tee.arith.maxBigIntSize`. This is however not guaranteed. When a function does not support a given bigInt size beyond this limit, it SHALL panic and not produce invalid results.

8.3 Data Types

This specification version has three data types for the arithmetical operations. These are `TEE_BigInt`, `TEE_BigIntFMM`, and `TEE_BigIntFMMContext`. Before using the arithmetic operations, the TA developer SHALL allocate and initialize the memory for the input and output operands This API provides entry points to determine the correct sizes of the needed memory allocations.

8.3.1 TEE_BigInt

The `TEE_BigInt` type is a placeholder for the memory structure of the TEE core internal representation of a large multi-precision integer.

Since: TEE Internal API v1.0

```
typedef uint32_t TEE_BigInt;
```

The following constraints are put on the internal representation of the `TEE_BigInt`:

1. The size of the representation SHALL be a multiple of 4 bytes.
2. The extra memory within the representation to store metadata SHALL NOT exceed 8 bytes.
3. The representation SHALL be stored 32-bit aligned in memory.

Exactly how a multi-precision integer is represented internally is implementation-specific but it SHALL be stored within a structure of the maximum size given by the macro `TEE_BigIntSizeInU32` (see section 8.4.1).

By defining a `TEE_BigInt` as a `uint32_t` for the TA, we allow the TA developer to allocate static space for multiple occurrences of `TEE_BigInt` at compile time which obey constraints 1 and 3. The allocation can be done with code similar to this:

```
uint32_t      twoints[2 * TEE_BigIntSizeInU32(1024)];
TEE_BigInt*  first  = twoints;
TEE_BigInt*  second = twoints + TEE_BigIntSizeInU32(1024);

/* Or if we do it dynamically */
TEE_BigInt* op1;
op1  = TEE_Malloc(TEE_BigIntSizeInU32(1024) * sizeof(TEE_BigInt),
                  TEE_MALLOC_NO_FILL | TEE_MALLOC_NO_SHARE);
/* use op1 */
TEE_Free(op1);
```

Conversions from an external representation to the internal `TEE_BigInt` representation and vice versa can be done by using functions from section 8.6.

Most functions in the TEE Arithmetical API take one or more `TEE_BigInt` pointers as parameters; for example, `func(TEE_BigInt *op1, TEE_BigInt *op2)`. When describing the parameters and what the function does, this specification will refer to the integer represented in the structure to which the pointer `op1` points, by simply writing `op1`. It will be clear from the context when the pointer value is referred to and when the integer value is referred to.

Since the internal representation of `TEE_BigInt` is implementation-specific, TA implementers SHALL pass the first address of a `TEE_BigInt` structure to functions that use them. A `TEE_BigInt` pointer that points to a location other than the start of a `TEE_BigInt` is a programmer error.

8.3.2 TEE_BigIntFMMContext

Usually, such a fast modular multiplication requires some additional data or derived numbers. That extra data is stored in a context that SHALL be passed to the fast modular multiplication function. The `TEE_BigIntFMMContext` is a placeholder for the TEE core internal representation of the context that is used in the fast modular multiplication operation.

Since: TEE Internal API v1.0

```
typedef uint32_t TEE_BigIntFMMContext;
```

The following constraints are put on the internal representation of the `TEE_BigIntFMMContext`:

1) The size of the representation SHALL be a multiple of 4 bytes.
2) The representation SHALL be stored 32-bit aligned in memory.

Exactly how this context is represented internally is implementation-specific but it SHALL be stored within a structure of the size given by the function `TEE_BigIntFMMContextSizeInU32` (see section 8.4.2).

Similarly to `TEE_BigInt`, we expose this type as a `uint32_t` to the TA, which helps `TEE_Malloc` to align the structure correctly when allocating space for a `TEE_BigIntFMMContext*`.

8.3.3 TEE_BigIntFMM

Some implementations may have support for faster modular multiplication algorithms such as Montgomery or Barrett multiplication for use in modular exponentiation. Typically, those algorithms require some transformation of the input before the multiplication can be carried out. The `TEE_BigIntFMM` is a placeholder for the memory structure that holds an integer in such a transformed representation.

Since: TEE Internal API v1.0

```
typedef uint32_t TEE_BigIntFMM;
```

The following constraints are put on the internal representation of the `TEE_BigIntFMM`:

1) The size of the representation SHALL be a multiple of 4 bytes.
2) The representation SHALL be stored 32-bit aligned in memory.

Exactly how this transformed representation is stored internally is implementation-specific but it SHALL be stored within a structure of the maximum size given by the function `TEE_BigIntFMMSizeInU32` (see section 8.4.3).

Similarly to `TEE_BigInt`, we expose this type as a `uint32_t` to the TA, which helps `TEE_Malloc` to align the structure correctly when allocating space for a `TEE_BigIntFMM*`.

8.4 Memory Allocation and Size of Objects

It is the responsibility of the Trusted Application to allocate and free memory for all TEE arithmetical objects, including all operation contexts, used in the Trusted Application. Once the arithmetical objects are allocated, the functions in the TEE Arithmetical API will never fail because of out-of-resources.

TEE implementer's note: Implementations of the TEE Arithmetical API SHOULD utilize memory from one or more pre-allocated pools to store intermediate results during computations to ensure that the functions do not fail because of lack of resources. All memory resources used internally SHALL be thread-safe. Such a pool of scratch memory could be:

- Internal memory of a hardware accelerator module
- Allocated from mutex protected system-wide memory
- Allocated from the heap of the TA instance, i.e. by using `TEE_Malloc` or `TEE_Realloc`

If the implementation uses a memory pool of temporary storage for intermediate results or if it uses hardware resources such as accelerators for some computations, the implementation SHALL either wait for the resource to become available or, for example in case of a busy hardware accelerator, resort to other means such as a software implementation.

8.4.1 TEE_BigIntSizeInU32

Since: TEE Internal API v1.0

```
#define TEE_BigIntSizeInU32(n) ((((n)+31)/32)+2)
```

Description

The `TEE_BigIntSizeInU32` macro calculates the size of the array of `uint32_t` values needed to represent an n-bit integer. This is defined as a macro (thereby mandating the maximum size of the internal representation) rather than as a function so that TA developers can use the macro in a static compile-time declaration of an array. Note that the implementation of the internal arithmetic functions assumes that memory pointed to by the `TEE_BigInt*` is 32-bit aligned.

Parameters

- n: maximum number of bits to be representable

8.4.2 TEE_BigIntFMMContextSizeInU32

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
size_t TEE_BigIntFMMContextSizeInU32( size_t modulusSizeInBits );
```

Description

The `TEE_BigIntFMMContextSizeInU32` function returns the size of the array of `uint32_t` values needed to represent a fast modular context using a given modulus size. This function SHALL never fail.

Parameters

- `modulusSizeInBits`: Size of modulus in bits

Specification Number: 10 **Function Number:** 0x1502

Return Value

Number of bytes needed to store a `TEE_BigIntFMMContext` given a modulus of length `modulusSizeInBits`.

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `modulusSizeInBits`.

8.4.3 TEE_BigIntFMMSizeInU32

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
size_t TEE_BigIntFMMSizeInU32( size_t modulusSizeInBits );
```

Description

The `TEE_BigIntFMMSizeInU32` function returns the size of the array of `uint32_t` values needed to represent an integer in the fast modular multiplication representation, given the size of the modulus in bits. This function SHALL never fail.

Normally from a mathematical point of view, this function would have needed the context to compute the exact required size. However, it is beneficial to have a function that does not take an initialized context as a parameter and thus the implementation may overstate the required memory size. It is nevertheless likely that a given implementation of the fast modular multiplication can calculate a very reasonable upper-bound estimate based on the modulus size.

Parameters

- `modulusSizeInBits`: Size of modulus in bits

Specification Number: 10 **Function Number:** 0x1501

Return Value

Number of bytes needed to store a `TEE_BigIntFMM` given a modulus of length `modulusSizeInBits`.

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `modulusSizeInBits`.

8.5 Initialization Functions

These functions initialize the arithmetical objects after the TA has allocated the memory to store them. The Trusted Application SHALL call the corresponding initialization function after it has allocated the memory for the arithmetical object.

8.5.1 TEE_BigIntInit

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_BigIntInit(
   [out]   TEE_BigInt  *bigInt,
           size_t      len );
```

Description

The `TEE_BigIntInit` function initializes `bigInt` and sets its represented value to zero. This function assumes that `bigInt` points to a memory area of `len uint32_t`. This can be done for example with the following memory allocation:

```
TEE_BigInt *a;
size_t len;
len = (size_t) TEE_BigIntSizeInU32(bitSize);
a = (TEE_BigInt*)TEE_Malloc(len*sizeof(TEE_BigInt), TEE_MALLOC_NO_FILL|TEE_MALLOC_NO_SHARE);
TEE_BigIntInit(a, len);
```

Parameters

- `bigInt`: A pointer to the `TEE_BigInt` to be initialized
- `len`: The size in `uint32_t` of the memory pointed to by `bigInt`

Specification Number: 10 **Function Number:** 0x1601

Panic Reasons

- If the implementation detects any error.
- If the provided value of `len` is larger than the number of bytes needed to represent `gpd.tee.arith.maxBigIntSize`.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `len`.

Versions prior to TEE Internal Core API v1.2 might not panic for large values of `len`.

8.5.2 TEE_BigIntInitFMMContext1

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_BigIntInitFMMContext1(
   [out]   TEE_BigIntFMMContext   *context,
           size_t                 len,
   [in]    TEE_BigInt             *modulus );
```

Description

This function replaces the `TEE_BigIntInitFMMContext` function, whose use is deprecated.

The `TEE_BigIntInitFMMContext1` function calculates the necessary prerequisites for the fast modular multiplication and stores them in a context. This function assumes that `context` points to a memory area of `len uint32_t`. This can be done for example with the following memory allocation:

```
TEE_BigIntFMMContext* ctx;
size_t len = (size_t) TEE_BigIntFMMContextSizeInU32(bitsize);
ctx=(TEE_BigIntFMMContext *)TEE_Malloc(len * sizeof(TEE_BigIntFFMContext),
                                       TEE_MALLOC_NO_FILL | TEE_MALLOC_NO_SHARE);
/*Code for initializing modulus*/
…
TEE_BigIntInitFMMContext1(ctx, len, modulus);
```

Even though a fast multiplication might be mathematically defined for any modulus, normally there are restrictions in order for it to be fast on a computer. This specification mandates that all implementations SHALL work for all odd moduli larger than 2 and less than 2 to the power of the implementation defined property `gpd.tee.arith.maxBigIntSize`.

It is not required that even moduli be supported. Common usage of this function will not make use of even moduli and so for performance reasons a technique without full even moduli support MAY be used. For this reason, partial or complete even moduli support are optional, and if an implementation will not be able to provide a result for a specific case of even moduli then it shall return TEE_ERROR_NOT_SUPPORTED.

Parameters

- `context`: A pointer to the `TEE_BigIntFMMContext` to be initialized
- `len`: The size in `uint32_t` of the memory pointed to by `context`
- `modulus`: The modulus, an odd integer larger than 2 and less than 2 to the power of `gpd.tee.arith.maxBigIntSize`

Specification Number: 10 **Function Number:** 0x1604

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_NOT_SUPPORTED`: The underlying implementation is unable to perform the operation on a particular modulus value. This may only be returned for even moduli inside the valid range, outside that range the described PANIC will occur.

Panic Reasons

- If the implementation detects any error.
- If the provided value of `modulus` is either less than two, or larger than or equal to 2^ `gpd.tee.arith.maxBigIntSize.`

8.5.3 TEE_BigIntInitFMM

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_BigIntInitFMM(
   [in]    TEE_BigIntFMM     *bigIntFMM,
           size_t            len );
```

Description

The `TEE_BigIntInitFMM` function initializes `bigIntFMM` and sets its represented value to zero. This function assumes that `bigIntFMM` points to a memory area of `len` `uint32_t`. This can be done for example with the following memory allocation:

```
TEE_BigIntFMM *a;
size_t len;
len = (size_t) TEE_BigIntFMMSizeInU32(modulusSizeinBits);
a = (TEE_BigIntFMM *)TEE_Malloc(len * sizeof(TEE_BigIntFMM),
                                TEE_MALLOC_NO_FILL | TEE_MALLOC_NO_SHARE );
TEE_BigIntInitFMM(a, len);
```

Parameters

- `bigIntFMM`: A pointer to the `TEE_BigIntFMM` to be initialized
- `len`: The size in `uint32_t` of the memory pointed to by `bigIntFMM`

Specification Number: 10 **Function Number:** 0x1602

Panic Reasons

- If the implementation detects any error.
- If the provided value of `len` is larger than the number of bytes needed to represent `gpd.tee.arith.maxBigIntSize`.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `len`.

Versions prior to TEE Internal Core API v1.2 might not panic for large values of `len`.

8.6 Converter Functions

TEE_BigInt contains the internal representation of a multi-precision integer. However, in many use cases some integer data comes from external sources or integers; for example, a local device gets an ephemeral Diffie-Hellman public key during a key agreement procedure. In this case the ephemeral key is expected to be in octet string format, which is a big-endian radix 256 representation for unsigned numbers. For example 0x123456789abcdef has the following octet string representation:

```
{0x01, 0x23, 0x45, 0x67, 0x89, 0xab, 0xcd, 0xef}
```

This section provides functions to convert to and from such alternative representations.

8.6.1 TEE_BigIntConvertFromOctetString

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_BigIntConvertFromOctetString(
   [out]    TEE_BigInt *dest,
   [inbuf]  uint8_t    *buffer, size_t bufferLen,
            int32_t     sign );
```

Description

The TEE_BigIntConvertFromOctetString function converts a bufferLen byte octet string buffer into a TEE_BigInt format. The octet string is in most significant byte first representation. The input parameter sign will set the sign of dest. It will be set to negative if sign < 0 and to positive if sign >= 0.

Parameters

- dest: Pointer to a TEE_BigInt to hold the result
- buffer: Pointer to the buffer containing the octet string representation of the integer
- bufferLen: The length of *buffer in bytes
- sign: The sign of dest is set to the sign of sign.

Specification Number: 10 **Function Number:** 0x1701

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_OVERFLOW: If memory allocation for the dest is too small

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for bufferLen.

8.6.2 TEE_BigIntConvertToOctetString

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
TEE_Result TEE_BigIntConvertToOctetString(
   [outbuf]    void*         buffer, size_t *bufferLen,
   [in]        TEE_BigInt   *bigInt );
```

Description

The `TEE_BigIntConvertToOctetString` function converts the absolute value of an integer in `TEE_BigInt` format into an octet string. The octet string is written in a most significant byte first representation.

Parameters

- `buffer`, `bufferLen`: Output buffer where converted octet string representation of the integer is written
- `bigInt`: Pointer to the integer that will be converted to an octet string

Specification Number: 10 **Function Number:** 0x1703

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is too small to contain the octet string

Panic Reasons

- If the Implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `bufferLen`.

8.6.3 TEE_BigIntConvertFromS32

Since: TEE Internal Core API v1.2 – See Backward Compatibility statement below.

```
void TEE_BigIntConvertFromS32(
   [out]   TEE_BigInt  *dest,
           int32_t     shortVal);
```

Description

The `TEE_BigIntConvertFromS32` function sets `*dest` to the value `shortVal`.

Parameters

- `dest`: Pointer to the start of an array reference by `TEE_BigInt *` into which the result is stored.
- `shortVal`: Input value

Specification Number: 10 **Function Number:** 0x1702

Result Size

The result SHALL point to a memory allocation which is at least large enough for holding a 32-bit signed value in a `TEE_BigInt` structure.

Panic Reasons

- If the memory pointed to by `dest` has not been initialized as a `TEE_BigInt` capable of holding at least a 32-bit value.
- If the implementation detects any error.

Backward Compatibility

Versions prior to TEE Internal Core API v1.2 did not include the clarification of panic due to an uninitialized `dest` pointer.

8.6.4 TEE_BigIntConvertToS32

Since: TEE Internal API v1.0

```
TEE_Result TEE_BigIntConvertToS32(
   [out]   int32_t     *dest,
   [in]    TEE_BigInt  *src );
```

Description

The `TEE_BigIntConvertToS32` function sets `*dest` to the value of `src`, including the sign of `src`. If `src` does not fit within an `int32_t`, the value of `*dest` is undefined.

Parameters

- `dest`: Pointer to an `int32_t` to store the result
- `src`: Pointer to the input value

Specification Number: 10 **Function Number:** 0x1704

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OVERFLOW`: If `src` does not fit within an `int32_t`

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

8.7 Logical Operations

8.7.1 TEE_BigIntCmp

Since: TEE Internal API v1.0

```
int32_t TEE_BigIntCmp(
    [in]  TEE_BigInt *op1,
    [in]  TEE_BigInt *op2 );
```

Description

The `TEE_BigIntCmp` function checks whether `op1` > op2, `op1` == op2, or `op1` < op2.

Parameters

- `op1`: Pointer to the first operand
- op2: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1801

Return Value

A negative number if `op1` < op2; `0` if `op1` == op2; and a positive number if `op1` > op2.

Panic Reasons

- If the implementation detects any error.

8.7.2 TEE_BigIntCmpS32

Since: TEE Internal API v1.0

```
int32_t TEE_BigIntCmpS32(
   [in]    TEE_BigInt  *op,
           int32_t     shortVal );
```

Description

The `TEE_BigIntCmpS32` function checks whether op > `shortVal`, op == `shortVal`, or op < `shortVal`.

Parameters

- op: Pointer to the first operand
- `shortVal`: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1802

Return Value

A negative number if op < `shortVal`; `0` if op == `shortVal`; and a positive number if op > `shortVal`.

Panic Reasons

- If the implementation detects any error.

8.7.3 TEE_BigIntShiftRight

Since: TEE Internal Core API v1.1.1 – See Backward Compatibility note below.

```
void TEE_BigIntShiftRight(
   [out]   TEE_BigInt  *dest,
   [in]    TEE_BigInt  *op
           size_t      bits );
```

Description

The `TEE_BigIntShiftRight` function computes `|dest| = |op| >> bits` and `dest` will have the same sign as `op`.[6] If `bits` is greater than the bit length of `op` then the result is zero. `dest` and `op` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the shifted result
- op: Pointer to the operand to be shifted
- `bits`: Number of bits to shift

Specification Number: 10 **Function Number:** 0x1805

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for `bits`.

[6] The notation `|x|` means the absolute value of `x`.

8.7.4 TEE_BigIntGetBit

Since: TEE Internal API v1.0

```
bool TEE_BigIntGetBit(
    [in] TEE_BigInt  *src,
         uint32_t    bitIndex );
```

Description

The `TEE_BigIntGetBit` function returns the `bitIndex`th bit of the natural binary representation of `|src|`. A `true` return value indicates a "1" and a `false` return value indicates a "`0`" in the `bitIndex`th position. If `bitIndex` is larger than the number of bits in op, the return value is `false`, thus indicating a "`0`".

Parameters

- `src`: Pointer to the integer
- `bitIndex`: The offset of the bit to be read, starting at offset `0` for the least significant bit

Specification Number: 10 **Function Number:** 0x1803

Return Value

The Boolean value of the `bitIndex`th bit in `|src|`. `True` represents a "1" and `false` represents a "`0`".

Panic Reasons

- If the implementation detects any error.

8.7.5 TEE_BigIntGetBitCount

Since: TEE Internal API v1.0

```
uint32_t TEE_BigIntGetBitCount(
    [in] TEE_BigInt  *src );
```

Description

The `TEE_BigIntGetBitCount` function returns the number of bits in the natural binary representation of `|src|`; that is, the magnitude of `src`.

Parameters

- `src`: Pointer to the integer

Specification Number: 10 **Function Number:** 0x1804

Return Value

The number of bits in the natural binary representation of `|src|`. If `src` equals zero, it will return `0`.

Panic Reasons

- If the implementation detects any error.

8.7.6 TEE_BigIntSetBit

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_BigIntSetBit(
   [inout] TEE_BigInt          *op,
           uint32_t            bitIndex,
           bool                value);
```

Description

The TEE_BigIntSetBit function sets the bitIndexth bit of the natural binary representation of |op| to 1 or 0, depending on the parameter value. If value is true the bit will be set, and if value is false the bit will be cleared. If bitIndex is larger than the number of bits in op, the function will return an overflow error.

Parameters

- op: Pointer to the integer
- bitIndex: The offset of the bit to be set, starting at offset 0 for the least significant bit.
- value: The bit value to set where true represents a "1" and false represents a "0".

Specification Number: 10 **Function Number:** 0x1806

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_OVERFLOW: If the bitIndexth bit is larger than allocated bit length of op

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

8.7.7 TEE_BigIntAssign

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_BigIntAssign(
   [out] TEE_BigInt        *dest,
    [in]  TEE_BigInt        *src);
```

Description

The `TEE_BigIntAssign` function assigns the value of `src` to `dest`. The parameters `src` and `dest` MAY point within the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to be assigned.
- `src`: Pointer to the source operand.

Specification Number: 10 **Function Number:** 0x1807

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OVERFLOW`: In case the `dest` operand cannot hold the value of `src`

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

8.7.8 TEE_BigIntAbs

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_BigIntAbs(
   [out] TEE_BigInt        *dest,
    [in]  TEE_BigInt        *src);
```

Description

The `TEE_BigIntAbs` function assigns the value of `|src|` to `dest`. The parameters `src` and `dest` MAY point within the same memory region but SHALL point to the start address of a `TEE_BigInt.`

Parameters

- `dest`: Pointer to `TEE_BigInt` to be assigned.
- `src`: Pointer to the source operand.

Specification Number: 10 **Function Number:** 0x1808

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OVERFLOW`: In case the `dest` operand cannot hold the value of `|src|`

Panic Reasons

- If the implementation detects any error associated with this function that is not explicitly associated with a defined return code for this function.

8.8 Basic Arithmetic Operations

This section describes basic arithmetical operations addition, subtraction, negation, multiplication, squaring, and division.

8.8.1 TEE_BigIntAdd

Since: TEE Internal API v1.0

```
void TEE_BigIntAdd(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntAdd` function computes `dest` = op1 + op2. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to store the result op1 + op2
- op1: Pointer to the first operand
- op2: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1901

Result Size

Depending on the sign of `op1` and `op2`, the result may be larger or smaller than `op1` and `op2`. For the worst case, `dest` SHALL have memory allocation for holding `max(magnitude(op1), magnitude(op2)) + 1` bits.[7]

Panic Reasons

- If the implementation detects any error.

[7] The magnitude function is defined in section 8.7.5.

8.8.2 TEE_BigIntSub

Since: TEE Internal API v1.0

```
void TEE_BigIntSub(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntSub` function computes `dest` = `op1` – `op2`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to store the result `op1 – op2`
- op1: Pointer to the first operand
- op2: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1906

Result Size

Depending on the sign of `op1` and `op2`, the result may be larger or smaller than `op1` and `op2`. For the worst case, the result SHALL have memory allocation for holding `max(magnitude(op1), magnitude(op2))` + `1` bits.

Panic Reasons

- If the implementation detects any error.

8.8.3 TEE_BigIntNeg

Since: TEE Internal API v1.0

```
void TEE_BigIntNeg(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op );
```

Description

The `TEE_BigIntNeg` function negates an operand: `dest` = `-op`. `dest` and `op` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to store the result `-op`
- op: Pointer to the operand to be negated

Specification Number: 10 **Function Number:** 0x1904

Result Size

The result SHALL have memory allocation for `magnitude(op)` bits.

Panic Reasons

- If the implementation detects any error.

8.8.4 TEE_BigIntMul

Since: TEE Internal API v1.0

```
void TEE_BigIntMul(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntMul` function computes `dest` = `op1 * op2`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to store the result `op1 * op2`
- op1: Pointer to the first operand
- op2: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1903

Result Size

The result SHALL have memory allocation for `(magnitude(op1)` + `magnitude(op2))` bits.

Panic Reasons

- If the implementation detects any error.

8.8.5 TEE_BigIntSquare

Since: TEE Internal API v1.0

```
void TEE_BigIntSquare(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op );
```

Description

The `TEE_BigIntSquare` function computes `dest` = `op * op`. `dest` and `op` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to store the result `op * op`
- op: Pointer to the operand to be squared

Specification Number: 10 **Function Number:** 0x1905

Result Size

The result SHALL have memory allocation for `2*magnitude(op)` bits.

Panic Reasons

- If the implementation detects any error.

8.8.6 TEE_BigIntDiv

Since: TEE Internal API v1.0

```
void TEE_BigIntDiv(
   [out]   TEE_BigInt *dest_q,
   [out]   TEE_BigInt *dest_r,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntDiv` function computes `dest_r` and `dest_q` such that op1 = `dest_q` * op2 + `dest_r`. It will round `dest_q` towards zero and `dest_r` will have the same sign as op1. Example:

op1	op2	dest_q	dest_r	Expression
53	7	7	4	53 = 7*7 + 4
-53	7	-7	-4	-53 = (-7)*7 + (-4)
53	-7	-7	+4	53 = (-7)*(-7) + 4
-53	-7	7	-4	-53 = 7*(-7) + (-4)

To call `TEE_BigIntDiv` with op2 equal to zero is considered a programming error and will cause the Trusted Application to panic.

The memory pointed to by `dest_q` and `dest_r` SHALL NOT overlap. However, it is possible that `dest_q` == op1, `dest_q` == op2, `dest_r` == op1, `dest_r` == op2, when `dest_q` and `dest_r` do not overlap. If a `NULL` pointer is passed for either `dest_q` or `dest_r`, the implementation MAY take advantage of the fact that it is only required to calculate either `dest_q` or `dest_r`.

Parameters

- `dest_q`: Pointer to a `TEE_BigInt` to store the quotient. `dest_q` can be `NULL`.
- `dest_r`: Pointer to a `TEE_BigInt` to store the remainder. `dest_r` can be `NULL`.
- op1: Pointer to the first operand, the dividend
- op2: Pointer to the second operand, the divisor

Specification Number: 10 **Function Number:** 0x1902

Result Sizes

The quotient, `dest_q`, SHALL have memory allocation sufficient to hold a `TEE_BigInt` with magnitude:

- `0` if `|op1| <= |op2|` and
- `magnitude(op1) - magnitude(op2)` if `|op1| > |op2|`.

The remainder `dest_r` SHALL have memory allocation sufficient to hold a `TEE_BigInt` with `magnitude(op2)` bits.

Panic Reasons

- If op2 == `0`
- If the implementation detects any other error.

8.9 Modular Arithmetic Operations

To reduce the number of tests the modular functions needs to perform on entrance and to speed up the performance, all modular functions (except `TEE_BigIntMod`) assume that input operands are normalized, i.e. non-negative and smaller than the modulus, and the modulus SHALL be greater than one, otherwise it is a Programmer Error and the behavior of these functions are undefined. This normalization can be done by using the reduction function in section 8.9.1.

8.9.1 TEE_BigIntMod

Since: TEE Internal API v1.0

```
void TEE_BigIntMod(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op,
   [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntMod` function computes `dest = op (mod n)` such that `0 <= dest < n`. `dest` and `op` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region. For negative `op` the function follows the normal convention that `-1 = (n-1) mod n`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `op (mod n)`. The result `dest` will be in the interval `[0, n-1]`.
- op: Pointer to the operand to be reduced `mod n`
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A03

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.[8]

Panic Reasons

- If `n < 2`
- If the implementation detects any other error.

[8] The magnitude function is defined in section 8.7.5.

8.9.2 TEE_BigIntAddMod

Since: TEE Internal API v1.0

```
void TEE_BigIntAddMod(
    [out]   TEE_BigInt *dest,
    [in]    TEE_BigInt *op1,
    [in]    TEE_BigInt *op2,
    [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntAddMod` function computes `dest = (op1 + op2) (mod n)`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op1 + op2) (mod n)`
- op1: Pointer to the first operand. Operand SHALL be in the interval `[0,n-1]`.
- op2: Pointer to the second operand. Operand SHALL be in the interval `[0,n-1]`.
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A01

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n < 2`
- If the implementation detects any other error.

8.9.3 TEE_BigIntSubMod

Since: TEE Internal API v1.0

```
void TEE_BigIntSubMod(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2,
   [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntSubMod` function computes `dest = (op1 - op2) (mod n)`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op1 - op2) (mod n)`
- op1: Pointer to the first operand. Operand SHALL be in the interval `[0,n-1]`.
- op2: Pointer to the second operand. Operand SHALL be in the interval `[0,n-1]`.
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A06

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n < 2`
- If the implementation detects any other error.

8.9.4 TEE_BigIntMulMod

Since: TEE Internal API v1.0

```
void TEE_BigIntMulMod(
    [out]   TEE_BigInt *dest,
    [in]    TEE_BigInt *op1,
    [in]    TEE_BigInt *op2,
    [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntMulMod` function computes `dest = (op1 * op2) (mod n)`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op1 * op2) (mod n)`
- op1: Pointer to the first operand. Operand SHALL be in the interval `[0,n-1]`.
- op2: Pointer to the second operand. Operand SHALL be in the interval `[0,n-1]`.
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A04

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n < 2`
- If the implementation detects any other error.

8.9.5 TEE_BigIntSquareMod

Since: TEE Internal API v1.0

```
void TEE_BigIntSquareMod(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op,
   [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntSquareMod` function computes `dest = (op * op) (mod n)`. `dest` and `op1` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op * op) (mod n)`
- op: Pointer to the operand. Operand SHALL be in the interval `[0,n-1]`.
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A05

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n < 2`
- If the implementation detects any other error.

8.9.6 TEE_BigIntInvMod

Since: TEE Internal API v1.0

```
void TEE_BigIntInvMod(
   [out]   TEE_BigInt *dest,
   [in]    TEE_BigInt *op,
   [in]    TEE_BigInt *n );
```

Description

The `TEE_BigIntInvMod` function computes `dest` such that `dest` * op = `1` `(mod n)`. `dest` and `op` `MAY` point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. This function assumes that `gcd(op,n)` is equal to `1`, which can be checked by using the function in section 8.10.1. If `gcd(op,n)` is greater than `1`, then the result is unreliable.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op^-1) (mod n)`
- op: Pointer to the operand. Operand SHALL be in the interval `[1,n-1]`.
- n: Pointer to the modulus. Modulus SHALL be larger than `1`.

Specification Number: 10 **Function Number:** 0x1A02

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n < 2`
- If `op = 0`
- If the implementation detects any other error.

8.9.7 TEE_BigIntExpMod

Since: TEE Internal Core API v1.2

```
TEE_Result TEE_BigIntExpMod(
   [out]   TEE_BigInt           *dest,
   [in]    TEE_BigInt           *op1,
   [in]    TEE_BigInt           *op2,
   [in]    TEE_BigInt           *n,
   [in]    TEE_BigIntFMMContext *context );
```

Description

The `TEE_BigIntExpMod` function computes `dest = (op1 ^ op2) (mod n)`. All or some of `dest`, `op1`, and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. The value `n` SHALL point to a unique memory region. In order to utilize the FMM capabilities, a pre-computed `TEE_BigIntFMMContext1` MAY be supplied. The `context` parameter MAY be `NULL`. If it is not `NULL`, the `context` SHALL be initialized using the same modulus `n` as provided as parameter.

Even though a fast multiplication might be mathematically defined for any modulus, normally there are restrictions in order for it to be fast on a computer. This specification mandates that all implementations SHALL work for all odd moduli larger than 2 and less than 2 to the power of the implementation defined property `gpd.tee.arith.maxBigIntSize`.

It is not required that even moduli be supported. Common usage of this function will not make use of even moduli and so for performance reasons a technique without full even moduli support MAY be used. For this reason, partial or complete even moduli support are optional, and if an implementation will not be able to provide a result for a specific case of even moduli then it shall return `TEE_ERROR_NOT_SUPPORTED`.

Parameters

- `dest`: Pointer to `TEE_BigInt` to hold the result `(op1 ^ op2) (mod n)`
- op1: Pointer to the first operand. Operand SHALL be in the interval `[0,n-1]`.
- op2: Pointer to the second operand. Operand SHALL be non-negative.
- n: Pointer to the modulus. Modulus SHALL be an odd integer larger than 2 and less than 2 to the power of `gpd.tee.arith.maxBigIntSize`.
- `context`: Pointer to a context previously initialized using `TEE_BigIntInitFMMContext1`, or `NULL`.

Specification Number: 10 **Function Number:** 0x1A07

Return Code

- `TEE_SUCCESS` if the value of n is supported for this operation.
- `TEE_ERROR_NOT_SUPPORTED` if the value of n is not supported.

Result Size

The result `dest` SHALL have memory allocation for `magnitude(n)` bits.

Panic Reasons

- If `n <= 2`
- If the implementation detects any other error.

8.10 Other Arithmetic Operations

8.10.1 TEE_BigIntRelativePrime

Since: TEE Internal API v1.0

```
bool TEE_BigIntRelativePrime(
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntRelativePrime` function determines whether `gcd(op1, op2) == 1`. `op1` and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`.

Parameters

- op1: Pointer to the first operand
- op2: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1B03

Return Value

- `true` if `gcd(op1, op2) == 1`
- `false` otherwise

8.10.2 TEE_BigIntComputeExtendedGcd

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
void TEE_BigIntComputeExtendedGcd(
   [out]   TEE_BigInt *gcd,
   [out]   TEE_BigInt *u,
   [out]   TEE_BigInt *v,
   [in]    TEE_BigInt *op1,
   [in]    TEE_BigInt *op2 );
```

Description

The `TEE_BigIntComputeExtendedGcd` function computes the greatest common divisor of the input parameters `op1` and `op2`. `op1` and `op2` SHALL NOT both be zero. Furthermore it computes coefficients `u` and `v` such that `u * op1 + v * op2 == gcd`. `op1` and `op2` MAY point to the same memory region but SHALL point to the start address of a `TEE_BigInt`. `u`, `v`, or both can be `NULL`. If both are `NULL`, then the function only computes the gcd of `op1` and `op2`.

Parameters

- `gcd`: Pointer to `TEE_BigInt` to hold the greatest common divisor of `op1` and `op2`
- `u`: Pointer to `TEE_BigInt` to hold the first coefficient
- `v`: Pointer to `TEE_BigInt` to hold the second coefficient
- `op1`: Pointer to the first operand
- `op2`: Pointer to the second operand

Specification Number: 10 **Function Number:** 0x1B01

Result Sizes

- The `gcd` result SHALL be able to hold `max(magnitude(op1), magnitude(op2))` bits.[9]
- If `op1 != 0` and `op2 != 0`, then `|u| < |op2/gcd|` and `|v| < |op1/gcd|`.[10]
- If `op1 != 0` and `op2 = 0`, then `v = 0`.
- If `op2 != 0` and `op1 = 0`, then `u = 0`.

Panic Reasons

- If `op1` and `op2` are both zero.
- If the implementation detects any other error.

Backward Compatibility

Versions prior to TEE Internal Core API v1.2 did not make it explicit that setting both `op1` and `op2` to zero is illegal. Behavior of older versions in this case is therefore undefined.

[9] The magnitude function is defined in section 8.7.5.

[10] The notation `|x|` means the absolute value of `x`.

8.10.3 TEE_BigIntIsProbablePrime

Since: TEE Internal API v1.0

```
int32_t TEE_BigIntIsProbablePrime(
     [in] TEE_BigInt *op,
          uint32_t    confidenceLevel );
```

Description

The TEE_BigIntIsProbablePrime function performs a probabilistic primality test on op. The parameter confidenceLevel is used to specify the probability of a non-conclusive answer. If the function cannot guarantee that op is prime or composite, it SHALL iterate the test until the probability that op is composite is less than 2^(-confidenceLevel). Values smaller than 80 for confidenceLevel will not be recognized and will default to 80. The maximum honored value of confidenceLevel is implementation-specific, but SHALL be at least 80.

The algorithm for performing the primality test is implementation-specific, but its correctness and efficiency SHALL be equal to or better than the Miller-Rabin test.

Parameters

- op: Candidate number that is tested for primality
- confidenceLevel: The desired confidence level for a non-conclusive test. This parameter (usually) maps to the number of iterations and thus to the running time of the test. Values smaller than 80 will be treated as 80.

Specification Number: 10 **Function Number:** 0x1B02

Return Value

- 0: If op is a composite number
- 1: If op is guaranteed to be prime
- -1: If the test is non-conclusive but the probability that op is composite is less than 2^(-confidenceLevel)

Panic Reasons

- If the implementation detects any error.

8.11 Fast Modular Multiplication Operations

This part of the API allows the implementer of the TEE Internal Core API to give the TA developer access to faster modular multiplication routines, possibly hardware accelerated. These functions MAY be implemented using Montgomery or Barrett or any other suitable technique for fast modular multiplication. If no such support is possible the functions in this section MAY be implemented using regular multiplication and modular reduction. The data type `TEE_BigIntFMM` is used to represent the integers during repeated multiplications such as when calculating a modular exponentiation. The internal representation of the `TEE_BigIntFMM` is implementation-specific.

8.11.1 TEE_BigIntConvertToFMM

Since: TEE Internal API v1.0

```
void TEE_BigIntConvertToFMM(
   [out]  TEE_BigIntFMM          *dest,
   [in]   TEE_BigInt             *src,
   [in]   TEE_BigInt             *n,
   [in]   TEE_BigIntFMMContext   *context );
```

Description

The `TEE_BigIntConvertToFMM` function converts `src` into a representation suitable for doing fast modular multiplication. If the operation is successful, the result will be written in implementation-specific format into the buffer `dest`, which SHALL have been allocated by the TA and initialized using `TEE_BigIntInitFMM`.

Parameters

- `dest`: Pointer to an initialized `TEE_BigIntFMM` memory area
- `src`: Pointer to the `TEE_BigInt` to convert
- n: Pointer to the modulus
- `context`: Pointer to a context previously initialized using `TEE_BigIntInitFMMContext1`

Specification Number: 10 **Function Number:** 0x1C03

Panic Reasons

- If the implementation detects any error.

8.11.2 TEE_BigIntConvertFromFMM

Since: TEE Internal API v1.0

```
void TEE_BigIntConvertFromFMM(
    [out]   TEE_BigInt              *dest,
    [in]    TEE_BigIntFMM           *src,
    [in]    TEE_BigInt              *n,
    [in]    TEE_BigIntFMMContext    *context );
```

Description

The `TEE_BigIntConvertFromFMM` function converts `src` in the fast modular multiplication representation back to a `TEE_BigInt` representation.

Parameters

- `dest`: Pointer to an initialized `TEE_BigInt` memory area to hold the converted result
- `src`: Pointer to a `TEE_BigIntFMM` holding the value in the fast modular multiplication representation
- `n`: Pointer to the modulus
- `context`: Pointer to a context previously initialized using `TEE_BigIntInitFMMContext1`

Specification Number: 10 **Function Number:** 0x1C02

Panic Reasons

- If the implementation detects any error.

8.11.3 TEE_BigIntComputeFMM

Since: TEE Internal API v1.0

```
void TEE_BigIntComputeFMM(
   [out]   TEE_BigIntFMM           *dest,
   [in]    TEE_BigIntFMM           *op1,
   [in]    TEE_BigIntFMM           *op2,
   [in]    TEE_BigInt              *n,
   [in]    TEE_BigIntFMMContext    *context );
```

Description

The `TEE_BigIntComputeFMM` function calculates `dest` = op1 * op2 in the fast modular multiplication representation. The pointers `dest`, op1, and op2 SHALL each point to a `TEE_BigIntFMM` which has been previously initialized with the same modulus and context as used in this function call; otherwise the result is undefined. All or some of `dest`, op1, and op2 MAY point to the same memory region but SHALL point to the start address of a `TEE_BigIntFMM`.

Parameters

- `dest`: Pointer to `TEE_BigIntFMM` to hold the result `op1 * op2` in the fast modular multiplication representation
- op1: Pointer to the first operand
- op2: Pointer to the second operand
- n: Pointer to the modulus
- `context`: Pointer to a context previously initialized using `TEE_BigIntInitFMMContext1`

Specification Number: 10 **Function Number:** 0x1C01

Panic Reasons

- If the implementation detects any error.

9 Peripheral and Event APIs

Since: TEE Internal Core API v1.2

> **Note:** The Peripheral and Event APIs were originally introduced in [TEE TUI Low] v1.0. They are incorporated in this document as of TEE Internal Core API v1.2. This document supersedes the text in [TEE TUI Low] v1.0 and in the event of any discrepancy, this document prevails.

The Peripheral and Event APIs, where provided by a Trusted OS, enable interaction between Trusted Applications and peripherals.

The Peripheral and Event APIs are optional, but if one is implemented the other is also required. A sentinel `TEE_CORE_API_EVENT`, defined in section 3.1.3, is set on implementations where they are supported.

9.1 Introduction

9.1.1 Peripherals

A peripheral is an ancillary component used to interact with a system, with the software interface between peripheral and system being provided by a device driver. On a typical device that includes a TEE, there may be many peripherals. The TEE is not expected to have software drivers for interacting with every peripheral attached to the device.

There are several classes of peripheral:

- Peripherals that are temporarily or permanently isolated from non-TEE entities, managed by the TEE, and fully usable by a TA through the APIs the TEE offers. These devices are described as TEE ownable.
- Peripherals that are under the total control of the REE or other entity outside the TEE and are not usable by the TEE.
- Peripherals where the TEE cannot interpret events – because it does not have the required driver – but where the TEE can control the flow of events, for example by routing flow through the TEE or by controlling the clock on a bus. These devices are described as TEE controllable.
- Peripherals for which a TEE can parse and forward events, even though the TEE does not fully control that source; e.g. a sockets interface to the REE. As the interface is hosted by the REE, it is REE controlled, but TEE parseable.

TA and TEE implementers should be aware of potential side channel attacks and provide and/or control appropriate interfaces to restrict those attacks. For example, a TEE could be configured to stop access by entities outside the TEE to specific peripherals such as accelerometers to prevent indirect interpretation of touch screen use while the user is interacting with a TA using a TUI.

The `TEE_Peripheral_GetPeripherals` function enables the TA to discover which peripherals the TEE knows about, and their characteristics, while other functions support low-level interaction with peripherals.

When a data source (or sink) is handed back to the REE, or transferred between TA instances, any state specific to previous TA activity or TA/user interaction SHALL be removed to prevent information leakage.

9.1.1.1 Access to Peripherals from a TA

Peripherals which are under the full or partial control of the TEE (i.e. peripherals which are TEE ownable, TEE parseable, or TEE controllable) MAY support exclusive access by no more than one TA at any one time.

A Trusted OS MAY provide additional access control mechanisms which are out of scope of this specification, either because they are described in separate GlobalPlatform specifications or because they are implementation-specific. An (informative) example is a Trusted OS that limits access to a peripheral to those TAs that reside in specific security domains.

The Trusted OS SHALL recover ownership of all peripherals with open handles from a TA in the following scenarios:

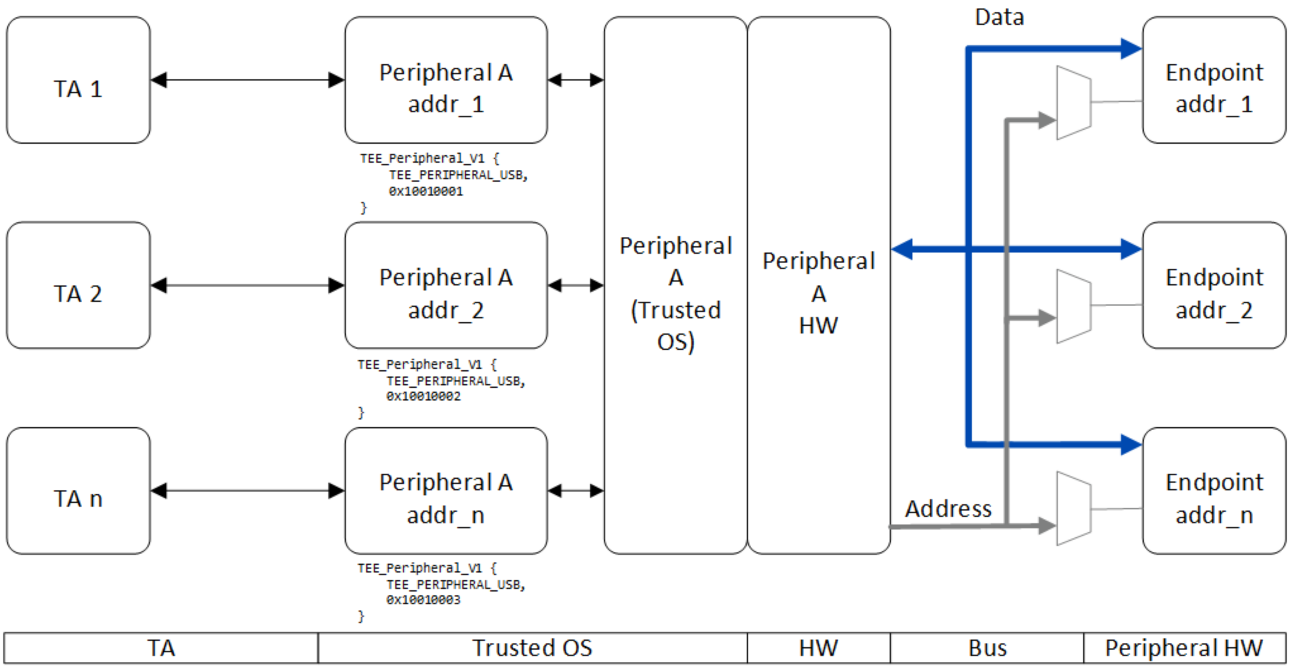
- The TA Panics.
- `TA_DestroyEntryPoint` is called for the TA owning the peripheral.

9.1.1.1.1 Multiple Access to Peripherals (informative)

Some peripherals offer multiple channels, addressing capability, or other mechanisms which have the potential to allow access to multiple endpoints. It may be convenient in some scenarios to assign different logical endpoints to different TAs, while supporting a model of exclusive access to the peripheral per TA.

One approach, shown in the following figure, is to implement a separate driver interface for each of the multiple endpoints. For example, a driver for an I²C interface may support separate endpoints for each I²C address, while itself being the exclusive owner of the I²C peripheral. Such drivers SHOULD ensure that information leakage between clients of the different endpoints is prevented.

Figure 9-1: Example of Multiple Access to Bus-oriented Peripheral (Informative)



9.1.2 Event Loop

The event loop is a mechanism by which a TA can enquire for and then process messages from types of peripherals including pseudo-peripherals. The event loop can simplify TA programming in scenarios where peripheral interaction occurs asynchronously with respect to TEE operation.

Events are polymorphic, with the ability to transport device-specific payloads.

The underlying implementation of the event loop is implementation-dependent; however, the Trusted OS SHALL ensure that:

- A TA can only successfully obtain an event source for a peripheral for which it already has an open handle. This ensures that if a peripheral supports exclusive access by a single TA, sensitive information coming from a peripheral can be consumed by only that TA, preventing opportunities for information leakage.
- Events submitted to the event queue for a given peripheral are submitted in the order in which they occur. No guarantee is made of the ordering of events from different peripherals.
- An error scenario in the Event API which results in a Panic SHALL NOT cause a Panic in TAs which are blocked waiting on synchronous operations. It will either be attributed to a TEE level problem (e.g. a corrupt library) or will occur in the `TEE_Event_Wait` function.

9.1.3 Peripheral State

The peripheral state API provides an abstracted interface to some of the hardware features of the underlying device. It can be desirable to enable a TA to read and/or configure the hardware in a specific way, for example it may be necessary to set data transmission rates on a serial peripheral, or to discover the manufacturer of a biometric sensor

The Peripheral API provides a mechanism by which TAs can discover information about the peripherals they use, and by which modifiable parameters can be identified and updated. It is intended to ensure that peripherals for which GlobalPlatform specifies interfaces can be used in a portable manner by TAs.

It is expected that other GlobalPlatform specifications may define state items for peripherals.

9.1.4 Overview of Peripheral and Event APIs

Figure 9-2 shows how the functions and structures of the Peripheral API are related. The notation is an adaptation of UML in which:

- “F” denotes a function call.
- “S” denotes a C struct.
- “E” denotes an enumeration: A constrained set of values of type uint32_t.
- “H” denotes a handle type, which may be an opaque pointer or some other integer type used as a unique identifier.
- Arrows are used to denote whether a value is returned from a function call or is a parameter to a function call.
- Dashed lines indicate other types of useful relationship.

Figure 9-3 shows the Event API in a similar format. Structures that are common to the Peripheral and Event APIs are shown in both diagrams to make the relation between the API sets explicit.

Figure 9-2: Peripheral API Overview

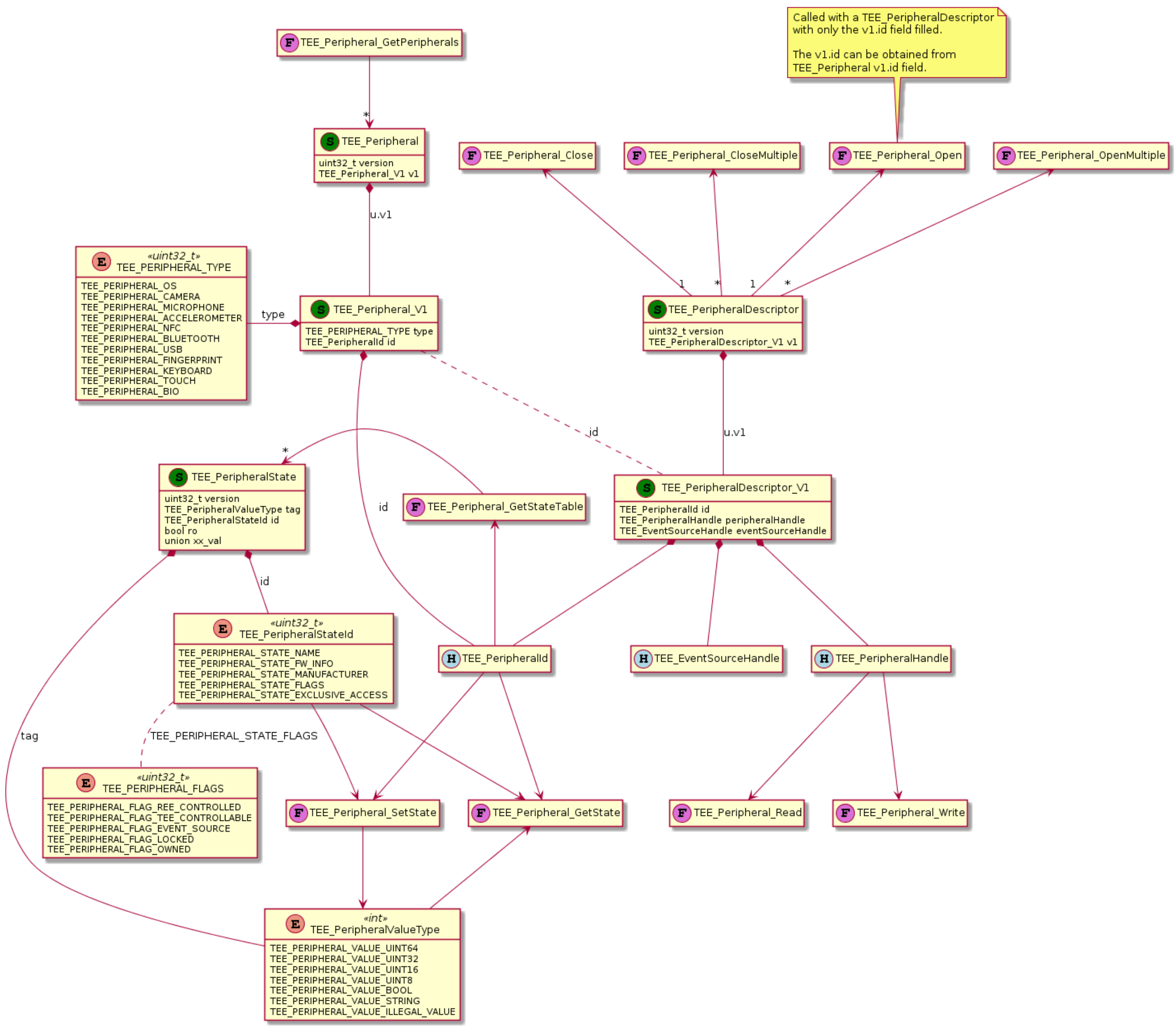
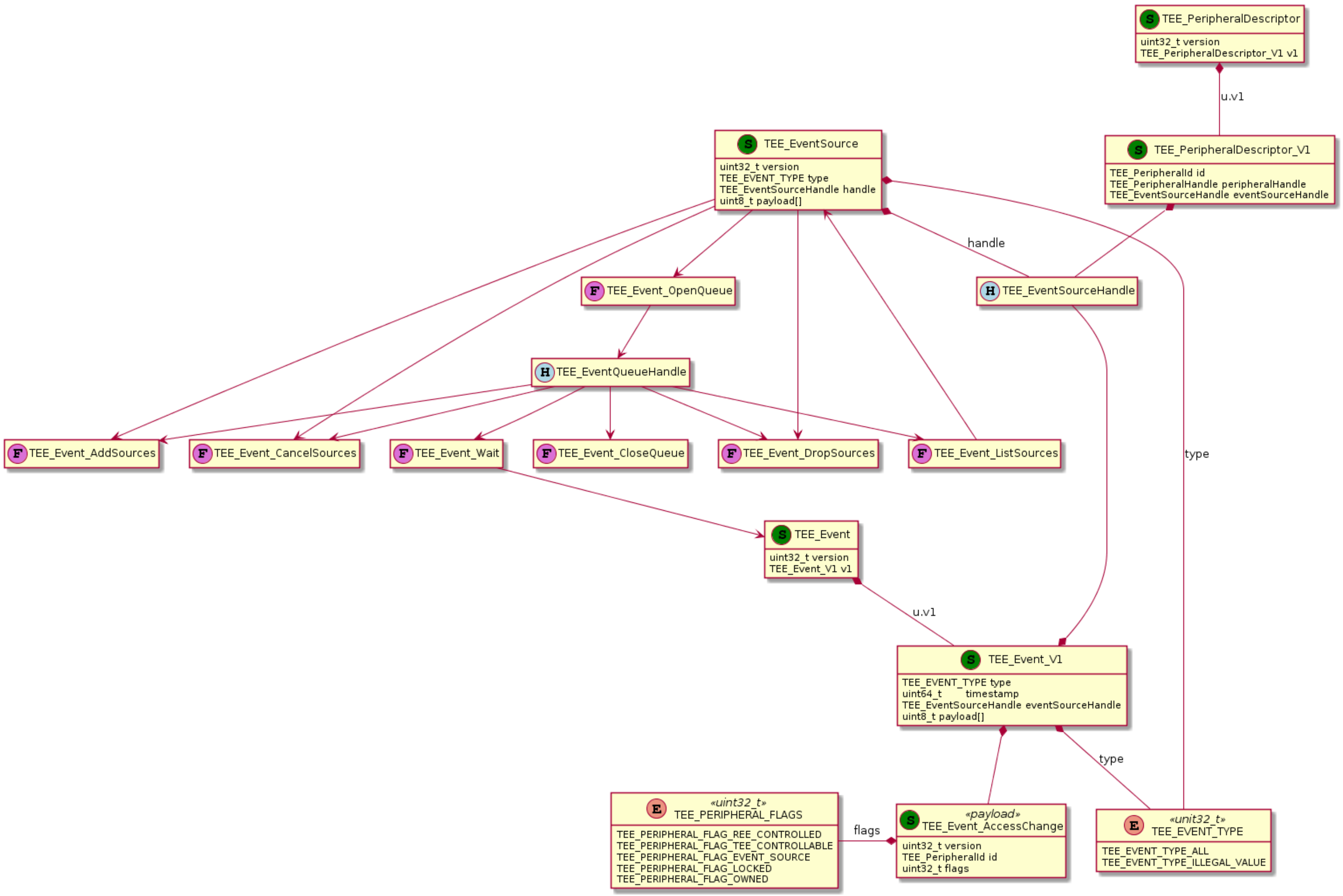


Figure 9-3: Event API Overview



9.2 Constants

9.2.1 Handles

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

The value `TEE_INVALID_HANDLE` is used by the peripheral subsystem to denote an invalid handle.

```
#define TEE_INVALID_HANDLE   ((TEE_EventQueueHandle) (0))
```

9.2.2 Maximum Sizes

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

Table 9-1 defines the maximum size of structure payloads.

If another specification supported by a given Trusted OS requires a larger payload to support events, these SHALL be implemented using pointers or handles to other structures that fit within the defined maximum structure payloads.

Table 9-1: Maximum Sizes of Structure Payloads

Constant Name	Value
`TEE_MAX_EVENT_PAYLOAD_SIZE`	32 bytes

Backward Compatibility

[TEE TUI Low] v1.0 offered the option of supporting larger payloads. This option is no longer supported.

9.2.3 TEE_EVENT_TYPE

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

`TEE_EVENT_TYPE` is a value indicating the source of an event.

```
#if defined(TEE_CORE_API_EVENT)
  typedef uint32_t TEE_EVENT_TYPE;
#endif
```

To distinguish the event types defined in various specifications:

- GlobalPlatform event types SHALL have nibble 8 (the high nibble) = `0`, and SHALL include the specification number as a 3-digit BCD (Binary Coded Decimal) value in nibbles 7 through 5.

  For example, GPD_SPE_**123** may define specification unique event type codes `0x01230000` to `0x0123ffff`.

  All event types defined in this specification have the high word set to `0x0010`.
- Event types created by external bodies SHALL have nibble 8 = 1.
- Implementation defined event types SHALL have nibble 8 = 2.

Table 9-2 lists event types defined to date.

Implementations may not support all event types; however, it is recommended that TA developers define event handlers for all of the events defined on the peripherals they support. To determine which event types are supported by a particular peripheral, the developer can consult the documentation for that peripheral.

Table 9-2: `TEE_EVENT_TYPE` Values

Constant Name	Value
Reserved for future use	`0x00000000 – 0x0000ffff`
Reserved for GlobalPlatform TEE specifications numbered 001 - 009	`0x00010000 – 0x0009ffff`
`TEE_EVENT_TYPE_ALL`	`0x00100000`
`TEE_EVENT_TYPE_CORE_CLIENT_CANCEL`	`0x00100001`
`TEE_EVENT_TYPE_CORE_TIMER`	`0x00100002`
`TEE_EVENT_TYPE_ACCESS_CHANGE`	`0x00100003`
Reserved for future versions of this specification	`0x00100004 – 0x0010fffe`
`TEE_EVENT_TYPE_ILLEGAL_VALUE`	`0x0010ffff`
Reserved for GlobalPlatform TEE specifications numbered 011 - 041	`0x00110000 – 0x0041ffff`
`TEE_EVENT_TYPE_BIO` Defined in [TEE TUI Bio]; if the Biometrics API is not implemented, reserved.	`0x00420000`
Reserved for [TEE TUI Bio]	`0x00420001 – 0x0042ffff`
Reserved for GlobalPlatform TEE specifications numbered 043 – 054	`0x00430000 – 0x0054ffff`
`TEE_EVENT_TYPE_TUI_ALL`	`0x00550000`
`TEE_EVENT_TYPE_TUI_BUTTON`	`0x00550001`
`TEE_EVENT_TYPE_TUI_KEYBOARD`	`0x00550002`
`TEE_EVENT_TYPE_TUI_REE`	`0x00550003`
`TEE_EVENT_TYPE_TUI_TOUCH`	`0x00550004`
Reserved for [TEE TUI Low]	`0x00550005 – 0x0055ffff`
Reserved for GlobalPlatform TEE specifications numbered 056 – 999	`0x00560000 – 0x0999ffff`
Reserved for future use	`0x099a0000 – 0x0fffffff`
Reserved for external bodies; number space managed by GlobalPlatform	`0x10000000 – 0x1fffffff`
Implementation defined	`0x20000000 – 0x2fffffff`
Reserved for future use	`0x30000000 – 0xffffffff`

`TEE_EVENT_TYPE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when set in the `TEE_Event` structure.

9.2.4 TEE_PERIPHERAL_TYPE

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

`TEE_PERIPHERAL_TYPE` is a value used to identify a peripheral attached to the device.

```
#if defined(TEE_CORE_API_EVENT)
  typedef uint32_t TEE_PERIPHERAL_TYPE;
#endif
```

The `TEE_Peripheral_GetPeripherals` function lists all the peripherals known to the TEE.

Table 9-3: `TEE_PERIPHERAL_TYPE` Values

Constant Name	Value
Reserved	0x00000000
TEE_PERIPHERAL_OS	0x00000001
TEE_PERIPHERAL_CAMERA	0x00000002
TEE_PERIPHERAL_MICROPHONE	0x00000003
TEE_PERIPHERAL_ACCELEROMETER	0x00000004
TEE_PERIPHERAL_NFC	0x00000005
TEE_PERIPHERAL_BLUETOOTH	0x00000006
TEE_PERIPHERAL_USB	0x00000007
TEE_PERIPHERAL_FINGERPRINT	0x00000008
TEE_PERIPHERAL_KEYBOARD	0x00000009
TEE_PERIPHERAL_TOUCH	0x0000000A
TEE_PERIPHERAL_BIO	0x0000000B
Reserved for GlobalPlatform specifications	0x0000000C – 0x3fffffff
Reserved for other Specification Development Organizations (SDOs) under Liaison Statement (LS)	0x40000000 – 0x7ffffffe
TEE_PERIPHERAL_ILLEGAL_VALUE	0x7fffffff
Implementation defined	0x80000000 – 0xffffffff

`TEE_PERIPHERAL_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when returned by the `TEE_Peripheral_GetPeripherals` function.

9.2.5 TEE_PERIPHERAL_FLAGS

Table 9-4: `TEE_PERIPHERAL_FLAGS` Values

Constant Name	Value	Meaning
`TEE_PERIPHERAL_FLAG_REE_CONTROLLED`	`0x00000000`	The Trusted OS does not control this peripheral. All events can be processed by the REE.
`TEE_PERIPHERAL_FLAG_TEE_CONTROLLABLE`	`0x00000001`	The Trusted OS can control this peripheral. Events SHALL NOT be passed to the REE.
`TEE_PERIPHERAL_FLAG_EVENT_SOURCE`	`0x00000002`	The TEE can parse the events generated by this peripheral. The peripheral can be attached to an event queue.
`TEE_PERIPHERAL_FLAG_LOCKED`	`0x00000004`	This peripheral has been locked for access by **a** TA or the REE.
`TEE_PERIPHERAL_FLAG_OWNED`	`0x00000008`	This peripheral has been locked for access by **this** TA instance.
Set bits reserved for use by GlobalPlatform	`0x007FFFF0`	
`TEE_PERIPHERAL_FLAG_ILLEGAL_VALUE`	`0x00800000`	
Set bits reserved for implementation defined flags	`0xFF000000`	

`TEE_PERIPHERAL_FLAG_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when it is set in `TEE_PERIPHERAL_STATE_FLAGS`.

The flags `TEE_PERIPHERAL_FLAG_REE_CONTROLLED` and `TEE_PERIPHERAL_FLAG_TEE_CONTROLLABLE` are mutually exclusive.

If an event source has the `TEE_PERIPHERAL_FLAG_TEE_CONTROLLABLE` flag but not the `TEE_PERIPHERAL_FLAG_EVENT_SOURCE` flag, the TEE can control the source, but not understand it. Any events generated while the TEE has control of the source SHALL be dropped.

9.2.6 TEE_PeripheralStateId Values

`TEE_PeripheralState` instances are used to provide information about peripherals to a TA. The following field values, which represent legal values of type `TEE_PeripheralStateId` which can be used to identify specific peripheral state items, are defined in this specification. Other specifications may define additional values for `TEE_PeripheralStateId`.

Table 9-5: `TEE_PeripheralStateId` Values

Constant Name	Value
Reserved	0x00000000
TEE_PERIPHERAL_STATE_NAME	0x00000001
TEE_PERIPHERAL_STATE_FW_INFO	0x00000002
TEE_PERIPHERAL_STATE_MANUFACTURER	0x00000003
TEE_PERIPHERAL_STATE_FLAGS	0x00000004
Reserved for GlobalPlatform specifications	0x00000005 – 0x3fffffff
Reserved for other SDOs under LS	0x40000000 – 0x7ffffffe
TEE_PERIPHERAL_STATE_ILLEGAL_VALUE	0x7fffffff
Implementation defined	0x80000000 – 0xffffffff

`TEE_PERIPHERAL_STATE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when set in the `TEE_PeripheralState` structure.

9.3 Peripheral State Table

Every peripheral instance has a table of associated state information. A TA can obtain this table by calling `TEE_Peripheral_GetStateTable`. Each item in the state table is of `TEE_PeripheralState` type.

The peripheral state table can be used to retrieve standardized, and peripheral specific, information about the peripheral. It also contains identifiers that can then be used for direct get/put control of specific aspects of the peripheral.

For example, a serial interface peripheral may expose interfaces to its control registers to provide direct access to readable parity error counters and writable baud rate settings.

The state table returned by `TEE_Peripheral_GetStateTable` is a read-only snapshot of peripheral state at function call time. Some of the values in the table may support modification by the caller using the `TEE_Peripheral_SetState` function – this is indicated by the value of the `ro` field.

The following sections define the state table items which could be present in the peripheral state table. Other specifications may define additional items.

9.3.1 Peripheral Name

Peripherals SHALL provide a state table entry that defines a printable name for the peripheral.

Table 9-6: `TEE_PERIPHERAL_STATE_NAME` Values

`TEE_PeripheralValueType` Field	Value
`tag`	`TEE_PERIPHERAL_VALUE_STRING`
`id`	`TEE_PERIPHERAL_STATE_NAME`
`ro`	`true`
`u.stringVal`	Pointer to a `NULL`-terminated printable string which contains a printable peripheral name; SHALL be unique among the peripherals that are presented to a given TA. Note: In [TEE TUI Low] v1.0, uniqueness was recommended but not required.

9.3.2 Firmware Information

Peripherals MAY provide a state table entry that identifies the firmware version executing on the peripheral. This entry is only relevant to peripherals which contain a processor.

Table 9-7: `TEE_PERIPHERAL_STATE_FW_INFO` Values

`TEE_PeripheralValueType` Field	Value
`tag`	`TEE_PERIPHERAL_VALUE_STRING`
`id`	`TEE_PERIPHERAL_STATE_FW_INFO`
`ro`	`true`
`u.stringVal`	Pointer to a `NULL`-terminated printable string which contains information about the firmware running in the peripheral

9.3.3 Manufacturer

Peripherals MAY provide a state table entry that identifies the manufacturer of the peripheral.

Table 9-8: TEE_PERIPHERAL_STATE_MANUFACTURER Values

TEE_PeripheralValueType Field	Value
tag	TEE_PERIPHERAL_VALUE_STRING
id	TEE_PERIPHERAL_STATE_MANUFACTURER
ro	true
u.stringVal	Pointer to a NULL-terminated printable string which contains information about the manufacturer of the peripheral

9.3.4 Flags

Peripherals SHALL provide a state table entry that provides information about the way in which the Trusted OS can manage the input and output from this peripheral from the calling TA using one or more of the values defined for TEE_PERIPHERAL_FLAGS – these may be combined in a bitwise manner.

Table 9-9: TEE_PERIPHERAL_STATE_FLAGS Values

TEE_PeripheralValueType Field	Value
tag	TEE_PERIPHERAL_VALUE_UINT32
id	TEE_PERIPHERAL_STATE_FLAGS
ro	true
u.uint32Val	A combination of zero or more of the TEE_PERIPHERAL_FLAGS values defined in section 9.2.5

9.3.5 Exclusive Access

Peripherals SHALL provide a state table entry that identifies whether the peripheral supports exclusive access.

Table 9-10: TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS Values

TEE_PeripheralValueType Field	Value
tag	TEE_PERIPHERAL_VALUE_BOOL
id	TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS
ro	true
u.boolVal	Set to true if this peripheral can be opened for exclusive access.

The value of the TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS field SHALL be set to the same value on all TAs running on a given TEE which have access to that peripheral.

9.4 Operating System Pseudo-peripheral

The Operating System pseudo-peripheral provides a mechanism by which events originating in the Trusted OS **or** the REE can be provided to a Trusted Application.

A single instance of the Operating System pseudo-peripheral is provided by a Trusted OS supporting the Peripheral and Event APIs. It has `TEE_PERIPHERAL_TYPE` set to `TEE_PERIPHERAL_OS`.

A Trusted Application can determine the source of an Event generated by the Operating System pseudo-peripheral by looking at the event type. This information about the event source is trustworthy because it is generated within the Trusted OS. Events originating outside the Trusted OS may be less trustworthy than those originating from within the Trusted OS, and Trusted Application developers should take account of this in their designs.

The Operating System pseudo-peripheral SHALL NOT expose a `TEE_PeripheralHandle`, as it supports neither the polled Peripheral API nor writeable state. It SHALL expose a `TEE_EventSourceHandle`.

The Operating System pseudo-peripheral SHALL NOT be lockable for exclusive access and SHALL be exposed to all TA instances. Any TA in the Trusted OS can subscribe to its event queue if it wishes to do so.

9.4.1 State Table

The peripheral state table for the Operating System pseudo-peripheral SHALL contain the values listed in the following table.

Table 9-11: `TEE_PERIPHERAL_OS` State Table Values

`TEE_PeripheralValueType.id`	`TEE_PeripheralValueType.u`
`TEE_PERIPHERAL_STATE_NAME`	`"TEE"`
`TEE_PERIPHERAL_STATE_FLAGS`	`TEE_PERIPHERAL_FLAG_EVENT_SOURCE`
`TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS`	`false`

9.4.2 Events

The Operating System pseudo-peripheral, when opened, SHALL return a `TEE_PeripheralDescriptor` which SHALL contain a valid `TEE_EventSourceHandle` and an invalid `TEE_PeripheralHandle` because it acts only as an event source.

The Operating System pseudo-peripheral can act as a source for the event types listed in section 9.6.9.

9.5 Session Pseudo-peripheral

The Session pseudo-peripheral provides a mechanism by which the events private to a specific TA session may be provided to a Trusted Application.

An instance of the Session pseudo-peripheral is provided by a Trusted OS to each open TA session, it has `TEE_PERIPHERAL_TYPE` set to `TEE_PERIPHERAL_SESSION`.

The Session pseudo-peripheral SHALL NOT expose a `TEE_PeripheralHandle`, as it supports neither the polled Peripheral API nor writeable state. It SHALL expose a `TEE_EventSourceHandle`.

The Session pseudo-peripheral SHALL be exposed only the specific session of an executing TA instance.

9.5.1 State Table

The peripheral state table for the Operating System pseudo-peripheral SHALL contain the values listed in the following table.

Table 9-12: `TEE_PERIPHERAL_SESSION` State Table Values

TEE_PeripheralValueType.id	**TEE_PeripheralValueType.u**
TEE_PERIPHERAL_STATE_NAME	"Session"
TEE_PERIPHERAL_STATE_FLAGS	TEE_PERIPHERAL_FLAG_EVENT_SOURCE
TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS	true

9.5.2 Events

The Session pseudo-peripheral, when opened, SHALL return a `TEE_PeripheralDescriptor` which SHALL contain a valid `TEE_EventSourceHandle` and an invalid `TEE_PeripheralHandle` because it acts only as an event source.

The Session pseudo-peripheral can act as a source for the following event types:

- `TEE_Event_ClientCancel` (see section 9.6.9.2)
- `TEE_Event_Timer` (see section 9.6.9.3)

9.6 Data Structures

Several data structures defined in this specification are versioned. This allows a TA written against an earlier version of this API than that implemented by a TEE to request the version of the structure it understands.

9.6.1 TEE_Peripheral

`TEE_Peripheral` is a structure used to provide information about a single peripheral to a TA.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
   typedef struct
   {
      uint32_t             version;
      union  {
            TEE_Peripheral_V1 v1;
            } u;
   } TEE_Peripheral;

   typedef struct
   {
      TEE_PERIPHERAL_TYPE    periphType;
      TEE_PeripheralId       id;
   } TEE_Peripheral_V1;
#endif
```

The structure fields have the following meanings:

- `version`: The version of the structure – currently always 1.
- `periphType`: The type of the peripheral.
- `id`: A unique identifier for a given peripheral on a TEE.

A TEE may have more than one peripheral of the same `TEE_PERIPHERAL_TYPE`. The id parameter provides a TEE-unique identifier for a specific peripheral, and the implementation SHOULD provide further information about the specific peripheral instance in the `TEE_PERIPHERAL_STATE_NAME` field described in section 9.3.1.

The `id` parameter for a given peripheral SHOULD NOT change between Trusted OS version updates on a device. The `id` parameter is not necessarily consistent between different examples of the same device.

9.6.2 TEE_PeripheralDescriptor

`TEE_PeripheralDescriptor` is a structure collecting the information required to access a peripheral.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
   typedef struct
   {
     uint32_t          version;
     union {
                        TEE_PeripheralDescriptor_V1 v1;
     } u;
   } TEE_PeripheralDescriptor

  typedef struct
  {
   TEE_PeripheralId      id;
   TEE_PeripheralHandle  peripheralHandle;
   TEE_EventSourceHandle eventSourceHandle;
  } TEE_PeripheralDescriptor_V1;
#endif
```

The structure fields have the following meanings:

- The `version` field identifies the version of the `TEE_PeripheralDescriptor` structure. In this version of the specification it SHALL be set to 1.
- The `id` field contains a unique identifier for the peripheral with which this `TEE_PeripheralDescriptor` instance is associated.
- The `peripheralHandle` field contains a `TEE_PeripheralHandle` which, if valid, enables an owning TA to perform API calls which might alter peripheral state.
- The `eventSourceHandle` field contains a `TEE_EventSourceHandle` which can be used to attach events generated by the peripheral to an event queue.

9.6.3 TEE_PeripheralHandle

A `TEE_PeripheralHandle` is an opaque handle used to manage direct access to a peripheral.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct __TEE_PeripheralHandle* TEE_PeripheralHandle;
#endif
```

TA implementations SHOULD NOT assume that the same `TEE_PeripheralHandle` will be returned for different sessions.

The value `TEE_INVALID_HANDLE` is used to indicate an invalid `TEE_PeripheralHandle`. All other values returned by the Trusted OS denote a valid `TEE_PeripheralHandle`.

9.6.4 TEE_PeripheralId

A `TEE_PeripheralId` is a `uint32_t`, used as a unique identifier for a peripheral on a given TEE.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef uint32_t TEE_PeripheralId;
#endif
```

`TEE_PeripheralId` SHALL be unique on a given TEE, and SHALL be constant for a given peripheral between TEE reboots. If a peripheral is removed and reinserted, the same value of `TEE_PeripheralId` SHALL be associated with it.

9.6.5 TEE_PeripheralState

`TEE_PeripheralState` is a structure containing the current value of an individual peripheral state value on a given TEE.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct
  {
    uint32_t                version;
    TEE_PeripheralValueType tag;
    TEE_PeripheralStateId   id;
    bool                    ro;
    union {
      uint64_t              uint64Val;
      uint32_t              uint32Val;
      uint16_t              uint16Val;
      uint8_t               uint8Val;
      bool                  boolVal;
      const char*           stringVal;
    } u;
  } TEE_PeripheralState;
#endif
```

The structure fields have the following meanings:

- The `version` field identifies the version of the `TEE_PeripheralState` structure. In this version of the specification it SHALL be set to 1.
- The `tag` field is a `TEE_PeripheralStateValueType` instance indicating which field in the union, u, should be accessed to obtain the correct configuration value.
- The `id` field is a unique identifier for this node in the peripheral configuration tree. It can be used in the set/get API calls to select a peripheral configuration value directly.
- The `ro` field is `true` if this configuration value cannot be updated by the calling TA. A TA SHOULD NOT call `TEE_PeripheralSetState` with a given `TEE_PeripheralStateId` if the `ro` field of the corresponding `TEE_PeripheralState` is `true`. An implementation MAY generate an error if this is not respected.
- The union field, u, contains fields representing the different data types which can be used to store peripheral configuration information.

A Trusted OS MAY indicate different `TEE_PeripheralState` information to different TAs on the system. Therefore a TA SHOULD NOT pass `TEE_PeripheralState` to another TA as the information it contains may not be valid for the other TA.

9.6.6 TEE_PeripheralStateId

A `TEE_PeripheralStateId` is an identifier for a peripheral state entry on a given TEE.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef uint32_t TEE_PeripheralStateId;
#endif
```

Legal values in this specification for `TEE_PeripheralStateId` are listed in section 9.2.6. Further values may be defined in other specifications.

9.6.7 TEE_PeripheralValueType

`TEE_PeripheralValueType` indicates which of several types has been used to store the configuration information in a `TEE_PeripheralState.tag` field.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef uint32_t TEE_PeripheralValueType;
#endif
```

Table 9-13: `TEE_PeripheralValueType` Values

Constant Name	Value
TEE_PERIPHERAL_VALUE_UINT64	0x00000000
TEE_PERIPHERAL_VALUE_UINT32	0x00000001
TEE_PERIPHERAL_VALUE_UINT16	0x00000002
TEE_PERIPHERAL_VALUE_UINT8	0x00000003
TEE_PERIPHERAL_VALUE_BOOL	0x00000004
TEE_PERIPHERAL_VALUE_STRING	0x00000005
Reserved	0x00000006 – 0x7FFFFFFE
TEE_PERIPHERAL_VALUE_ILLEGAL_VALUE	0x7FFFFFFF
Implementation defined	0x80000000 – 0xFFFFFFFF

`TEE_PERIPHERAL_VALUE_ILLEGAL_VALUE` is reserved for testing and validation and SHALL be treated as an undefined value when provided to the `TEE_Peripheral_SetState` function.

9.6.8 TEE_Event

`TEE_Event` is a container for events in the event loop.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
   typedef struct {
     uint32_t                  version;
     union {
                                TEE_Event_V1 v1;
            } u;
   } TEE_Event;

   typedef struct {
     TEE_EVENT_TYPE            eventType;
     uint64_t                  timestamp;
     TEE_EventSourceHandle     eventSourceHandle;
     uint8_t                   payload[TEE_MAX_EVENT_PAYLOAD_SIZE];
   } TEE_Event_V1;
#endif
```

The `TEE_Event` structure holds an individual event; the payload holds an array of bytes whose contents are interpreted according to the type of the event:

- `version`: The version of the structure – currently always 1.
- `eventType`: A value identifying the type of event.
- `timestamp`: The time the event occurred given as milliseconds since the TEE was started. The value of `timestamp` is guaranteed to increase monotonically so that the ordering of events in time is guaranteed. A Trusted OS SHOULD use the same underlying source of time information as used for `TEE_GetSystemTime`, described in section 7.2.1.
- `eventSourceHandle`: The handle of the specific event source that created this event.
- `payload`: A block of `TEE_MAX_EVENT_PAYLOAD_SIZE` bytes. The content of `payload`, while defined for `TEE_PERIPHERAL_OS`, is not generally defined in this specification. Payloads specific to particular APIs may be defined in other specifications. Any unused trailing bytes SHALL be zero.

In general, if an event cannot be sufficiently described within the constraints of the `payload` field of `TEE_MAX_EVENT_PAYLOAD_SIZE`, the contents of the field may be data structure containing handles or pointers to further structures that together fully describe the event.

9.6.9 Generic Payloads

This section describes a generic `payload` field of the `TEE_Event` structure. Each `TEE_Event` structure that the implementation can return has a version field and a union of the different versions, thereby permitting a TA to specify the version of the returned structure in the invoking command. When a command requests a particular version, the TEE can return any of the following:

- A structure of the requested version
- A structure of an earlier version
- An error indicating that it cannot support the request

The following table from [TEE TUI Low] v1.0.1 is duplicated here for convenience.

Table 9-14: Value of `version` in `payload` Structures

Structure	Value of `version` in `payload` Structure
`TEE_Event`	1
`TEE_Event_TUI_Button`	1
`TEE_Event_TUI_Keyboard`	1
`TEE_Event_TUI_REE`	1
`TEE_Event_TUI_TEE`	1
`TEE_Event_TUI_Touch`	1
`TEE_Peripheral`	1
`TEE_PeripheralDescriptor`	1
`TEE_TUIDisplayInfo`	1
`TEE_TUISurfaceBuffer`	1
`TEE_TUISurfaceInfo`	1

The rules associated with `TEE_Event` structure versioning are defined in [TEE TUI Low] section 3.11.

9.6.9.1 TEE_Event_AccessChange

This event is generated if the accessibility of a peripheral to this TA changes.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct {
    uint32_t         version;
    TEE_PeripheralId id;
    uint32_t         flags;
  } TEE_Event_AccessChange;
#endif
```

The structure fields have the following meanings:

- `version`: The version of the structure – currently always 1.
- `id`: The `TEE_PeripheralId` for the peripheral for which the access change event was generated. This uniquely identifies the peripheral for which the access status has changed.
- `flags`: The new state of `TEE_PERIPHERAL_STATE_FLAGS`. For details of the legal values for this field, see the description of the `u.uint32Val` field in section 9.3.4.

This event SHALL be sent to all TAs which have registered to the `TEE_PERIPHERAL_OS` event queue when an access permission change occurs – including the TA which initiated the change.

A consequence of `TEE_Event_AccessChange` is that some of the peripheral state table information may change. As such, each TA instance SHOULD call `TEE_Peripheral_GetStateTable` to obtain fresh information when it receives this event.

9.6.9.2 TEE_Event_ClientCancel

When a `TEE_Event_V1` with `eventType` of `TEE_EVENT_TYPE_CORE_CLIENT_CANCEL` is received, the `TEE_Event_V1 payload` has type `TEE_Event_ClientCancel`.

Since: TEE Internal Core API v1.2

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct {
    uint32_t         version;
  } TEE_Event_ClientCancel;
#endif
```

The structure fields have the following meanings:

- `version`: The version of the structure – currently always 1.

This event SHALL be sent only to the TA session for which cancellation was requested on the appropriate `TEE_PERIPHERAL_SESSION` event queue when cancellation was requested.

9.6.9.3 TEE_Event_Timer

When a TEE_Event_V1 with eventType of TEE_EVENT_TYPE_CORE_CLIENT_TIMER is received in a given TA session context, the TEE_Event_V1 payload has type TEE_Event_Timer.

Since: TEE Internal Core API v1.2

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct {
    uint8_t          payload[TEE_MAX_EVENT_PAYLOAD_SIZE];
  } TEE_Event_Timer;
#endif
```

The structure fields have the following meanings:

- payload: A byte array containing a payload whose contents are defined by the TA when the timer is created.

This event SHALL be sent only to the TA session for which timer event was requested on the appropriate TEE_PERIPHERAL_SESSION event queue when cancellation was requested.

9.6.10 TEE_EventQueueHandle

A TEE_EventQueueHandle is an opaque handle for an event queue.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct __TEE_EventQueueHandle* TEE_EventQueueHandle;
#endif
```

A Trusted OS SHOULD ensure that the value of TEE_EventQueueHandle returned to a TA is not predictable and SHALL ensure that it does contain all or part of a machine address.

The value TEE_INVALID_HANDLE is used to indicate an invalid TEE_EventQueueHandle. All other values returned by the Trusted OS denote a valid TEE_EventQueueHandle.

9.6.11 TEE_EventSourceHandle

A TEE_EventSourceHandle is an opaque handle for a specific source of events, for example a biometric sensor.

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  typedef struct __TEE_EventSourceHandle* TEE_EventSourceHandle;
#endif
```

The value TEE_INVALID_HANDLE is used to indicate an invalid TEE_EventSourceHandle. All other values returned by the Trusted OS denote a valid TEE_EventSourceHandle.

9.7 Peripheral API Functions

9.7.1 TEE_Peripheral_Close

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_Close(
      TEE_PeripheralDescriptor *peripheralDescriptor
  );
#endif
```

Description

The `TEE_Peripheral_Close` function is used by a TA to release a single peripheral. On successful return, the `peripheralHandle` and `eventSourceHandle` values pointed to by `peripheral` SHALL be `TEE_INVALID_HANDLE`.

Specification Number: 10 **Function Number:** 0x2001

Parameters

- `peripheralDescriptor`: A pointer to a `TEE_PeripheralDescriptor` structure.

Return Code

- `TEE_SUCCESS`: In case of success. At least one of `peripheralHandle` and `eventSourceHandle` points to a valid handle.
- `TEE_ERROR_BAD_STATE`: The calling TA does not have a valid open handle to the peripheral.
- `TEE_ERROR_BAD_PARAMETERS`: `peripheral` is `NULL`.

Panic Reasons

`TEE_Peripheral_Close` SHALL NOT panic.

9.7.2 TEE_Peripheral_CloseMultiple

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_CloseMultiple(
         const    uint32_t                  numPeripherals,
         [inout]  TEE_PeripheralDescriptor *peripheralDescriptors
      );
#endif
```

Description

TEE_Peripheral_CloseMultiple is a convenience function which closes all the peripherals identified in the buffer pointed to by peripherals. In contrast to TEE_Peripheral_OpenMultiple, there is no guarantee of atomicity; the function simply attempts to close all the requested peripherals.

Specification Number: 10 **Function Number:** 0x2002

Parameters

- numPeripherals: The number of entries in the TEE_PeripheralDescriptor buffer pointed to by peripherals.
- peripheralDescriptors: A pointer to a buffer of numPeripherals instances of TEE_PeripheralDescriptor. The interpretation and treatment of each individual entry in the buffer of descriptors is as described for TEE_Peripheral_Close in section 9.7.1.

Return Code

- TEE_SUCCESS: In case of success, which is defined as all the requested TEE_PeripheralDescriptor instances having been successfully closed.
- TEE_ERROR_BAD_STATE: The calling TA does not have a valid open handle to at least one of the peripherals.
- TEE_ERROR_BAD_PARAMETERS: peripherals is NULL and/or numPeripherals is 0.

Panic Reasons

TEE_Peripheral_CloseMultiple SHALL NOT panic.

9.7.3 TEE_Peripheral_GetPeripherals

Since: TEE Internal Core API v1.3 – See Backward Compatibility statement below.

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_GetPeripherals(
         [inout]    uint32_t*       version,
         [outbuf]   TEE_Peripheral* peripherals, size_t* size
      );
#endif
```

Description

The `TEE_Peripheral_GetPeripherals` function returns information about the peripherals known to the TEE. This function MAY list all peripherals attached to the implementation and SHALL list all peripherals visible to the calling TA. The TEE may not be able to control all the peripherals. Of those that the TEE can control, it may not be able to parse the events generated, so not all can be used as event sources.

Specification Number: 10 **Function Number:** 0x2003

Parameters

- `version`:
  - On entry, the highest version of the `TEE_Peripheral` structure understood by the calling program.
  - On return, the actual version returned, which may be lower than the value requested.
- `peripherals`: A pointer to an array of `TEE_Peripheral` structures. This will be populated with information about the available sources on return. Each structure in the array returns information about one peripheral.
- `size`:
  - On entry, the size of `peripherals` in bytes.
  - On return, the actual size of the buffer containing the `TEE_Peripheral` structures in bytes. The combination of `peripherals` and `size` complies with the *`[outbuf]`* behavior specified in section 3.4.4.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_UNSUPPORTED_VERSION`: If the version of the `TEE_Peripheral` structure requested is not supported.
- `TEE_ERROR_OUT_OF_MEMORY`: If the system ran out of resources.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is not large enough to hold all the sources.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.

Panic Reasons

- If `version` is `NULL`.
- If `peripherals` is `NULL` and/or `*size` is not zero.

- See section 3.4.4 for reasons for *[outbuf]* generated panic.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, `TEE_ERROR_OLD_VERSION` was returned if the version of the `TEE_Peripheral` structure requested is not supported. This return code has been renamed `TEE_ERROR_UNSUPPORTED_VERSION`; however, the value remains unchanged.

9.7.4 TEE_Peripheral_GetState

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_GetState(
            const TEE_PeripheralId      id,
            const TEE_PeripheralStateId stateId,
      [out] TEE_PeripheralValueType*    periphType,
      [out] void*                       value
  );
#endif
```

Description

The `TEE_Peripheral_GetState` function enables a TA which knows the state ID of a peripheral state item to fetch the value of this directly. A TA does not need to have an open handle to a peripheral to obtain information about its state – this allows a TA to discover information about peripherals available to it before opening a handle.

Specification Number: 10 **Function Number:** 0x2004

Parameters

- `id`: The unique peripheral identifier for the peripheral in which we are interested.
- `stateID`: The identifier for the state item for which the value is requested.
- `periphType`: On return, contains a value of `TEE_PeripheralValueType` which determines how the data pointed to by `value` should be interpreted.
- `value`: On return, points to the value of the requested state item.

The caller SHALL ensure that the buffer pointed to by `value` is large enough to accommodate whichever is the larger of `uint64_t` and `char*` on a given TEE platform.

Return Code

- `TEE_SUCCESS`: State information has been fetched.
- `TEE_ERROR_BAD_PARAMETERS`: The value of one or both of `id` or `stateId` are not valid for this TA; `periphType` or `value` is `NULL`.

Panic Reasons

`TEE_Peripheral_GetState` SHALL NOT panic.

9.7.5 TEE_Peripheral_GetStateTable

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_GetStateTable(
      [in] TEE_PeripheralId id,
      [outbuf] TEE_PeripheralState* stateTable, size_t* bufSize
  );
#endif
```

Description

The `TEE_Peripheral_GetStateTable` function fetches a buffer containing zero or more instances of `TEE_PeripheralState`. These provide a snapshot of the state of a peripheral.

Specification Number: 10 **Function Number:** 0x2005

Parameters

- `id`: The `TEE_PeripheralId` for the peripheral from which the TA wishes to read data
- `stateTable`: A buffer of at least `bufSize` bytes that on successful return is overwritten with an array of `TEE_PeripheralState` structures.
- `bufSize`:
  - On entry, the size of `stateTable` in bytes.
  - On return, the actual number of bytes in the array. The combination of `stateTable` and `bufSize` complies with the *[outbuf]* behavior specified in section 3.4.4.

Return Code

- `TEE_SUCCESS`: Data has been written to the peripheral.
- `TEE_ERROR_BAD_PARAMETERS`: The value of `id` or `stateTable` is `NULL` and/or `bufSize` is `0`.

Panic Reasons

- See section 3.4.4 for reasons for *[outbuf]* generated panic.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.7.6 TEE_Peripheral_Open

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_Open(
    [inout]   TEE_PeripheralDescriptor *peripheralDescriptor
  );
#endif
```

Description

The `TEE_Peripheral_Open` function is used by a TA to obtain descriptor(s) enabling access to a single peripheral. If the TA needs to open more than one peripheral for related activities, it MAY use `TEE_Peripheral_OpenMultiple`.

If this function executes successfully and if `TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS` indicates that exclusive access is supported, then the Trusted OS guarantees that neither the REE, nor any other TA, has access to the peripheral. If `TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS` indicates that exclusive access is not supported, the calling TA SHOULD assume that it does not have exclusive access to the peripheral.

The Trusted OS returns handles which can be used by the TA to manage interactions with the peripheral. If `TEE_Peripheral_Open` succeeds, at least one of `peripheralHandle` and `eventSourceHandle` is set to a valid handle value.

It is an error to call `TEE_Peripheral_Open` for a peripheral which is already owned by the calling TA instance.

Specification Number: 10 **Function Number:** 0x2006

Parameters

- `peripheralDescriptor`: A pointer to a `TEE_PeripheralDescriptor` structure. The fields of the structure pointed to are used as follows:
  - `id`: This is the unique identifier for a specific peripheral, as returned by `TEE_Peripheral_GetPeripherals`. This field SHALL be set on entry, and SHALL be unchanged on return.
  - `peripheralHandle`: On entry, the value is ignored and will be overwritten. On return, the value is set as follows:
    - `TEE_INVALID_HANDLE`: This peripheral does not support the Peripheral API.
    - Other value: An opaque handle which can be used with the Peripheral API functions.
  - `eventSourceHandle`: On entry, the value is ignored and will be overwritten. On return, the value is set as follows:
    - `TEE_INVALID_HANDLE`: This peripheral does not support the Event API.
    - Other value: An opaque handle which can be used with the Event API functions.

Return Code

- `TEE_SUCCESS`: In case of success. At least one of `peripheralHandle` and `eventSourceHandle` points to a valid handle.
- `TEE_ERROR_BAD_PARAMETERS`: `peripheral is NULL`.

- TEE_ERROR_ACCESS_DENIED: If the system was unable to acquire exclusive access to a peripheral for which TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS indicates exclusive access is possible.

Panic Reasons

- If peripheral->id is not known to the system.
- If peripheral->id is already owned by the calling TA instance.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.7.7 TEE_Peripheral_OpenMultiple

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_OpenMultiple(
         const    uint32_t                  numPeripherals,
         [inout]  TEE_PeripheralDescriptor *peripheralDescriptors
      );
#endif
```

Description

The TEE_Peripheral_OpenMultiple function is used by a TA to atomically obtain access to multiple peripherals.

TEE_Peripheral_OpenMultiple behaves as though a call to TEE_Peripheral_Open is made to each TEE_PeripheralDescriptor in peripherals in turn, but ensures that all or none of the peripherals have open descriptors on return. This function should be used where a TA needs simultaneous control of multiple peripherals to operate correctly.

If this function executes successfully, the Trusted OS guarantees that neither the REE, nor any other TA, has access to any requested peripheral for which exclusive access is supported (as indicated by TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS). If an error is returned, the Trusted OS guarantees that no handle is open for any of the requested peripherals.

The Trusted OS returns handles which can be used by the TA to manage interactions with the peripheral. If TEE_Peripheral_OpenMultiple succeeds, at least one of peripheralHandle and eventSourceHandle fields in each descriptor is set to a valid handle value. If an error is returned, all the peripheralHandle and eventSourceHandle fields in each descriptor SHALL contain TEE_INVALID_HANDLE.

Specification Number: 10 **Function Number:** 0x2007

Parameters

- numPeripherals: The number of entries in the TEE_PeripheralDescriptor buffer pointed to by peripherals.
- peripheralDescriptors: A pointer to a buffer of numPeripherals instances of TEE_PeripheralDescriptor. The interpretation and treatment of each individual entry in the buffer of descriptors is as described for TEE_Peripheral_Open in section 9.7.6.

Return Code

- TEE_SUCCESS: In case of success. At least one of peripheralHandle and eventSourceHandle points to a valid handle in every entry in peripherals.
- TEE_ERROR_BAD_PARAMETERS: peripherals is NULL and/or numPeripherals is 0.
- TEE_ERROR_ACCESS_DENIED: If the system was unable to acquire exclusive access to all the requested peripherals.

Panic Reasons

- If peripheralDescriptors[x].id for any instance, x, of TEE_PeripheralDescriptor is not known to the system.

- If `peripheralDescriptors[x].id` for any instance, `x`, of `TEE_PeripheralDescriptor` is already owned by the calling TA.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.7.8 TEE_Peripheral_Read

Since: TEE Internal Core API v1.2 – See Backward Compatibility note below.

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_Read(
         [in]      TEE_PeripheralHandle peripheralHandle,
         [outbuf]  void *buf,   size_t *bufSize
      );
#endif
```

Description

The `TEE_Peripheral_Read` function provides a low-level API to read data from the peripheral denoted by `peripheralHandle`. The `peripheralHandle` field of the peripheral descriptor must be a valid handle for this function to succeed.

The calling TA allocates a buffer of `bufSize` bytes before calling. On return, this will contain as much data as is available from the peripheral, up to the limit of `bufSize`. The `bufSize` parameter will be updated with the actual number of bytes placed into `buf`.

`TEE_Peripheral_Read` is designed to allow a TA to implement polled communication with peripherals. The function SHALL NOT wait on any hardware signal and SHALL retrieve only the data which is available at the time of calling.

While some peripherals may support both the event queue and the polling interface, it is recommended that TA implementers do not attempt to use both polling and the event queue to read data from the same peripheral. Peripheral behavior if both APIs are used on the same peripheral is undefined.

Note: Depending on the use case, polled interfaces can result in undesirable power consumption profiles.

Specification Number: 10 **Function Number:** 0x2008

Parameters

- `peripheralHandle`: A valid `TEE_PeripheralHandle` for the peripheral from which the TA wishes to read data.
- `buf`: A buffer of at least `bufSize` bytes which, on successful return, will be overwritten with data read back from the peripheral.
- `bufSize`:
  - On entry, the size of `buf` in bytes.
  - On return, the actual number of bytes read from the peripheral. The combination of `buf` and `bufSize` complies with the *`[outbuf]`* behavior specified in section 3.4.4.

Return Code

- `TEE_SUCCESS`: Data has been read from the peripheral. The value of `bufSize` indicates the number of bytes read.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is not large enough to hold all the sources.
- `TEE_ERROR_EXCESS_DATA`: Data was read successfully, but the peripheral has more data available to read. In this case, `bufSize` is the same value as was indicated when the function was called. It is recommended that the TA read back the remaining data from the peripheral before continuing.

- `TEE_ERROR_BAD_PARAMETERS`: The value of `peripheralHandle` is `TEE_INVALID_HANDLE`; or `buf` is `NULL` and `bufSize` is not zero.

Panic Reasons

- If the calling TA does not provide a valid `peripheralHandle`.
- See section 3.4.4 for reasons for *[outbuf]* generated panic.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

[TEE TUI Low] v1.0 did not include the `TEE_ERROR_SHORT_BUFFER` return value.

9.7.9 TEE_Peripheral_SetState

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_SetState(
      const TEE_PeripheralHandle    handle,
      const TEE_PeripheralStateId   stateId,
      const TEE_PeripheralValueType periphType,
      const void*                   value
  );
#endif
```

Description

The `TEE_Peripheral_SetState` function enables a TA to set the value of a writeable peripheral state item. Items are only writeable if the `ro` field of the `TEE_PeripheralState` for the state item is `false`. The value of the `ro` field can change between a call to `TEE_Peripheral_GetState` and a subsequent call to `TEE_Peripheral_SetState`.

TAs SHOULD call `TEE_Peripheral_GetStateTable` for the peripheral id in question to determine which state items are writeable by the TA.

Note that any previous snapshot of peripheral state will not be updated after a call to `TEE_Peripheral_SetState`.

Specification Number: 10 **Function Number:** 0x2009

Parameters

- `handle`: A valid open handle for the peripheral whose state is to be updated.
- `stateId`: The identifier for the state item for which the value is requested.
- `periphType`: A value of `TEE_PeripheralValueType` which determines how the data pointed to by `value` should be interpreted.
- `value`: The address of the value to be written to the state item.

Return Code

- `TEE_SUCCESS`: State information has been updated.
- `TEE_ERROR_BAD_PARAMETERS`: The value of one or both of `handle` or `stateId` are not valid for this TA; or `periphType` is not a value defined in `TEE_PeripheralValueType`; or `value` is `NULL`; or the value which is being written is read-only.

Panic Reasons

`TEE_Peripheral_SetState` SHALL NOT panic.

9.7.10 TEE_Peripheral_Write

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Peripheral_Write(
         [in]      TEE_PeripheralHandle peripheralHandle,
         [inbuf]   void *buf,   size_t bufSize
     );
#endif
```

Description

The `TEE_Peripheral_Write` function provides a low-level API to write data to the peripheral denoted by `peripheralHandle`. The `peripheralHandle` field of the peripheral descriptor must be a valid handle for this function to succeed.

The calling TA allocates a buffer of `bufSize` bytes before calling and fills it with the data to be written.

Specification Number: 10 **Function Number:** 0x200A

Parameters

- `peripheralHandle`: A valid `TEE_PeripheralHandle` for the peripheral from which the TA wishes to read data.
- `buf`: A buffer of at least `bufSize` bytes containing data which has, on successful return, been written to the peripheral.
- `bufSize`: The size of `buf` in bytes.

Return Code

- `TEE_SUCCESS`: Data has been written to the peripheral.
- `TEE_ERROR_BAD_PARAMETERS`: `buf` is `NULL` and/or `bufSize` is `0`.

Panic Reasons

- If `peripheralHandle` is not a valid open handle to a peripheral.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8 Event API Functions

9.8.1 TEE_Event_AddSources

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_AddSources(
               uint32_t                numSources,
         [in]  TEE_EventSourceHandle   *sources,
         [in]  TEE_EventQueueHandle     *handle
  );
#endif
```

Description

The `TEE_Event_AddSources` function atomically adds new event sources to an existing queue acquired by a call to `TEE_Event_OpenQueue`. If the function succeeds, events from this source are exclusively available to this queue.

If the function fails, the queue is still valid. The queue SHALL contain events from the original sources and MAY contain some of the requested sources. In case of error, the caller should use `TEE_Event_ListSources` to determine the current state of the queue.

It is not an error to add an event source to a queue to which it is already attached.

Specification Number: 10 **Function Number:** 0x2101

Parameters

- `numSources`: Defines how many sources are provided.
- `sources`: An array of `TEE_EventSourceHandle` that the TA wants to add to the queue.
- `handle`: The handle for the queue.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_BAD_STATE`: If the handle does not represent a currently open queue.
- `TEE_ERROR_BUSY`: If any requested resource cannot be reserved.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.
- `TEE_ERROR_OUT_OF_MEMORY`: If the system ran out of resources.

Panic Reasons

- If `handle` is invalid.
- If the `sources` array does not contain `numSources` elements.
- If any pointer in `sources` is `NULL`.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8.2 TEE_Event_CancelSources

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_CancelSources(
               uint32_t                numSources,
         [in]  TEE_EventSourceHandle *sources,
         [in]  TEE_EventQueueHandle   *handle
);
#endif
```

Description

The `TEE_Event_CancelSources` function drops all existing events from a set of sources from a queue previously acquired by a call to `TEE_Event_OpenQueue`.

New events from these sources will continue to be added to the queue, unless the TA has released the sources using `TEE_Event_DropSources` or `TEE_Event_CloseQueue`.

It is not an error to cancel an event source that is not currently attached to the queue.

Specification Number: 10 **Function Number:** 0x2102

Parameters

- `numSources`: Defines how many sources are provided.
- `sources`: An array of `TEE_EventSourceHandle`. Events from these sources are cleared from the queue.
- `handle`: The handle for the queue.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OUT_OF_MEMORY`: If the system ran out of resources.
- `TEE_ERROR_BAD_STATE`: If the handle does not represent a currently open queue.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.

Panic Reasons

- If `handle` is invalid.
- If the `sources` array does not contain `numSources` elements.
- If any pointer in `sources` is `NULL`.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8.3 TEE_Event_CloseQueue

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_CloseQueue( [in] TEE_EventQueueHandle *handle );
#endif
```

Description

The `TEE_Event_CloseQueue` function releases resources previously acquired by a call to `TEE_Event_OpenQueue`.

All outstanding events on the queue will be invalidated.

Specification Number: 10 **Function Number:** 0x2103

Parameters

- `handle`: The handle to the `TEE_EventQueueHandle` to close.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_BAD_STATE`: If the handle does not represent a currently open queue.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.

Panic Reasons

- If `handle` is invalid.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8.4 TEE_Event_DropSources

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_DropSources(
                 uint32_t                 numSources,
          [in]   TEE_EventSourceHandle   *sources,
          [in]   TEE_EventQueueHandle     *handle
  );
#endif
```

Description

The TEE_Event_DropSources function removes one or more event sources from an existing queue previously acquired by a call to TEE_Event_OpenQueue. No more events from these sources are added to the queue. Events from these sources will be available to the REE, until they are reserved by this or another TA using TEE_Event_AddSources or TEE_Event_OpenQueue.

Events from other event sources will continue to be added to the queue. It is permissible to have a queue with no current event sources attached to it.

It is not an error to drop an event source that is not currently attached to the queue.

Specification Number: 10 **Function Number:** 0x2104

Parameters

- numSources: Defines how many sources are provided.
- sources: An array of TEE_EventSourceHandle. Events from these sources are cleared from the queue.
- handle: The handle for the queue.

Return Code

- TEE_SUCCESS: In case of success.
- TEE_ERROR_BAD_STATE: If the handle does not represent a currently open queue.
- TEE_ERROR_ITEM_NOT_FOUND: If one or more sources was not attached to the queue. All other sources are dropped.
- TEE_ERROR_EXTERNAL_CANCEL: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.

Panic Reasons

- If handle is invalid.
- If the sources array does not contain numSources elements.
- If any pointer in sources is NULL.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8.5 TEE_Event_ListSources

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_ListSources(
        [in]       TEE_EventQueueHandle    *handle,
        [outbuf]   TEE_EventSourceHandle   *sources, size_t* bufSize
  );
#endif
```

Description

The `TEE_Event_ListSources` function returns information about sources currently attached to a queue.

Specification Number: 10 **Function Number:** 0x2105

Parameters

- `handle`: The handle for the queue.
- `sources`: A buffer of at least `bufSize` bytes that on successful return is overwritten with an array of `TEE_EventSourceHandle` structures.
- `bufSize`:
  - On entry, the size of `sources` in bytes.
  - On return, the actual number of bytes in the array. The combination of `sources` and `bufSize` complies with the *[outbuf]* behavior specified in section 3.4.4.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_OUT_OF_MEMORY`: If the system ran out of resources.
- `TEE_ERROR_SHORT_BUFFER`: If the output buffer is not large enough to hold all the sources.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.

Panic Reasons

- If `handle` is invalid.
- If `bufSize` is `NULL`.
- If `sources` is `NULL`.
- See section 3.4.4 for reasons for *[outbuf]* generated panic.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

9.8.6 TEE_Event_OpenQueue

Since: TEE Internal Core API v1.3 – See Backward Compatibility statement below.

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_OpenQueue(
      [inout]     uint32_t               *version,
                  uint32_t                numSources,
                  uint32_t                timeout,
      [in]        TEE_EventSourceHandle  *sources,
      [out]       TEE_EventQueueHandle   *handle
  );
#endif
```

Description

The `TEE_Event_OpenQueue` function claims an exclusive access to resources for the current TA instance.

This function allows for multiple event sources to be reserved.

It is possible for multiple TAs to open queues at the same time provided they do not try to reserve any of the same resources.

An individual TA SHALL NOT open multiple queues; instead, the TA SHOULD use `TEE_Event_AddSources` and `TEE_Event_DropSources` to add and remove event sources from the queue.

The `TEE_EventQueue` will be closed automatically if no calls to `TEE_Event_Wait` are made for timeout milliseconds. This has the same guarantees as the `TEE_Wait` function.

Specification Number: 10 **Function Number:** 0x2106

Parameters

- `version`:
  - On entry, the highest version of the `TEE_Event` structure understood by the calling program.
  - On return, the actual version of the `TEE_Event` structure that will be added to the queue, which may be lower than the value requested.
- `numSources`: Defines how many sources are provided.
- `timeout`: The timeout for this function in milliseconds.
- `sources`: An array of `TEE_EventSourceHandle`, as returned from `TEE_Event_ListSources`.
- `handle`: The handle for this queue. This value SHOULD be zero on entry. It is set if this function successfully claims an exclusive access to the resources for the current TA instance and `numSources` is not zero.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_BUSY`: If any requested resource cannot be reserved.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.
- `TEE_ERROR_UNSUPPORTED_VERSION`: If the version of the `TEE_Event` structure requested is not supported.

- TEE_ERROR_OUT_OF_MEMORY: If the system ran out of resources.

Panic Reasons

- If version is invalid.
- If handle is NULL.
- If the sources array does not contain numSources elements.
- If any pointer in sources is NULL.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

Backward Compatibility

Prior to TEE Internal Core API v1.3, TEE_ERROR_OLD_VERSION was returned if the version of the TEE_Event structure requested is not supported. This return code has been renamed TEE_ERROR_UNSUPPORTED_VERSION; however, the value remains unchanged.

9.8.7 TEE_Event_TimerCreate

Since: TEE Internal Core API v1.2

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_TimerCreate(
    [in] TEE_EventQueueHandle *handle,
    [in] uint64_t             period,
    [in] uint8_t              payload[TEE_MAX_EVENT_PAYLOAD_SIZE]
  );
#endif
```

Description

The `TEE_Event_TimerCreate` function creates a one-shot timer which, on expiry, will cause `TEE_Event_Timer` to be placed onto the event queue designated by `handle`.

Although the accuracy of `period` cannot be guaranteed, events are timestamped if the TA requires an accurate measure of the time between events.

Specification Number: 10 **Function Number:** 0x2108

Parameters

- `handle`: The handle for the queue.
- `period`: The minimum timer period in milliseconds. The accuracy of the timer period is subject to the constraints of `TEE_Wait` (see section 7.2.2).
- `payload`: A payload chosen by the TA which is returned in the `TEE_Event_Timer` payload when the timer expires.

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_BUSY`: If any requested resource cannot be reserved.
- `TEE_ERROR_OUT_OF_MEMORY`: If the system ran out of resources.

Panic Reasons

- If `handle` is invalid.

9.8.8 TEE_Event_Wait

Since: TEE Internal Core API v1.2 (originally defined identically in [TEE TUI Low] v1.0)

```
#if defined(TEE_CORE_API_EVENT)
  TEE_Result TEE_Event_Wait(
    [in]       TEE_EventQueue  *handle,
               uint32_t        timeout,
    [inout]    TEE_Event       *events,
    [inout]    uint32_t        *numEvents,
    [out]      uint32_t        *dropped
);
#endif
```

Description

The `TEE_Event_Wait` function fetches events that have been returned from a peripheral reserved by `TEE_Event_OpenQueue`. Events are not guaranteed to be delivered as the event queue has a finite size. If the event queue is full, the oldest event(s) SHALL be dropped first, and the dropped event count SHALL be updated with the number of dropped events. Events MAY also be dropped out of order for reasons outside the scope of this specification, but the dropped event count SHOULD reflect this.

The API allows one or more events to be obtained at a time to minimize any context switching overhead, and to allow a TA to process bursts of events en masse.

Obtaining events has a timeout, allowing a TA with more responsibilities than just user interaction to attend to these periodically without needing to use multi-threading.

The `TEE_Event_Wait` function opens the input event stream. If the stream is not available for exclusive access within the specified timeout, an error is returned. A zero timeout means this function returns immediately. This has the same guarantees as the `TEE_Wait` function.

Events are returned in order of decreasing age: `events[0]` is the oldest available event, `events[1]` the next oldest, etc.

On entry, `*numEvents` contains the number of events pointed to by `events`.

`*numEvents` can be `0` on entry, which allows the TA to query whether input is available. If timeout == `0`, the function should return `TEE_SUCCESS` if there are pending events and `TEE_ERROR_TIMEOUT` if there is no pending event.

On return, `*numEvents` contains the actual number of events written to `events`.

If the function returns with any status other than `TEE_SUCCESS`, `*numEvents` = `0`.

If there are no events available in the given timeout, `*numEvents` is set to zero and this function returns an error.

If any events occur, the function returns as soon as possible, and does not wait until `*numEvents` events have occurred.

If `dropped` is non-`NULL`, the current count of dropped events is written to this location.

This function is cancellable. If the cancelled flag of the current instance is set and the TA has unmasked the effects of cancellation, then this function returns earlier than the requested timeout.

- If the operation was cancelled by the client, `TEE_ERROR_CANCEL` is returned. See section 4.10 for more details about cancellations.
- If the cancellation was not sourced by the client, the TEE SHOULD cancel the function and `TEE_ERROR_EXTERNAL_CANCEL` is returned.

Specification Number: 10 **Function Number:** 0x2107

Parameters

- `handle`: The handle for the queue
- `timeout`: The timeout in milliseconds
- `events`: A pointer to an array of `TEE_Event` structures
- `numEvents`:
  - On entry, the maximum number of events to return
  - On return, the actual number of events returned
- `dropped`: A pointer to a count of dropped events

Return Code

- `TEE_SUCCESS`: In case of success.
- `TEE_ERROR_BAD_STATE`: If `handle` does not represent a currently open queue.
- `TEE_ERROR_TIMEOUT`: If there is no event to return within the timeout.
- `TEE_ERROR_EXTERNAL_CANCEL`: If the operation has been cancelled by an external event which occurred in the REE while the function was in progress.
- `TEE_ERROR_CANCEL`: If the operation was cancelled by anything other than an event in the REE.

Panic Reasons

- If `handle` is invalid.
- If `events` is `NULL`.
- If `numEvents` is `NULL`.
- If `dropped` is `NULL`.
- If the implementation detects any error associated with the execution of this function that is not explicitly associated with a defined return code for this function.

6848 # Annex A Panicked Function Identification

6849 If this specification is used in conjunction with [TEE TA Debug], then the specification number is 10 and the
6850 values listed in the following table SHALL be associated with the function declared.

6851 **Table A-1: Function Identification Values**

Category	Function	Function Number in hexadecimal	Function Number in decimal
TA Interface	`TA_CloseSessionEntryPoint`	`0x101`	`257`
	`TA_CreateEntryPoint`	`0x102`	`258`
	`TA_DestroyEntryPoint`	`0x103`	`259`
	`TA_InvokeCommandEntryPoint`	`0x104`	`260`
	`TA_OpenSessionEntryPoint`	`0x105`	`261`
Property Access	`TEE_AllocatePropertyEnumerator`	`0x201`	`513`
	`TEE_FreePropertyEnumerator`	`0x202`	`514`
	`TEE_GetNextProperty`	`0x203`	`515`
	`TEE_GetPropertyAsBinaryBlock`	`0x204`	`516`
	`TEE_GetPropertyAsBool`	`0x205`	`517`
	`TEE_GetPropertyAsIdentity`	`0x206`	`518`
	`TEE_GetPropertyAsString`	`0x207`	`519`
	`TEE_GetPropertyAsU32`	`0x208`	`520`
	`TEE_GetPropertyAsUUID`	`0x209`	`521`
	`TEE_GetPropertyName`	`0x20A`	`522`
	`TEE_ResetPropertyEnumerator`	`0x20B`	`523`
	`TEE_StartPropertyEnumerator`	`0x20C`	`524`
	`TEE_GetPropertyAsU64`	`0x20D`	`525`
Panic Function	`TEE_Panic`	`0x301`	`769`
Internal Client API	`TEE_CloseTASession`	`0x401`	`1025`
	`TEE_InvokeTACommand`	`0x402`	`1026`
	`TEE_OpenTASession`	`0x403`	`1027`
Cancellation	`TEE_GetCancellationFlag`	`0x501`	`1281`
	`TEE_MaskCancellation`	`0x502`	`1282`
	`TEE_UnmaskCancellation`	`0x503`	`1283`

Category	Function	Function Number in hexadecimal	Function Number in decimal
Memory Management	TEE_CheckMemoryAccessRights	0x601	1537
	TEE_Free	0x602	1538
	TEE_GetInstanceData	0x603	1539
	TEE_Malloc	0x604	1540
	TEE_MemCompare	0x605	1541
	TEE_MemFill	0x606	1542
	TEE_MemMove	0x607	1543
	TEE_Realloc	0x608	1544
	TEE_SetInstanceData	0x609	1545
Generic Object	TEE_CloseObject	0x701	1793
	TEE_GetObjectBufferAttribute	0x702	1794
	TEE_GetObjectInfo (deprecated)	0x703	1795
	TEE_GetObjectValueAttribute	0x704	1796
	TEE_RestrictObjectUsage (deprecated)	0x705	1797
	TEE_GetObjectInfo1	0x706	1798
	TEE_RestrictObjectUsage1	0x707	1799
Transient Object	TEE_AllocateTransientObject	0x801	2049
	TEE_CopyObjectAttributes (deprecated)	0x802	2050
	TEE_FreeTransientObject	0x803	2051
	TEE_GenerateKey	0x804	2052
	TEE_InitRefAttribute	0x805	2053
	TEE_InitValueAttribute	0x806	2054
	TEE_PopulateTransientObject	0x807	2055
	TEE_ResetTransientObject	0x808	2056
	TEE_CopyObjectAttributes1	0x809	2057
Persistent Object	TEE_CloseAndDeletePersistentObject (deprecated)	0x901	2305
	TEE_CreatePersistentObject	0x902	2306
	TEE_OpenPersistentObject	0x903	2307
	TEE_RenamePersistentObject	0x904	2308
	TEE_CloseAndDeletePersistentObject1	0x905	2309

Category	Function	Function Number in hexadecimal	Function Number in decimal
Persistent Object Enumeration	TEE_AllocatePersistentObjectEnumerator	0xA01	2561
	TEE_FreePersistentObjectEnumerator	0xA02	2562
	TEE_GetNextPersistentObject	0xA03	2563
	TEE_ResetPersistentObjectEnumerator	0xA04	2564
	TEE_StartPersistentObjectEnumerator	0xA05	2565
Data Stream Access	TEE_ReadObjectData	0xB01	2817
	TEE_SeekObjectData	0xB02	2818
	TEE_TruncateObjectData	0xB03	2819
	TEE_WriteObjectData	0xB04	2820
Generic Operation	TEE_AllocateOperation	0xC01	3073
	TEE_CopyOperation	0xC02	3074
	TEE_FreeOperation	0xC03	3075
	TEE_GetOperationInfo	0xC04	3076
	TEE_ResetOperation	0xC05	3077
	TEE_SetOperationKey	0xC06	3078
	TEE_SetOperationKey2	0xC07	3079
	TEE_GetOperationInfoMultiple	0xC08	3080
	TEE_IsAlgorithmSupported	0xC09	3081
Message Digest	TEE_DigestDoFinal	0xD01	3329
	TEE_DigestUpdate	0xD02	3330
	TEE_DigestExtract	0xD03	3331
Symmetric Cipher	TEE_CipherDoFinal	0xE01	3585
	TEE_CipherInit	0xE02	3586
	TEE_CipherUpdate	0xE03	3587
MAC	TEE_MACCompareFinal	0xF01	3841
	TEE_MACComputeFinal	0xF02	3842
	TEE_MACInit	0xF03	3843
	TEE_MACUpdate	0xF04	3844
Authenticated Encryption	TEE_AEDecryptFinal	0x1001	4097
	TEE_AEEncryptFinal	0x1002	4098
	TEE_AEInit	0x1003	4099
	TEE_AEUpdate	0x1004	4100
	TEE_AEUpdateAAD	0x1005	4101

Category	Function	Function Number in hexadecimal	Function Number in decimal
Asymmetric	TEE_AsymmetricDecrypt	0x1101	4353
	TEE_AsymmetricEncrypt	0x1102	4354
	TEE_AsymmetricSignDigest	0x1103	4355
	TEE_AsymmetricVerifyDigest	0x1104	4356
Key Derivation	TEE_DeriveKey	0x1201	4609
Random Data Generation	TEE_GenerateRandom	0x1301	4865
Time	TEE_GetREETime	0x1401	5121
	TEE_GetSystemTime	0x1402	5122
	TEE_GetTAPersistentTime	0x1403	5123
	TEE_SetTAPersistentTime	0x1404	5124
	TEE_Wait	0x1405	5125
Memory Allocation and Size of Objects	TEE_BigIntFMMSizeInU32	0x1501	5377
	TEE_BigIntFMMContextSizeInU32	0x1502	5378
Initialization	TEE_BigIntInit	0x1601	5633
	TEE_BigIntInitFMM	0x1602	5634
	TEE_BigIntInitFMMContext (deprecated)	0x1603	5635
	TEE_BigIntInitFMMContext1	0x1604	5636
Converter	TEE_BigIntConvertFromOctetString	0x1701	5889
	TEE_BigIntConvertFromS32	0x1702	5890
	TEE_BigIntConvertToOctetString	0x1703	5891
	TEE_BigIntConvertToS32	0x1704	5892
Logical Operation	TEE_BigIntCmp	0x1801	6145
	TEE_BigIntCmpS32	0x1802	6146
	TEE_BigIntGetBit	0x1803	6147
	TEE_BigIntGetBitCount	0x1804	6148
	TEE_BigIntShiftRight	0x1805	6149
	TEE_BigIntSetBit	0x1806	6150
	TEE_BigIntAssign	0x1807	6151
	TEE_BigIntAbs	0x1808	6152

Category	Function	Function Number in hexadecimal	Function Number in decimal
Basic Arithmetic	TEE_BigIntAdd	0x1901	6401
	TEE_BigIntDiv	0x1902	6402
	TEE_BigIntMul	0x1903	6403
	TEE_BigIntNeg	0x1904	6404
	TEE_BigIntSquare	0x1905	6405
	TEE_BigIntSub	0x1906	6406
Modular Arithmetic	TEE_BigIntAddMod	0x1A01	6657
	TEE_BigIntInvMod	0x1A02	6658
	TEE_BigIntMod	0x1A03	6659
	TEE_BigIntMulMod	0x1A04	6660
	TEE_BigIntSquareMod	0x1A05	6661
	TEE_BigIntSubMod	0x1A06	6662
	TEE_BigIntExpMod	0x1A07	6663
Other Arithmetic	TEE_BigIntComputeExtendedGcd	0x1B01	6913
	TEE_BigIntIsProbablePrime	0x1B02	6914
	TEE_BigIntRelativePrime	0x1B03	6915
Fast Modular Multiplication	TEE_BigIntComputeFMM	0x1C01	7169
	TEE_BigIntConvertFromFMM	0x1C02	7170
	TEE_BigIntConvertToFMM	0x1C03	7171
Peripherals	TEE_Peripheral_Close	0x2001	8193
	TEE_Peripheral_CloseMultiple	0x2002	8194
	TEE_Peripheral_GetPeripherals	0x2003	8195
	TEE_Peripheral_GetState	0x2004	8196
	TEE_Peripheral_GetStateTable	0x2005	8197
	TEE_Peripheral_Open	0x2006	8198
	TEE_Peripheral_OpenMultiple	0x2007	8199
	TEE_Peripheral_Read	0x2008	8200
	TEE_Peripheral_SetState	0x2009	8201
	TEE_Peripheral_Write	0x200A	8202

Category	Function	Function Number in hexadecimal	Function Number in decimal
Events	TEE_Event_AddSources	0x2101	8449
	TEE_Event_CancelSources	0x2102	8450
	TEE_Event_CloseQueue	0x2103	8451
	TEE_Event_DropSources	0x2104	8452
	TEE_Event_ListSources	0x2105	8453
	TEE_Event_OpenQueue	0x2106	8454
	TEE_Event_Wait	0x2107	8455
	TEE_Event_TimerCreate	0x2108	8456

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Annex B Deprecated Functions, Identifiers, Properties, and Attributes

B.1 Deprecated Functions

The functions in this section are deprecated and have been replaced by new functions as noted in their descriptions. These functions will be removed at some future major revision of this specification.

Backward Compatibility

While new TA code SHOULD use the new functions, the old functions SHALL be present in an implementation until removed from the specification.

B.1.1 TEE_GetObjectInfo – Deprecated

```
void TEE_GetObjectInfo(
         TEE_ObjectHandle      object,
   [out] TEE_ObjectInfo*       objectInfo );
```

Description

Since: TEE Internal API v1.0; deprecated in TEE Internal Core API v1.1

Use of this function is deprecated – new code SHOULD use the `TEE_GetObjectInfo1` function instead.

The `TEE_GetObjectInfo` function returns the characteristics of an object. It fills in the following fields in the structure `TEE_ObjectInfo`:

- `objectType`: The parameter `objectType` passed when the object was created. If the object is corrupt then this field is set to `TEE_TYPE_CORRUPTED_OBJECT` and the rest of the fields are set to `0`.
- `objectSize`: Set to `0` for an uninitialized object
- `maxObjectSize`
  - For a persistent object, set to `keySize`
  - For a transient object, set to the parameter `maxKeySize` passed to `TEE_AllocateTransientObject`
- `objectUsage`: A bit vector of the `TEE_USAGE_XXX` bits defined in Table 5-4. Initially set to `0xFFFFFFFF`.
- `dataSize`
  - For a persistent object, set to the current size of the data associated with the object
  - For a transient object, always set to `0`
- `dataPosition`
  - For a persistent object, set to the current position in the data for this handle. Data positions for different handles on the same object may differ.
  - For a transient object, set to `0`
- `handleFlags`: A bit vector containing one or more of the following flags:
  - `TEE_HANDLE_FLAG_PERSISTENT`: Set for a persistent object
  - `TEE_HANDLE_FLAG_INITIALIZED`

        - For a persistent object, always set
        - For a transient object, initially cleared, then set when the object becomes initialized
    - `TEE_DATA_FLAG_XXX`: Only for persistent objects, the flags used to open or create the object

Parameters

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

Specification Number: 10 **Function Number:** 0x703

Panic Reasons

- If `object` is not a valid opened object handle.
- If the implementation detects any other error.

B.1.2 TEE_RestrictObjectUsage – Deprecated

```
void TEE_RestrictObjectUsage(
   TEE_ObjectHandle  object,
   uint32_t          objectUsage );
```

Description

Since: TEE Internal API v1.0; deprecated in TEE Internal Core API v1.1

Use of this function is deprecated – new code SHOULD use the `TEE_RestrictObjectUsage1` function instead.

The `TEE_RestrictObjectUsage` function restricts the object usage flags of an object handle to contain at most the flags passed in the `objectUsage` parameter.

For each bit in the parameter `objectUsage`:

- If the bit is set to 1, the corresponding usage flag in the object is left unchanged.
- If the bit is set to `0`, the corresponding usage flag in the object is cleared.

For example, if the usage flags of the object are set to `TEE_USAGE_ENCRYPT | TEE_USAGE_DECRYPT` and if `objectUsage` is set to `TEE_USAGE_ENCRYPT | TEE_USAGE_EXTRACTABLE`, then the only remaining usage flag in the object after calling the function `TEE_RestrictObjectUsage` is `TEE_USAGE_ENCRYPT`.

Note that an object usage flag can only be cleared. Once it is cleared, it cannot be set to 1 again on a persistent object.

A transient object's object usage flags are reset using the `TEE_ResetTransientObject` function. For a transient object, resetting the object also clears all the key material stored in the container.

For a persistent object, setting the object usage SHALL be an atomic operation.

If the supplied object is persistent and corruption is detected then this function does nothing and returns. The object handle is not closed since the next use of the handle will return the corruption and delete it.

Parameters

- `object`: Handle on an object
- `objectUsage`: New object usage, an OR combination of one or more of the `TEE_USAGE_XXX` constants defined in Table 5-4

Specification Number: 10 **Function Number:** 0x705

Panic Reasons

- If `object` is not a valid opened object handle.
- If the implementation detects any other error.

B.1.3 TEE_CopyObjectAttributes – Deprecated

```
void TEE_CopyObjectAttributes(
          TEE_ObjectHandle destObject,
          TEE_ObjectHandle srcObject );
```

Description

Since: TEE Internal API v1.0; deprecated in TEE Internal Core API v1.1

Use of this function is deprecated – new code SHOULD use the `TEE_CopyObjectAttributes1` function instead.

The `TEE_CopyObjectAttributes` function populates an uninitialized object handle with the attributes of another object handle; that is, it populates the attributes of `destObject` with the attributes of `srcObject`. It is most useful in the following situations:

- To extract the public key attributes from a key-pair object
- To copy the attributes from a persistent object into a transient object

`destObject` SHALL refer to an uninitialized object handle and SHALL therefore be a transient object.

The source and destination objects SHALL have compatible types and sizes in the following sense:

- The type of `destObject` SHALL be a subtype of `srcObject`, i.e. one of the conditions listed in Table 5-11 SHALL be true.
- The size of `srcObject` SHALL be less than or equal to the maximum size of `destObject`.

The effect of this function on `destObject` is identical to the function `TEE_PopulateTransientObject` except that the attributes are taken from `srcObject` instead of from parameters.

The object usage of `destObject` is set to the bitwise AND of the current object usage of `destObject` and the object usage of `srcObject`.

If the source object is corrupt then this function copies no attributes and leaves the target object uninitialized.

Parameters

- `destObject`: Handle on an uninitialized transient object
- `srcObject`: Handle on an initialized object

Specification Number: 10 **Function Number:** 0x802

Panic Reasons

- If `srcObject` is not initialized.
- If `destObject` is initialized.
- If the type and size of `srcObject` and `destObject` are not compatible.
- If the implementation detects any other error.

B.1.4 TEE_CloseAndDeletePersistentObject – Deprecated

```
void TEE_CloseAndDeletePersistentObject( TEE_ObjectHandle object );
```

Description

Since: TEE Internal API v1.0; deprecated in TEE Internal Core API v1.1

Use of this function is deprecated – new code SHOULD use the `TEE_CloseAndDeletePersistentObject1` function instead.

The `TEE_CloseAndDeletePersistentObject` function marks an object for deletion and closes the object handle.

The object handle SHALL have been opened with the write-meta access right, which means access to the object is exclusive.

Deleting an object is atomic; once this function returns, the object is definitely deleted and no more open handles for the object exist. This SHALL be the case even if the object or the storage containing it have become corrupted.

If the storage containing the object is unavailable then this routine SHALL panic.

If `object` is `TEE_HANDLE_NULL`, the function does nothing.

Parameters

- `object`: The object handle

Specification Number: 10 **Function Number:** 0x901

Panic Reasons

- If `object` is not a valid handle on a persistent object opened with the write-meta access right.
- If the storage containing the object is now inaccessible
- If the implementation detects any other error.

B.1.5 TEE_BigIntInitFMMContext – Deprecated

```
void TEE_BigIntInitFMMContext(
   [out]   TEE_BigIntFMMContext   *context,
           size_t                  len,
   [in]    TEE_BigInt             *modulus );
```

Description

Since: TEE Internal Core API v1.1.1; deprecated in TEE Internal Core API v1.2 – See Backward Compatibility note below.

Use of this function is deprecated – new code SHOULD use the TEE_BigIntInitFMMContext1 function instead.

The TEE_BigIntInitFMMContext function calculates the necessary prerequisites for the fast modular multiplication and stores them in a context. This function assumes that context points to a memory area of len uint32_t. This can be done for example with the following memory allocation:

```
TEE_BigIntFMMContext* ctx;
uint_t len = TEE_BigIntFMMContextSizeInU32(bitsize);
ctx=(TEE_BigIntFMMContext *) TEE_Malloc(len * sizeof(TEE_BigIntFFMContext), 0);
/*Code for initializing modulus*/
…
TEE_BigIntInitFMMContext(ctx, len, modulus);
```

Even though a fast multiplication might be mathematically defined for any modulus, normally there are restrictions in order for it to be fast on a computer. This specification mandates that all implementations SHALL work for all odd moduli larger than 2 and less than 2 to the power of the implementation defined property gpd.tee.arith.maxBigIntSize.

Parameters

- context: A pointer to the TEE_BigIntFMMContext to be initialized
- len: The size in uint32_t of the memory pointed to by context
- modulus: The modulus, an odd integer larger than 2 and less than 2 to the power of gpd.tee.arith.maxBigIntSize

Specification Number: 10 **Function Number:** 0x1603

Panic Reasons

- If the implementation detects any error.

Backward Compatibility

TEE Internal Core API v1.1 used a different type for len.

B.2 Deprecated Object Identifiers

Table B-1 lists deprecated object identifiers and their replacements. The deprecated identifiers will be removed at some future major revision of this specification.

Backward Compatibility

While new TA code SHOULD use the new identifiers, the old identifiers SHALL be recognized in an implementation until removed from the specification.

Table B-1: Deprecated Object Identifiers

Identifier in v1.1	History	Replacement Identifier
`TEE_TYPE_CORRUPTED *`	**Since:** TEE Internal Core API v1.1 Deprecated in TEE Internal Core API v1.1.1	`TEE_TYPE_CORRUPTED_OBJECT`
`TEE_TYPE_CORRUPTED_OBJECT`	**Since:** TEE Internal Core API v1.1 Deprecated in TEE Internal Core API v1.1.1	None (had been used only in a now deprecated function)

* As the value of the deprecated identifier `TEE_TYPE_CORRUPTED` was not previously formally defined, that value SHOULD be the same as the value of the Replacement Identifier. This value can be found in Table 6-13.

B.3 Deprecated Algorithm Identifiers

Table B-2 lists deprecated algorithm identifiers and their replacements. The deprecated identifiers will be removed at some future major revision of this specification.

Backward Compatibility

While new TA code SHOULD use the new identifiers, the old identifiers SHALL be recognized in an implementation until removed from the specification.

Table B-2: Deprecated Algorithm Identifiers

Identifier in v1.1	Replacement Identifier
DSA algorithm identifiers should be tied to the size of the digest, not the key. The key size information is provided with the key material.	
TEE_ALG_DSA_2048_SHA224*	TEE_ALG_DSA_SHA224
TEE_ALG_DSA_2048_SHA256*	TEE_ALG_DSA_SHA256
TEE_ALG_DSA_3072_SHA256*	TEE_ALG_DSA_SHA256
In some cases an incomplete identifier was used for DSA algorithms.	
ALG_DSA_SHA1*	TEE_ALG_DSA_SHA1
ALG_DSA_SHA224*	TEE_ALG_DSA_SHA224
ALG_DSA_SHA256*	TEE_ALG_DSA_SHA256
In some cases the ECDSA algorithm was not sufficiently defined and did not indicate digest size.	
TEE_ALG_ECDSA*	TEE_ALG_ECDSA_SHA512
ECDSA algorithm identifiers should be tied to the size of the digest, not the key. The key size information is provided with the key material.	
TEE_ALG_ECDSA_P192*	TEE_ALG_ECDSA_SHA1
TEE_ALG_ECDSA_P224*	TEE_ALG_ECDSA_SHA224
TEE_ALG_ECDSA_P256*	TEE_ALG_ECDSA_SHA256
TEE_ALG_ECDSA_P384*	TEE_ALG_ECDSA_SHA384
TEE_ALG_ECDSA_P521*	TEE_ALG_ECDSA_SHA512

Identifier in v1.1	Replacement Identifier
A number of algorithm identifier declarations mistakenly included "_NIST" and/or the curve type. The curve type can be found in the key material.	
TEE_ALG_ECDH_NIST_P192_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_NIST_P224_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_NIST_P256_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_NIST_P384_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_NIST_P521_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P192	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P224	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P256	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P384	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P521	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P192_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P224_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P256_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P384_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET
TEE_ALG_ECDH_P521_DERIVE_SHARED_SECRET[+]	TEE_ALG_ECDH_DERIVE_SHARED_SECRET

* As the values of the deprecated algorithm identifiers were not previously formally defined, those values SHOULD be the same as the values of the Replacement Identifier. In each case, this value can be found in Table 6-11.

\+ As the values of the deprecated algorithm identifiers were not previously formally defined. those values SHOULD be the same as the values of the deprecated `TEE_ALG_ECDH_Pxxx` equivalent. In each case, the particular value can be found in Table 6-11.

B.4 Deprecated Properties

Table B-3: Deprecated Properties

Property	History	Replacement
`gpd.tee.apiversion`	**Since:** TEE Internal API v1.0 Deprecated in TEE Internal Core API v1.1.2	Deprecated in favor of `gpd.tee.internalCore.version`.
`gpd.tee.cryptography.ecc`	**Since:** TEE Internal Core API v1.1 Deprecated in TEE Internal Core API v1.2	No direct replacement. The function `TEE_IsAlgorithmSupported` can be used to determine which, if any, ECC curves are supported.

`gpd.tee.trustedStorage.antiRollback.protectionLevel`	**Since:** TEE Internal Core API v1.2
	Deprecated in TEE Internal Core API v1.3
		Deprecated in favor of a rollback protection property for each Trusted Storage Space.
		`gpd.tee.trustedStorage.perso.rollbackProtection`
		`gpd.tee.trustedStorage.private.rollbackProtection`
		`gpd.tee.trustedStorage.protected.rollbackProtection`

`gpd.tee.trustedStorage.rollbackDetection.protectionLevel`	**Since:** TEE Internal Core API v1.1 Deprecated in TEE Internal Core API v1.3	

B.5 Deprecated Object or Operation Attributes

Table B-4: Deprecated Object or Operation Attributes

Attribute	Value	History	Replacement
`TEE_ATTR_ECC_PUBLIC_VALUE_X`	`0xD0000146`	**Since:** TEE Internal Core API v1.2 Renamed in TEE Internal Core API v1.3	`TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_X`
`TEE_ATTR_ECC_PUBLIC_VALUE_Y`	`0xD0000246`	**Since:** TEE Internal Core API v1.2 Renamed in TEE Internal Core API v1.3	`TEE_ATTR_ECC_EPHEMERAL_PUBLIC_VALUE_Y`
`TEE_ATTR_ECC_PRIVATE_VALUE`	`0xD0000346`	**Since:** TEE Internal Core API v1.2 Deprecated in TEE Internal Core API v1.3	Redundant value. The correct value for this Attribute is `0xC0000341`.

Attribute	Value	History	Replacement
TEE_ATTR_ED25519_CTX	0xD0000643	**Since:** TEE Internal Core API v1.2 Deprecated in TEE Internal Core API v1.3	TEE_ATTR_EDDSA_CTX
TEE_ATTR_ED25519_PH	0xF0000543	**Since:** TEE Internal Core API v1.2 Deprecated in TEE Internal Core API v1.3	None.

B.6 Deprecated API Return Codes

Table B-5 lists deprecated return codes and their replacements. The deprecated return codes will be removed at some future major revision of this specification.

Backward Compatibility

While new TA code SHOULD use the new return codes, the old return codes SHALL be recognized in an implementation until removed from the specification.

Table B-5: Deprecated Return Codes

Return Code	History	Replacement Return Code
TEE_ERROR_OLD_VERSION	**Since:** TEE Internal Core API v1.2 Deprecated in TEE Internal Core API v1.3	TEE_ERROR_UNSUPPORTED_VERSION

Annex C Normative References for Algorithms

This annex provides normative references for the algorithms discussed earlier in this document.

Table C-1: Normative References for Algorithms

Name	References	URL

`TEE_ALG_AES_ECB_NOPAD`
`TEE_ALG_AES_CBC_NOPAD`
`TEE_ALG_AES_CTR`
	FIPS 197 (AES)
	NIST SP800-38A (ECB, CBC, CTR)
		http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf
		http://csrc.nist.gov/publications/nistpubs/800-38a/sp800-38a.pdf

`TEE_ALG_AES_CTS`	FIPS 197 (AES) NIST SP800-38A Addendum (CTS = CBC-CS3)	http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf http://csrc.nist.gov/publications/nistpubs/800-38a/addendum-to-nist_sp800-38A.pdf
`TEE_ALG_AES_XTS`	IEEE Std 1619-2007	http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=4493431
`TEE_ALG_AES_CCM`	FIPS 197 (AES) RFC 3610 (CCM)	http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf http://tools.ietf.org/html/rfc3610
`TEE_ALG_AES_GCM`	FIPS 197 (AES) NIST 800-38D (GCM)	http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf http://csrc.nist.gov/publications/nistpubs/800-38D/SP-800-38D.pdf

`TEE_ALG_DES_ECB_NOPAD`
`TEE_ALG_DES_CBC_NOPAD`
`TEE_ALG_DES3_ECB_NOPAD`
`TEE_ALG_DES3_CBC_NOPAD`
	FIPS 46 (DES, 3DES)
	FIPS 81 (ECB, CBC)
		http://csrc.nist.gov/publications/fips/fips46-3/fips46-3.pdf
		http://www.itl.nist.gov/fipspubs/fip81.htm

`TEE_ALG_AES_CBC_MAC_NOPAD`
`TEE_ALG_AES_CBC_MAC_PKCS5`
`TEE_ALG_DES_CBC_MAC_NOPAD`
`TEE_ALG_DES_CBC_MAC_PKCS5`
`TEE_ALG_DES3_CBC_MAC_NOPAD`
`TEE_ALG_DES3_CBC_MAC_PKCS5`
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TEE_ALG_RSASSA_PKCS1_V1_5_MD5 TEE_ALG_RSASSA_PKCS1_V1_5_SHA1 TEE_ALG_RSASSA_PKCS1_V1_5_SHA224 TEE_ALG_RSASSA_PKCS1_V1_5_SHA256 TEE_ALG_RSASSA_PKCS1_V1_5_SHA384 TEE_ALG_RSASSA_PKCS1_V1_5_SHA512 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_224 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_256 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_384 TEE_ALG_RSASSA_PKCS1_V1_5_SHA3_512 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA1 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA224 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA256 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA384 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA512 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_224 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_256 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_384 TEE_ALG_RSASSA_PKCS1_PSS_MGF1_SHA3_512	PKCS #1 (RSA, PKCS1 v1.5, PSS) RFC 1321 (MD5) FIPS 180-4 (SHA-1, SHA-2) FIPS 202 (SHA-3)	ftp://ftp.rsasecurity.com/pub/pkcs/pkcs-1/pkcs-1v2-1.pdf http://tools.ietf.org/html/rfc1321 http://csrc.nist.gov/publications/fips/fips180-4/fips-180-4.pdf https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf
TEE_ALG_DSA_SHA1 TEE_ALG_DSA_SHA224 TEE_ALG_DSA_SHA256 TEE_ALG_DSA_SHA256 TEE_ALG_DSA_SHA3_224 TEE_ALG_DSA_SHA3_256 TEE_ALG_DSA_SHA3_384 TEE_ALG_DSA_SHA3_512	FIPS 180-4 (SHA-1) FIPS 186-2 (DSA) * FIPS 202 (SHA-3)	http://csrc.nist.gov/publications/fips/fips180-4/fips-180-4.pdf http://csrc.nist.gov/publications/fips/archive/fips186-2/fips186-2.pdf https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf

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TEE_ALG_RSA_NOPAD	PKCS #1 (RSA primitive)	ftp://ftp.rsasecurity.com/pub/pkcs/pkcs-1/pkcs-1v2-1.pdf
TEE_ALG_DH_DERIVE_SHARED_SECRET	PKCS #3	ftp://ftp.rsasecurity.com/pub/pkcs/ps/pkcs-3.ps
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TEE_ALG_SHA1 TEE_ALG_SHA224 TEE_ALG_SHA256 TEE_ALG_SHA384 TEE_ALG_SHA512	FIPS 180-4	http://csrc.nist.gov/publications/fips/fips180-4/fips-180-4.pdf
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TEE_ALG_ED25519 TEE_ALG_ED448	RFC 8032	http://tools.ietf.org/html/rfc8032
TEE_ALG_X25519 TEE_ALG_X448	RFC 7748	http://tools.ietf.org/html/rfc7748
TEE_ALG_SM2_DSA_SM3	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_SM2_KEP	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_SM2_PKE	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_SM3	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_HMAC_SM3	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71

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TEE_ALG_SM4_CBC_NOPAD TEE_ALG_SM4_CBC_PKCS5	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_SM4_CTR	OCTA	http://www.sca.gov.cn/app-zxfw/zxfw/bzgfcx.jsp http://www.scctc.org.cn/templates/Download/index.aspx?nodeid=71
TEE_ALG_SHA3_224 TEE_ALG_SHA3_256 TEE_ALG_SHA3_384 TEE_ALG_SHA3_512 TEE_ALG_SHAKE128 TEE_ALG_SHAKE256	FIPS 202 NIST SP800-185, SHA-3 Derived Functions	https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-185.pdf
TEE_ALG_HKDF	RFC5869	https://tools.ietf.org/html/rfc5869
*	*This specification follows a superset of both FIPS 186-2 and FIPS 186-4. Available key sizes are defined in this specification and so no key size exclusions in FIPS 186-2 or FIPS 186-4 apply to this specification. Otherwise, when applied to this specification, if FIPS 186-4 conflicts with FIPS 186-2, then FIPS 186-4 is taken as definitive.*	

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Annex D Peripheral API Usage (Informative)

The following example code is informative, and is intended to provide basic usage information on the Peripheral API. Error handling is deliberately extremely simplistic and does not represent production quality code. No guarantee is made as to the quality and correctness of this code sample.

```
#include "tee_internal_api.h"

#if (TEE_CORE_API_MAJOR_VERSION != 1) && (TEE_CORE_API_MINOR_VERSION < 2)
#error "TEE Peripheral API not supported on TEE Internal Core API < 1.2"
#endif

#if !defined(TEE_CORE_API_EVENT)
#error "TEE Peripheral API not supported on this platform"
#endif


#define MAX_BUFFER               (256)

// Define a proprietary serial peripheral (as no peripheral supporting the
// polled Peripheral API is defined in this document). This is purely to
// illustrate how the API is used where such a peripheral is invented.
#define PROP_PERIPHERAL_UART           (0x80000001)

// The state below has tag=TEE_PERIPHERAL_VALUE_UINT32, ro=false
#define PROP_PERIPHERAL_STATE_BAUDRATE (0x80000001)
#define PROP_PERIPHERAL_UART_BAUD9600  (0x80)


// Trivial error handling
#define ta_assert(cond, val) if (!(cond)) TEE_Panic(val)
#define TA_GETPERIPHERALS (1)
#define TA_VERSIONFAIL    (2)
#define TA_GETSTATETABLE  (3)
#define TA_FAILBAUDRATE   (4)
#define TA_FAILOPEN       (5)
#define TA_FAILWRITE      (6)

static TEE_Peripheral*      peripherals;
static TEE_PeripheralState* peripheral_state;
```

```
void TestPeripherals()
{
  uint32_t                 ver;
  TEE_Result               res;
  size_t                   size;
  uint32_t                 max;
  TEE_PeripheralId         tee_id;
  TEE_EventSourceHandle    tee_e_handle;
  TEE_PeripheralDescriptor uart_descriptor;
  TEE_PeripheralId         uart_id;
  TEE_PeripheralHandle     uart_p_handle;
  uint32_t                 uart_baud;
  bool                     supports_exclusive;
  bool                     supports_baudrate_change;
  uint8_t                  buf[MAX_BUFFER];

  // Get TEE peripherals table. Catch errors, but assert rather than handle.
  // First call with NULL fetches the size of the peripherals table
  res = TEE_Peripheral_GetPeripherals(&ver, NULL, &size);
  peripherals = (TEE_Peripheral*) TEE_Malloc(size);

  res = TEE_Peripheral_GetPeripherals(&ver, peripherals, &size);

  ta_assert((res == TEE_SUCCESS) && (size <= sizeof(peripherals)),
            TA_GETPERIPHERALS);

  //****************************************************************
  // Find Peripheral ID for OS pseudo-peripheral (there is only one)
  // and for the proprietary UART (there is also only one, for simplicity)
  //****************************************************************

  max = size / sizeof(TEE_Peripheral);
  for (uint32_t i = 0; i < max; i++) {
    ta_assert(peripherals[i].version == 1, TA_VERSIONFAIL);
    if (peripherals[i].periphType == TEE_PERIPHERAL_TEE) {
      tee_id = peripherals[i].id;
      tee_e_handle = peripherals[i].e_handle;
    } else if (peripherals[i].periphType == PROP_PERIPHERAL_UART) {
      uart_id = peripherals[i].id;
      uart_p_handle = peripherals[i].p_handle;
    }
  }

  // Get state of the OS pseudo-peripheral.
  // Catch errors, but assert rather than recover.
  size = sizeof(peripheral_state);
  res = TEE_Peripheral_GetStateTable(tee_id, peripheral_state, &size);

  ta_assert((res == TEE_SUCCESS) && (size <= sizeof(peripheral_state)),
            TA_GETSTATETABLE);
```

```
// Check if exclusive access is supported by OS pseudo-peripheral
 supports_exclusive = false;
 max = size / sizeof(TEE_PeripheralState);
 for (uint32_t i = 0; i < max; i++) {
   if (peripheral_state[i].id == TEE_PERIPHERAL_STATE_EXCLUSIVE_ACCESS) {
     supports_exclusive = peripheral_state[i].u.boolVal;
     break;
   }
 }

 //**************************************************************
 // Set the baud rate on the proprietary UART pseudo-peripheral.
 //**************************************************************

 // Fetch the state table for the UART
 size = sizeof(peripheral_state);
 res = TEE_Peripheral_GetStateTable(uart_id, peripheral_state, &size);

 ta_assert((res == TEE_SUCCESS) && (size <= sizeof(peripheral_state)),
           TA_GETSTATETABLE);

 // Find the state information and check it is writeable
 max = size / sizeof(TEE_PeripheralState);
 supports_baudrate_change = false;
 uint32_t baudrate = PROP_PERIPHERAL_UART_BAUD9600;
 for (uint32_t i = 0; i < max; i++) {
   if (peripheral_state[i].id == PROP_PERIPHERAL_STATE_BAUDRATE) {
     supports_baudrate_change = peripheral_state[i].u.boolVal;
     break;
   }
 }

 // If so, change the baud rate.
 if (supports_baudrate_change) {
   res = TEE_PeripheralSetState(uart_id,
                                PROP_PERIPHERAL_STATE_BAUDRATE,
                                TEE_PERIPHERAL_VALUE_UINT32,
                                baudrate);
   ta_assert(res == TEE_SUCCESS, TA_FAILBAUDRATE);
 }

 // Open the UART
 uart_descriptor.id = uart_id;
 uart_descriptor.p_handle = TEE_INVALID_HANDLE;
 uart_descriptor_e_handle = TEE_INVALID_HANDLE;

 res = TEE_Peripheral_Open(&uart_descriptor);

 ta_assert((res == TEE_SUCCESS) &&
           (uart_descriptor.p_handle != TEE_INVALID_HANDLE),
           TA_FAILOPEN);
```

```
  // Write to the UART.
  for (uint32_t i = 0; i < MAX_BUFFER; i++)
    buf[i] = i;

  res = TEE_Peripheral_Write(uart_descriptor.p_handle, buf, MAX_BUFFER);

  ta_assert((res == TEE_SUCCESS), TA_FAILWRITE);
}
```

Functions

Functions by Category