GlobalPlatform Device Technology

TEE Sockets API Specification

Version 1.0.1

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Contents

Note: Annexes to this specification are provided as separate documents. See section 3.2.

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1 Introduction

This document, the GlobalPlatform TEE Sockets API Specification, specifies:

- The generic C interface used by a Trusted Application (TA) to establish and utilize network communications to a remote server using a socket style approach
- Generic error behavior of the functions

This general specification does not specify any particular protocol nor the data structures used to utilize a particular protocol. Each specific protocol, such as TCP and UDP, is described in detail in a separate Annex to this general specification.

1.1 Audience

This document is suitable for software developers implementing Trusted Applications running inside the Trusted Execution Environment (TEE) which need to make socket networking calls.

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://www.globalplatform.org/specificationsipdisclaimers.asp. 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

Table 1-1: Normative References

Standard / Specification	Description	Ref
GPD_SPE_007	GlobalPlatform Device Technology TEE Client API Specification	[TEE Client]
GPD_SPE_009	GlobalPlatform Device Technology TEE System Architecture	[TEE Sys Arch]
GPD_SPE_010	GlobalPlatform Device Technology TEE Internal Core API Specification	[TEE Core]
GPD_SPE_025	GlobalPlatform Device Technology TEE TA Debug Specification	[TEE Debug]
GPD_SPE_101	TEE Sockets API Specification Annex A: TCP/IP Specification of TEE Sockets API Specification	[Sockets TCP/IP]
GPD_SPE_102	TEE Sockets API Specification Annex B: UDP/IP Specification of TEE Sockets API Specification	[Sockets UDP/IP]

Standard / Specification	Description	Ref
GPD_SPE_103	TEE Sockets API Specification Annex C: TLS Specification of TEE Sockets API Specification	[Sockets TLS]
GPD_SPE_104	TEE Sockets API Specification Annex D: Example of Using TEE Sockets API Specification	[Socket Example]
IEEE Std 1003.1-2008	The Open Group Base Specifications Issue 7 (referred to as “the POSIX standard”)	[POSIX]
RFC 5246	The Transport Layer Security (TLS) Protocol	[TLS]
RFC 793 / RFC 791	Transmission Control Protocol and Internet Protocol (referred to as TCP/IP)	[RFC 793]
RFC 768 / RFC 791	User Datagram Protocol and Internet Protocol (referred to as UDP/IP)	[RFC 768]
RFC 2119	Key words for use in RFCs to Indicate Requirement Levels.	[RFC 2119]

Table 1-2: Informative References

Standard / Specification	Description	Ref
ISO/IEC 7498-1	Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model (referred to as “the OSI model”)	[ISO 7498]
IPsec	Base architecture for IPsec compliant systems.	[RFC 2401]
IKE	Describes version 2 of the Internet Key Exchange (IKE) protocol. IKE is a component of IPsec used for performing mutual authentication and establishing and maintaining Security Associations (SAs).	[RFC 5996]

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 technical terms used in this document are included in Table 1-3. Additional technical terms are defined in TEE Internal Core API Specification [TEE Core].

Table 1-3: Terminology and Definitions

Term	Definition
iSocket	Interface Socket

Term	Definition
iSocket instance	Instance of Interface Socket

1.5 Abbreviations and Notations

Selected abbreviations and notations used in this document are included in Table 1-4. Additional abbreviations and notations are defined in [TEE Core].

Table 1-4: Abbreviations and Notations

Abbreviation / Notation	Meaning
DRM	Digital Rights Management
IKE	Internet Key Exchange
IP	Internet Protocol
IPsec	Internet Protocol Security
PSK	Pre-Shared Key
TCP	Transmission Control Protocol
TLS	Transport Layer Security

1.6 Revision History

Table 1-5: Revision History

Date	Version	Description
June 2015	1.0	Public Release
January 2017	1.0.1	Public Release showing all non-trivial changes since v1.0. Changes include: • Added one error code • Expanded explanation of error handling • Redefined `TEE_iSocketHandle` structure • Defined the `open` function as cancellable • Clarified description of `close`, `send`, and `recv` functions

2 Background

TAs are commonly required to communicate with remote servers. Such communication is today typically performed by using the TEE Client API [TEE Client] to route Trusted Application (TA) data to or from a Client Application (CA), and the CA then manages a sockets interface in the Rich Execution Environment (REE) to the remote server.

Creating numerous TAs, all performing the same underlying tasks increases code size, risks, and effort and so it is seen as desirable to provide this common functionality inside the TEE.

Communication is normally depicted as layers of protocols (e.g. the OSI layer model [ISO 7498]), each performing specific tasks of the communication. For example, the Internet Protocol (IP) is a connectionless protocol, which enables network nodes to send messages across network boundaries to other nodes using the IP address. This protocol does not guarantee in-order delivery nor does it provide retransmission facilities in case of corrupted messages. To provide such features, the Transmission Control Protocol (TCP) can be utilized. On top of TCP we may choose to add encryption of the messages, and hence a new layer must be used, for example the Transport Layer Security (TLS) protocol. All these different layers basically provide the same functions to the user: open a connection, send and receive data, and close the connection.

Of course, there are many means of communication other than the Internet type of protocols. Modern devices often include short-range communication such as Bluetooth and near field communication but essentially, all the user needs is a set of functions performing the basic communication tasks.

From this point of view, GlobalPlatform has created a specification that is small and easily layered as the needs of the user change and new communication media are added to the device.

This version of the TEE Sockets API targets Client functionality. The API specified enables a TA developer to include basic network client functionality in a Trusted Application.

3 Requirements for TEE Sockets API

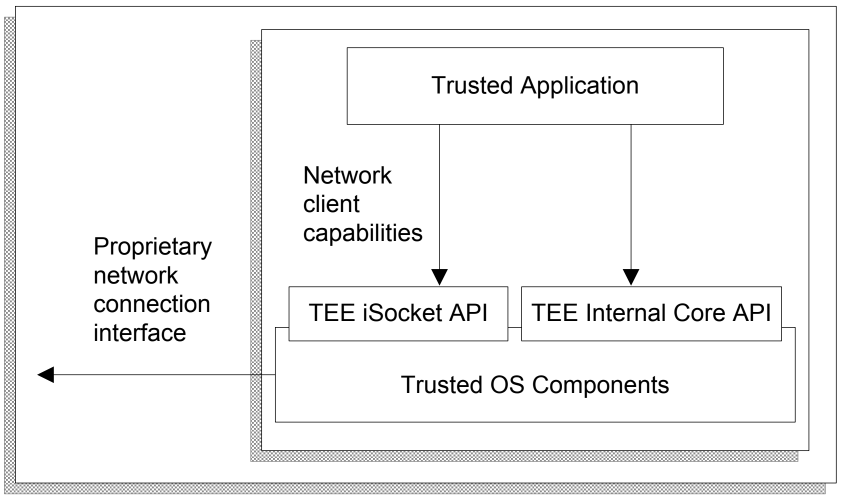
3.1 Assumptions and Scope

The intent of this specification is to provide a common homogeneous interface for the TA to communicate with other network nodes. The POSIX Sockets interface [POSIX], as provided by many operating systems, has limitations when it comes to layering different protocols. This specification modularizes the interface to provide a more flexible solution while sustaining the simplicity of the POSIX interface.

The modular approach also provides a simpler path to upgradable security and additional protocols. Each protocol is handled by an instance of an “Interface Socket” (iSocket), which can be plugged in on top of another iSocket to add protocol layers.

In the current version, this API defines mechanisms that allow the TA to act as a network client (i.e. connecting to external servers via the network).

Figure 3-1: TEE iSocket API Exposes Network Client Capabilities to TA



3.1.1 Streams and Boundary of Trust

The fundamental operation that a network connection performs is to transfer a bi-directional stream of data bytes (or packets) between entities that are located anywhere in a network.

The code that performs this transport functionality is distributed across the network and hence is not under the control of the TEE and cannot be trusted. This means that the data received from the network cannot be trusted and software executing in the TEE must treat it as such.

There is no reason why the network hardware and software (i.e. that which implements low level transport mechanisms such as TCP/IP and similar) should execute within the TEE[1]: to do so would not improve the trusted status of the data (since the data would still originate outside the TEE) and would add significant complexity to the system.

Network software that changes the level of trust of the data stream SHALL execute within the TEE. Other network software MAY execute within the TEE. For example, the implementation of the SSL/TLS algorithm ensures that the data received is that sent by the originator and hence improves its level of trust. Thus, TLS (or any other security protocol) SHALL be implemented within the Trusted OS component, while pure transport protocols, which do not change the level of trust of the data stream, MAY be implemented in the REE. See for example Figure 3-2.

If we remove the mechanics of network transport from the TEE all that remains is a mechanism for transport of streams of bytes into and out of TAs. Such a mechanism can be used for purposes other than networking (e.g. DRM data handling) and as such is defined in a non-networking specific manner.

The only part of the design that is network specific is stream setup, where network addresses and protocols must be specified.

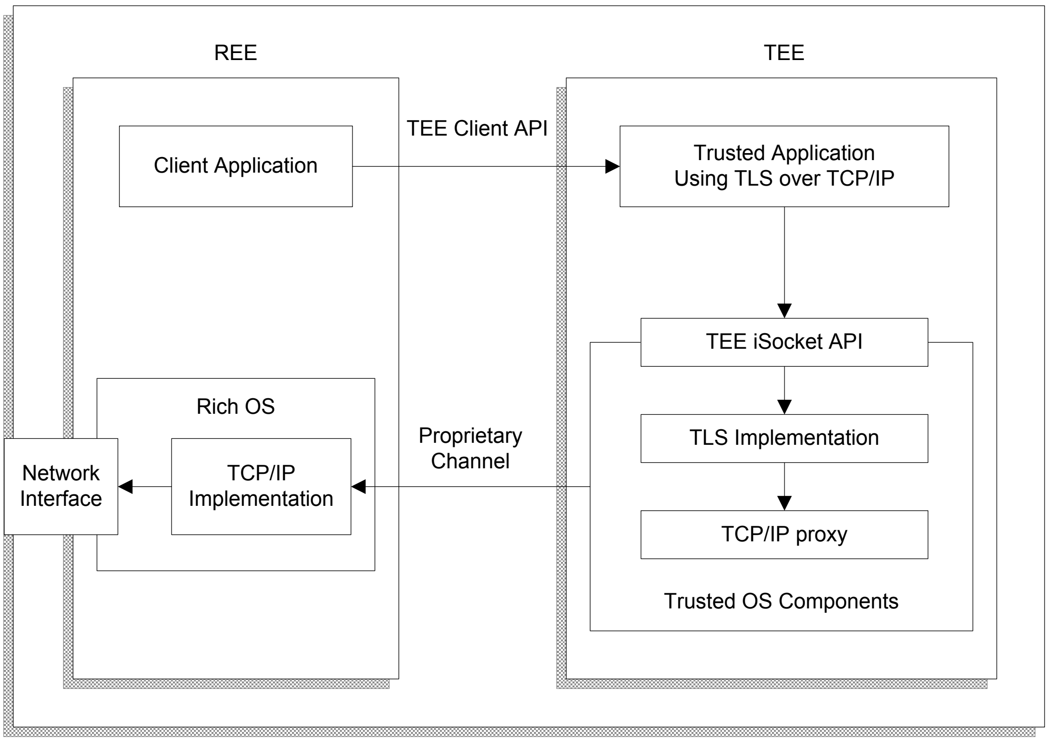
Two types of stream are considered:

- A byte stream where the data is described as a stream of bytes (e.g. TCP/IP [RFC 793])
- A message stream where the data is described as a stream of self-contained messages defined by the network transfer mechanism (e.g. UDP/IP [RFC 768]), hereafter referred to as datagrams

Both of these stream types are unprotected and additional layers are needed to provide confidentiality and/or integrity. An example of a protocol that provides this is TLS [TLS].

[1] There is an exception to this, which is when IPsec is used to protect the transferred data. Because IPsec is embedded within the IP framework, it is necessary for the whole IP stack to be embedded within the TEE. It is also necessary to embed the Internet Key Exchange (IKE) protocol implementation. This is a large volume of code, so support for IPsec is not specified currently.

Figure 3-2: Separation of Security Protocols and Pure Transport Protocols



3.2 Implementation of Specific Protocols

This specification provides the general API for accessing and handling client sockets of various kinds. For each specific protocol that GlobalPlatform decides to support, an Annex document to this specification will be created, in which all the protocol specific details are specified. In one sense, the current specification can be viewed as a virtual class definition, of which the specific protocol specifications are instances. Each specific protocol (or sometimes a group of closely related protocols) will have its own header file in addition to the generic one defining the general API.

This specification does not provide support for configuring carrier layer connections and hence, an REE application (or a proprietary TEE interface) may have to instigate a session before the TEE TA can start a socket layer protocol session.

This API does not include establishment of a transport layer. This is covered in an iSocket instance defined in the Annexes to this document.

3.3 Layered Connections

This specification is intended to provide an easy way for protocols to be layered. This means that, for example, a security protocol such as TLS can be layered on top of a transport protocol such as TCP. To decouple the different layers, the developer is free to choose the transport layer as appropriate. In a layered configuration, each protocol is opened and set up individually, starting at the lowest layer. Each protocol is also closed individually, starting at the highest layer. It is only during send and receive that the higher layers utilize the lower layers in order to send and receive data packages. Stacks of socket layers are opened in low to high order, and closed in high to low order. The highest layer is the layer that the TA will mainly interact with, so in the case of TCP/TLS the high layer is TLS. Once the layering is established it is expected the TA developer will interact with the highest layer, unless there is an error.

4 General Information

4.1 Error Handling

This API follows the TEE Internal Core API philosophy that any programmer avoidable error results in a TA level Panic. See section 2.2 of [TEE Core].

In addition to the error codes defined in [TEE Core], the following error codes are used throughout this API.

Table 4-1: Error Codes Specific to TEE Sockets API

Name	Value
`TEE_ISOCKET_ERROR_PROTOCOL`	0xF1007001
`TEE_ISOCKET_ERROR_REMOTE_CLOSED`	0xF1007002
`TEE_ISOCKET_ERROR_TIMEOUT`	0xF1007003
`TEE_ISOCKET_ERROR_OUT_OF_RESOURCES`	0xF1007004
`TEE_ISOCKET_ERROR_LARGE_BUFFER`	0xF1007005
`TEE_ISOCKET_WARNING_PROTOCOL`	0xF1007006
`TEE_ISOCKET_ERROR_HOSTNAME`	0xF1007007

Since protocols can be layered, and each protocol may have specific error codes that are only valid for that protocol, a generic `TEE_ISOCKET_ERROR_PROTOCOL` and `TEE_ISOCKET_WARNING_PROTOCOL` error code is defined. The `error` function defined in section 5.2.8 can be used to retrieve the specific error or warning from the last operation. All protocol specific errors SHALL be defined in the instance header file and SHALL follow the general guidelines in [TEE Core].

As described in section 3.3, Layered Connections, the TA developer is expected to interact with the highest layer, unless there is an error. If a `TEE_ISOCKET_ERROR_PROTOCOL` is returned from any function, lower layer investigation may be required. Calling the `error` function on a context that has returned a `TEE_ISOCKET_ERROR_PROTOCOL` may return `TEE_SUCCESS` if the error code was propagated and not caused in that context. Only the context causing a `TEE_ISOCKET_ERROR_PROTOCOL` shall store the protocol specific error. If the TA encounters a protocol specific error at the top context, it may use the `error` function to investigate each open context in order to determine which context caused the error. See [Socket Example][Socket Example] for an error handling example.

4.2 Specification Version Number Property

This specification defines a TEE property containing the version number of the specification the implementation conforms to. The property can be retrieved using the normal Property Access Functions defined in [TEE Core]. The property SHALL be named **“`gpd.tee.sockets.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 supported specification is not a maintenance version, this byte SHALL be set to zero.
- The least significant byte is reserved for future use. Currently this byte SHALL be set to zero.

Table 4-2: 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. If not a maintenance version, SHALL be set to zero.	Reserved for future use. Currently SHALL be set to zero.

The specification version number is also defined in the iSocket interface (described in section 5.2), stored in the 32-bit integer `TEE_iSocketVersion`, interpreted as described in Table 4-2. For a specific protocol, `TEE_iSocketVersion` does not need to have the same value as the property **`gpd.tee.sockets.version`**. A lower version number is acceptable and is interpreted as indicating that the specific protocol uses an earlier version of the iSocket interface.

4.3 Protocol Identifier

Each specific protocol will have a unique protocol identifier. This identifier is a byte and the value is specified by GlobalPlatform. This identifier is used to identify the protocol to which the `TEE_iSocket` structure belongs.

Table 4-3 specifies the protocol identifier ranges.

Table 4-3: Protocol Identifier Ranges

Protocol Identifier Range		Meaning
0x00	(0)	Reserved protocol identifier.
0x01 – 0x63	(1 – 99)	Reserved for proprietary protocols.
0x64 – 0xFF	(100 – 255)	Protocol identifiers assigned by GlobalPlatform. The protocol description associated with each value can be found in Annexes to this document.

4.4 Panicked Function Identification

The TEE TA Debug Specification [TEE Debug] mandates that each API function be assigned a *specification number* and a *function number* to be reported through the PRM and Debug functionality. Since TEE iSocket API is divided into this general API description and Annexes containing the protocol specifics, the functions defined in this specification are assigned only a function number. The specification number can be derived from the Annex document reference number.

Example

> The `open` function of this specification is assigned the function number 0x101. If the TLS protocol is defined in the Annex with document reference number "GPD_SPE_103", then the Panic identifier of the TLS `open` function will be: **Specification Number: 103, Function Number: 0x101**

If this specification is used in conjunction with the TEE TA Debug Specification ([TEE Debug]), then the specification number is based on the Annex that specifies the protocol in use (as described above) and the values listed in Table 4-4 SHALL be associated with the function declared.

Table 4-4: Function Identification Values

Category	Function	Function Number in hexadecimal	Function Number in decimal
Interface Socket	`open`	0x101	257
	`close`	0x102	258
	`send`	0x103	259
	`recv`	0x104	260
	`error`	0x105	261
	`ioctl`	0x106	262

5 TEE_iSocket (The Generic Interface Socket) API

The `TEE_iSocket` API is designed to supply a generic table of functions regardless of networking layer or client functionality and hence, the core of the API is a structure, containing function pointers.

5.1 Header File Name

The header file of the `TEE_iSocket` interface SHALL be named “**`tee_isocket.h`**”.

5.2 Functionality

The basic `TEE_iSocket` interface consists of six functions; **`open`**, **`close`**, **`send`**, **`recv`**, **`error`**, and **`ioctl`**. Implementations may add other fields provided that the structure begins with the field names, order, and types as specified here. Implementers of proprietary extensions should note that future versions of this specification may require additional fields as part of the standard initial segment.

The declaration can be seen below.

```
typedef const struct TEE_iSocket_s
{
  uint32_t   TEE_iSocketVersion;
  uint8_t    protocolID;

  TEE_Result (* open)(
             TEE_iSocketHandle    *ctx,
             void                 *setup,
             uint32_t             *protocolError );

  TEE_Result (* close)(
             TEE_iSocketHandle    ctx );

  TEE_Result (* send)(
             TEE_iSocketHandle    ctx,
             const void           *buf,
             uint32_t             *length,
             uint32_t             timeout );

  TEE_Result (* recv)(
             TEE_iSocketHandle    ctx,
             void                 *buf,
             uint32_t             *length,
             uint32_t             timeout );

  uint32_t  (* error) (
             TEE_iSocketHandle    ctx );

  TEE_Result (* ioctl) (
          TEE_iSocketHandle       ctx,
          uint32_t                commandCode,
          const void              *buf,
          uint32_t                *length );

} TEE_iSocket;
```

The structure contains constant function pointers that will implement the specifics of one particular layer of the communication stack. For a specific supported protocol layer, the Implementation SHOULD provide the following in the instance specific header file:

- A declaration of the corresponding setup structure as described in section 5.2.1.
- A declaration of a pointer to the specific instance of the `TEE_iSocket`.

5.2.1 TEE_iSocketHandle and Setup

The context that needs to be maintained varies for each connection and protocol, so a generic opaque type `TEE_iSocketHandle` is used. This is defined as a pointer to an implementation defined structure:

```
typedef ~~struct ~~void ~~TEE_iSocketHandle ~~* TEE_iSocketHandle;
```

In a specific protocol implementation, the handle must keep all data that is needed to maintain the connection from the time it is opened until it is closed.

The `setup` parameter given to `open` is also protocol specific and must contain all the data to open the connection. For example, a TCP/IP socket must know the address and port of the server to connect to. The `setup` parameter must be of a pointer to structure type, known as the setup structure. If no setup data is necessary for a particular protocol, the value of the `setup` parameter SHALL be `NULL`.

If a protocol is intended to be “on top” of a transporting protocol, for example such as TLS over TCP, the setup structure SHALL contain a pointer to the underlying `TEE_iSocket` and the instance handle.

5.2.2 Fatal Errors

Errors and the protocol specific errors returned by the functions of the TEE sockets interface can be “fatal” or “non-fatal”.

- If the `open` function returns anything other than `TEE_SUCCESS`, then the `TEE_iSocketHandle` equals `TEE_HANDLE_NULL`. The only valid operation on `TEE_HANDLE_NULL` is `close`.
- When a socket returns a fatal error in response to any other function, the only valid operations on that `TEE_iSocketHandle` instance are `close` and `error`.
- The return values table of each function description specifies whether each error is fatal.
- As TEE Sockets API structures are layered, it is recommended that if the lower layer returns a fatal error, then so should the current layer. This way the TA can be alerted of the error and can manage it accordingly. See section 3.3, Layered Connections, for a description of the layered socket structure.

5.2.3 Timely Manner

A number of actions in this API must be performed in a timely manner. It is Implementation defined as to what this may be but the Implementation should take into account any defined timeouts of the protocol in question.

5.2.4 Open

```
TEE_Result (* open) (
          [out] TEE_iSocketHandle *ctx,
          [in]  void              *setup,
          [out] uint32_t          *protocolError
);
```

Description

The open function tries to open the connection according to the prerequisites passed in the setup parameter (see section 5.2.1). If the connection is successful, it returns a handle to the socket in the out parameter *ctx. If the connection is not successful, the out parameter *ctx has the value TEE_HANDLE_NULL. After this function has been successfully called, any changes to the setup parameter SHALL NOT alter the behavior of the protocol in subsequent calls to the instance TEE_iSocket functions. In other words, the functionality and behavior of the protocol instance after a successful open function call SHALL only depend on the handle.

The open function call is blocking and should execute in a timely manner (see section 5.2.3, Timely Manner), which may vary depending on the communication channel and protocol. If the connection cannot be opened in a time frame appropriate to the protocol, the function returns TEE_ISOCKET_ERROR_TIMEOUT. If a configurable timeout is appropriate it MAY be specified in the setup structure.

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 action with the return code TEE_ERROR_CANCEL. If an annex defines a non-blocking sockets layer, then this function need not be cancellable.

Protocol specific errors are returned by returning the TEE_ISOCKET_ERROR_PROTOCOL or TEE_ISOCKET_WARNING_PROTOCOL and updating the out parameter *protocolError with the protocol-specific error code. If the return code is not TEE_ISOCKET_ERROR_PROTOCOL or TEE_ISOCKET_WARNING_PROTOCOL the contents of *protocolError will not be changed.

In a layered configuration, each layer must be allocated and initialized starting from the lowest layer, i.e. the open function must be called for each layer, using the returned handle in the setup of the next layer.

Specification Number: See section 4.4 **Function Number: 0x101**

Parameters

Name	Purpose
TEE_iSocketHandle *ctx	Handle to an implementation specific context.
void *setup	Protocol specific setup parameter.
uint32_t *protocolError	In case of a protocol specific error or warning, this parameter holds the error value. See specific protocol Annex specifications for the possible values.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
`TEE_SUCCESS`	No	In case of success.
`TEE_ERROR_CANCEL`	No	The TA has unmasked the effects of cancellation and the Client Application has set the task cancelled flag.
`TEE_ERROR_OUT_OF_MEMORY`	Yes	Failed to allocate memory for the socket handle.
`TEE_ERROR_BAD_PARAMETERS`	Yes	Error in the `setup` parameter. The requested setup cannot be achieved.
`TEE_ISOCKET_ERROR_OUT_OF_RESOURCES`	Yes	Failed to allocate resources for the socket.
`TEE_ISOCKET_ERROR_TIMEOUT`	No	The connection cannot be opened in a timely manner.
`TEE_ERROR_COMMUNICATION`	No	There is no route to the requested host or the host did not accept the connection.
`TEE_ISOCKET_ERROR_PROTOCOL`	Yes	Protocol specific error. Occurs under conditions defined in the relevant Annex. The error value is returned in the `*protocolError` parameter.
`TEE_ISOCKET_WARNING_PROTOCOL`	No	Occurs under conditions defined in the relevant Annex. The error value is returned in the `*protocolError` parameter.

If a value of `TEE_SUCCESS` is not returned, then the socket will not have been opened and so the fatal state of these errors (as defined in section 5.2.2) is irrelevant.

Panic Reasons

The `open` function SHALL panic if the following occurs:

- Any parameter is `NULL`.

The `open` function MAY panic if the following occurs:

- The `setup` parameter pointer does not point to a valid instance specific setup type.
- If the Implementation detects any error which cannot be represented by any defined or Implementation defined error code.

5.2.5 Close

```
TEE_Result (* close) (
             TEE_iSocketHandle ctx,
);
```

Description

The close function closes the socket, de-allocates the context, and frees any resources held by the handle, after which the handle is not valid anymore. ~~Calling this function with an already closed context is a programming error and will cause a Panic.~~ Calling this function with a TEE_HANDLE_NULL parameter will return TEE_SUCCESS.

The close function call is blocking and should execute in a timely manner. In a layered configuration, the layers must be closed starting from the highest layer. Higher layers SHALL NOT close underlying layers in this function.

~~The handle ctx should be considered to be in a state where the only valid operation on it is close or error.~~

If the close function cannot close the context in a timely manner, it SHALL return TEE_ISOCKET_ERROR_TIMEOUT. The handle ctx should be considered to be in a state where the only valid operation on it is close or error.

If the close function encounters an error specific to the protocol, the return value SHALL be TEE_ISOCKET_ERROR_PROTOCOL.

The close function may be called on an already closed handle. If it is, the error state SHALL be retained and the same return value SHALL be returned each time.

Specification Number: See section 4.4 **Function Number: 0x102**

Parameters

Name	Purpose
TEE_iSocketHandle ctx	Initialized implementation specific handle or TEE_HANDLE_NULL.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
TEE_SUCCESS	No	In case of success. The ctx handle may be invalid or already closed.
TEE_ISOCKET_ERROR_TIMEOUT	Yes	The connection could not be closed in a timely manner. A timeout may be caused by a remote party that failed to receive all data or failed to transmit all data in a timely manner.
TEE_ERROR_COMMUNICATION	Yes	The route to the host is down or an internal network interface is down.

Name	Fatal	Reason
`TEE_ISOCKET_ERROR_REMOTE_CLOSED`	Yes	The remote host has closed the connection. Some instances will never return this error due to statelessness. `TEE_ISOCKET_ERROR_REMOTE_CLOSED` is possible only if a prior data exchange was reported as successful but the connection was forcibly closed by the remote host.
`TEE_ISOCKET_ERROR_PROTOCOL`	Yes	Protocol specific error. See the `error` function for further information. All protocol specific errors returned from `close` are fatal errors.
`TEE_ISOCKET_ERROR_HOSTNAME`	Yes	Unable to reach the requested remote host.

Panic Reasons

The `close` function SHALL panic if either of the following occurs:

- The handle is not initialized.
- The handle is not a valid handle of the specific protocol. `TEE_HANDLE_NULL` is a valid handle.
- The Implementation detects any error which cannot be represented by any defined or implementation defined error code.

5.2.6 Send

```
TEE_Result (* send) (
                    TEE_iSocketHandle     ctx,
          [in]      const void            *buf,
          [inout]   uint32_t              *length,
                    uint32_t              timeout
);
```

Description

The `send` function transmits data to the remote network node. If `TEE_iSocket` instances are layered, the `send` function of the topmost protocol calls the `send` function of its lower layer after processing the message according to its protocol.

The parameter `buf` points to a memory region containing the bytes to be transmitted. The number of bytes to be sent is passed in `*length`. Unless `*length` is zero, on return, `*length` is updated with the actual number of bytes transmitted or passed on to the next lower layer in the stack.

The `send` function is a blocking function with a timeout. It tries to send the buffer (or at least propagate the data to lower level buffers) for a specific amount of time. After it sends or propagates the data, or after the specified time elapses (whichever comes first), it unconditionally returns. If no data was sent, it returns the error code `TEE_ISOCKET_ERROR_TIMEOUT`. If some data was transmitted, it returns `TEE_SUCCESS` and the `*length` parameter SHALL be updated with the number of successfully sent bytes. Note that a successful transmission does not guarantee that the remote node has received the data, unless the protocol makes specific guarantees. An error in transmission may be reported as a fatal error in a subsequent call to `send`, `recv`, `ioctl`, or `close`.

For a partially sent message, the `send` function SHALL NOT buffer the remaining bytes. It is the responsibility of the user to re-send those bytes.

For protocols that operate on a data stream, the `send` function SHOULD return as soon as at least part of the buffer has been sent. For protocols that operate on blocks of data, such as some encrypted protocols, it is the user's responsibility to provide large enough chunks of data to the `send` function in order to minimize fragmentation. It is protocol specific and implementation specific whether the `send` function internally buffers data in order to avoid fragmentation and small chunks.

For datagram-based protocols, the `send` function SHALL map one call to `send` to one datagram. If the buffer to transmit is too large for a single datagram, the `send` function returns `TEE_ISOCKET_ERROR_LARGE_BUFFER`, and sets the `*length` parameter to the maximum number of bytes that the protocol datagram can send. Furthermore, the `send` function SHALL NOT transmit any of the bytes in the buffer, when the error `TEE_ISOCKET_ERROR_LARGE_BUFFER` is returned.

~~For protocols that operate on a data stream, the send function SHOULD return as soon as at least part of the buffer has been sent. For protocols that operate on blocks of data, such as some encrypted protocols, it is the user's responsibility to provide large enough chunks of data to the send function, in order to minimize fragmentation. It is protocol specific and implementation specific whether the send function internally buffers data in order to avoid fragmentation and small chunks.~~

The `send` function is a cancellable function. If a cancel request is received during execution of the `send` function, the implementation SHALL ~~behave as if the timeout has been reached but the~~ return ~~code SHALL be~~ `TEE_ERROR_CANCEL` and SHALL update the `*length` with the number of received bytes. If the transmission was completed, the return code SHALL be `TEE_SUCCESS`.

Specification Number: See section 4.4 Function Number: 0x103

Parameters

Name	Purpose
`TEE_iSocketHandle ctx`	Initialized implementation specific handle.
`const void *buf`	The buffer containing the data to be sent or passed on to the next lower layer in the stack, unless `*length` is zero.
`uint32_t *length`	A pointer to the length in bytes of the buffer to be sent. On return, this parameter is updated with the number of bytes sent.
`uint32_t timeout`	The timeout of the operation in milliseconds. If `timeout == 0`, the function makes one attempt to send data and returns immediately. If `timeout == TEE_TIMEOUT_INFINITE` (defined in [TEE Core] `TEE_Wait`), the function blocks until all bytes are sent or a fatal error occurs.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
`TEE_SUCCESS`	No	In case of success.
`TEE_ERROR_CANCEL`	No	The function was cancelled.
`TEE_ISOCKET_ERROR_TIMEOUT`	No	The complete buffer could not be sent during the specified timeout period.
`TEE_ERROR_COMMUNICATION`	No	The route to the host is down or an internal network interface is down.
`TEE_ISOCKET_ERROR_REMOTE_CLOSED`	Yes	The remote host has closed the connection. Some instances will never return this error due to statelessness.
`TEE_ISOCKET_ERROR_PROTOCOL`	Yes	Protocol specific error. See the `error` function for further information. Each protocol specific error is defined in the corresponding Annex. Underlying protocols can be tested for errors recursively by applying the `struct_setup` (see the Annexes) underlying `ctx` to the `error` function. The error can be parsed individually depending on the `ProtocolID` from the underlying socket.

Name	Fatal	Reason
`TEE_ISOCKET_WARNING_PROTOCOL`	No	Protocol specific warning. See the `error` function for further information. Each protocol specific warming is defined in the corresponding Annex. Underlying protocols can be tested for warnings recursively by applying the `struct_setup` (see the Annexes) underlying `ctx` to the `error` function. The warning can be parsed individually depending on the `ProtocolID` from the underlying socket.
`TEE_ISOCKET_ERROR_LARGE_BUFFER`	No	The protocol is datagram-based and the buffer is too large to be sent in one datagram. No bytes from the buffer are sent.
`TEE_ISOCKET_ERROR_OUT_OF_RESOURCES`	Yes	Failed to allocate resources for the operation.

Panic Reasons

The `send` function SHALL panic if any of the following occurs:

- The handle is not initialized or is `NULL`.
- The handle is not a valid handle of the specific protocol.
- The parameter `buf == NULL`.
- The parameter `length == NULL`.
- The Implementation detects any error which cannot be represented by any defined or Implementation defined error code.

5.2.7 Recv

```
TEE_Result (* recv) (
                    TEE_iSocketHandle     ctx,
          [out]     void                  *buf,
          [inout]   uint32_t              *length,
                    uint32_t              timeout
);
```

Description

The `recv` function receives data from the remote network node. If `TEE_iSocket` instances are layered, the `recv` function of a given protocol layer calls the `recv` function of the next lower layer, and then processes the received message according to its protocol.

The parameter `buf` points to a memory region that will hold the received bytes. The maximum number of bytes to receive is passed in `*length`. On return, `*length` is updated with the actual number of bytes received.

The `recv` function is a blocking function with a timeout. It tries to receive data for the specific amount of time. After it receives the data, or after the specified time elapses (whichever comes first), it unconditionally returns. If no data was available during the timeout period, the function returns the code `TEE_ISOCKET_ERROR_TIMEOUT`. If some data was received during the timeout period, the `*length` parameter is updated and the return code is `TEE_SUCCESS`. The timeout parameter SHALL be passed on to the lower layer without increasing its value.

If `*length == 0`, the timeout parameter has no effect and `buf` may equal `NULL`, and the function immediately returns the number of bytes available for transfer in `*length`.

For datagram-based protocols, the `recv` function SHALL map one call to `recv` to one received datagram. This means that calling the `recv` function with `*length` **less than the size of the datagram**~~,~~ will not return the total number of bytes received, but only the length of the next datagram to be delivered. If the `recv` function is called with `*length` **less than the size of the datagram** and returns `*length == 0`, that means that there are no more datagrams to be delivered.

~~For datagram-based protocols, the `recv` function SHALL map one call to `recv` to one received datagram. This means that calling the `recv` function with `*length == 0`, will not return the total amount of bytes received, but only the length of the next datagram to be delivered. When calling the `recv` function with `*length == 0`, and it returns `*length == 0`, it means that there are no more datagrams to be delivered.~~ Datagram handling in this version of TEE Sockets API is different from the handling of conventional datagram sockets, as it does not handle truncated packets. The TA implementation has to allocate the full buffer for the entire packet to map one `recv` call to one received datagram. In order to detect the desired buffer size for receiving a datagram, call `recv` with `length == 0` and use the `[out] length` value for buffer memory allocation. If the defined buffer is too short for the incoming datagram, the superfluous bytes in the incoming datagram will be lost and `recv` will return `TEE_SUCCESS`. By comparing the `[out] length` value containing the number of received bytes with the size of the current buffer, an implementer can detect whether and how many bytes have been lost.

```
uint32_t length = 0;
err = udp.recv(ctx, NULL, &length, 0); /* Detect buffer length */
if (err != TEE_SUCCESS) …handle error…
if (length > 0)
{
    char *buffer = TEE_Malloc(length, 1);
    if (buffer != NULL)
    {
        err = udp.recv(ctx, buffer, &length, TIMEOUT);
    }
}
```

For protocols that operate on a data stream, the `recv` function SHOULD return as soon as at least part of the buffer has been received. For protocols that operate on blocks of data, such as some encrypted protocols, the `recv` function SHALL internally buffer data from lower layers until a complete block is received to operate on. In such cases, the `recv` function SHALL act as though the complete block of data to operate on is received in one package from the lower layers.

If there is a mismatch between the received data and the protocol specification, the function SHALL discard the data, set `*length = 0`, and return the error code `TEE_ISOCKET_ERROR_PROTOCOL`.

The `recv` function is a cancellable function. If a cancel request is received during execution of the `recv` function, the implementation SHALL ~~behave as if the timeout has been reached but the~~ return ~~code SHALL be~~ `TEE_ERROR_CANCEL`. If the complete buffer was received, the return value SHALL be `TEE_SUCCESS`.

Specification Number: See section 4.4 Function Number: 0x104

Parameters

Name	Purpose
`TEE_iSocketHandle ctx`	Initialized implementation specific handle.
`void *buf`	A pointer to an allocated memory buffer where the received bytes will be stored. If `*length == 0`, this buffer will not be touched and can be `NULL`.
`uint32_t *length`	A pointer to an integer holding the requested number of bytes to receive. The buffer must have allocated at least this number of bytes. On return, this parameter holds the actual number of bytes read. If the function is called with `*length == 0`, it returns the number of bytes that are ready to be received in `*length`.
`uint32_t timeout`	The timeout of the operation in milliseconds. If `timeout == TEE_TIMEOUT_INFINITE` (defined in [TEE Core] `TEE_Wait`), the function blocks until all requested bytes are received or a fatal error occurs. If `timeout == 0`, the function receives the data that is available but at most `*length` bytes.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
TEE_SUCCESS	No	In case of success.
TEE_ERROR_CANCEL	No	The function was cancelled.
TEE_ISOCKET_ERROR_TIMEOUT	No	Nothing was received during the timeout period. `*length` is set to zero.
TEE_ERROR_COMMUNICATION	Yes	The route to the host is down or an internal network interface is down.
TEE_ISOCKET_ERROR_REMOTE_CLOSED	Yes	The remote host has closed the connection. Some instances will never return this error due to statelessness.
TEE_ISOCKET_ERROR_PROTOCOL	Yes	Protocol specific error. See the `error` function for further information. Each protocol specific error is defined in the corresponding Annex.
TEE_ISOCKET_WARNING_PROTOCOL	No	Protocol specific warning. See the `error` function for further information. Occurs under conditions defined in the relevant Annex.
TEE_ISOCKET_ERROR_OUT_OF_RESOURCES	Yes	Failed to allocate resources for the operation.

Panic Reasons

The `recv` function SHALL panic if any of the following occurs:

- The handle is not initialized or is `NULL`.
- The handle is not a valid handle of the specific protocol.
- The parameter `length == NULL`.
- The parameter `*length != 0` and `buf == NULL`.
- The Implementation detects any error which cannot be represented by any defined or implementation defined error code.

5.2.8 Error

```
uint32_t (* error) (
              TEE_iSocketHandle   ctx
);
```

Description

The `error` function reports any protocol specific error. Some functions in the `TEE_iSocket` interface must return protocol specific errors or warnings and in such a case, the function returns the generic error `TEE_ISOCKET_ERROR_PROTOCOL` or `TEE_ISOCKET_WARNING_PROTOCOL`. The `error` function can be used to retrieve a more detailed error code. The definitions of the error codes are protocol specific. In a layered `TEE_iSocket` configuration, the TA developer needs to call the `error` function for each layer to find out where the protocol specific error occurred.

A protocol error is valid and may be retrieved until another operation on the socket has been performed, in which case the `error` function returns the status of the last operation. If no protocol specific error occurred during the last socket operation in that specific layer, the `error` function SHALL return `TEE_SUCCESS`.

Specification Number: See section 4.4 **Function Number: 0x105**

Parameters

Name	Purpose
`TEE_iSocketHandle ctx`	Initialized implementation specific handle.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
`TEE_SUCCESS`	No	The last operation on this `ctx` did not encounter any protocol errors.
Protocol specific error or warning value	Depends	Each protocol specific error or warning is defined in the corresponding Annex. If a function returns a `TEE_ISOCKET_ERROR_PROTOCOL`, it is considered fatal and the socket is closed. If a function returns a `TEE_ISOCKET_WARNING_PROTOCOL`, a warning occurred that is not fatal and the command was successful but with a warning.

Panic Reasons

The `error` function SHALL panic if either of the following occurs:

- The handle is not initialized or is `NULL`.
- The handle is not a valid handle of the specific protocol.
- The Implementation detects any error which cannot be represented by any defined or implementation defined error code.

5.2.9 ioctl

```
TEE_Result (* ioctl) (
              TEE_iSocketHandle   ctx,
              uint32_t            commandCode,
     [inout]  void                *buf,
     [inout]  uint32_t            *length
);
```

Description

The `ioctl` function is a way of extending the interface and providing protocol specific functionality to the interface. The parameter `commandCode` identifies what functionality is requested and depending on that, the `buf` parameter may be an input parameter, an output parameter, or both.

The most significant byte of the parameter `commandCode` indicates which protocol the `ioctl` function targets. If the most significant byte is zero, the `ioctl` function call is propagated throughout the stack of layered protocols.

The `commandCode` is constructed from a `protocolID` and a `commandID` as described in Table 5-1 and exemplified in Table 5-2.

Table 5-1: Structure of the `commandCode` Parameter

Bits	Function	Values	
Bits [31:24]	`protocolID`	0	Command is propagated through the stack of protocols. Each `commandCode` value that has this byte set to zero must be defined in this specification.
		Any other value	Command is intended for a specific protocol currently in the stack. The `commandCode` values for a specific protocol are defined in the instance specification of that protocol.
Bits [23:0]	`commandID`	0x000000 – 0xEFFFFF	Reserved for use in GlobalPlatform specifications.
		0xF00000 – 0xFFFFFF	Reserved for Implementation specific commands.

Table 5-2: Examples of commandCode Interpretations

Value	Interpretation
0x00123456	A general command that propagates through the protocol stack. It has a `commandID` of 0x123456, which indicates that GlobalPlatform defined it.
0x05F00001	A targeted command for the protocol having `protocolID` equal to 0x05. It has a `commandID` of 0xF00001, which indicates that it is Implementation specific.

The functionality of the `ioctl` function is as follows:

1. The byte `protocolID == 0`.
   a. If the protocol recognizes the `commandID` (has an internal function for the command), `ioctl` executes the corresponding internal function for the command.
      i. If the execution returns no error, `ioctl` invokes the `ioctl` function of the next lower protocol in the stack, using the same set of parameters (exchanging the `ctx`). The `ioctl` function returns with the return code of the lower protocol. If there is no lower layer protocol, it returns `TEE_SUCCESS`.
      ii. If the execution of the internal function returns an error, `ioctl` returns with that error.
   b. If the protocol does not recognize the `commandID`, `ioctl` invokes the `ioctl` function of the next lower protocol in the stack, using the same set of parameters (exchanging the `ctx`). The `ioctl` function returns with the return code of the lower protocol. If there is no lower layer protocol, it returns `TEE_SUCCESS`.
2. The byte `protocolID != 0`.
   a. If the parameter `protocolID` matches the protocol identifier of this protocol:
      i. If the protocol recognizes `commandID` (has an internal function for the command), `ioctl` executes the corresponding internal function for the command and returns `TEE_SUCCESS`, `TEE_ISOCKET_ERROR_PROTOCOL`, or `TEE_ISOCKET_WARNING_PROTOCOL` depending on the internal function.
      ii. If the protocol does not recognize `commandID`, it SHALL panic.
   b. If the parameter `protocolID` does not match the protocol identifier of this protocol, `ioctl` invokes the `ioctl` function of the next lower protocol in the stack, using the same set of parameters (exchanging the `ctx`). The `ioctl` function returns with the return code of the lower protocol. If there is no lower layer protocol, it SHALL panic.

Depending on the `commandCode`, the parameter `*buf` may be an input buffer, an output buffer, or both.

- If `*buf` is an input buffer, the parameter `*length` holds the length in bytes of the data in the buffer.
- If `*buf` is an output buffer, the parameter `*length` holds the number of bytes available in `*buf` for storing the output data, and upon return the `*length` parameter is updated with the actual number of bytes written into `*buf`.
- If `*buf` is both an input and an output buffer, the parameter `*length` acts as if it were a pure output buffer, and it is the responsibility of the internal function to interpret the correct number of bytes in the buffer to use as input data.

Specification Number: See section 4.4 **Function Number: 0x106**

Parameters

Name	Purpose
`TEE_iSocketHandle ctx`	Initialized implementation specific handle.
`uint32_t commandCode`	The requested command to execute. See section 5.3 and the accompanying text for a complete description.
`void *buf`	Pointer to a buffer holding input or output data of length `*length`. May be `NULL if *length == 0`.
`uint32_t *length`	Length of input data or allocated size of buffer for output data in bytes. For output data it is updated on return with the number of bytes written into `*buf`.

Return Values

See section 5.2.2 for the meaning of *fatal*.

Name	Fatal	Reason
`TEE_SUCCESS`	No	In case of success.
`TEE_ISOCKET_ERROR_PROTOCOL`	Yes	In case of an error. See the `error` function for further details. Each protocol specific error is defined in the corresponding Annex.
`TEE_ISOCKET_WARNING_PROTOCOL`	No	In case of a warning. See the `error` function for further details. Each protocol specific warning is defined in the corresponding Annex.

Panic Reasons

The `ioctl` function SHALL panic if any of the following occurs:

- The handle is not initialized or is `NULL`.
- The handle is not a valid handle of the specific protocol.
- The parameter `length == NULL`.
- The parameter `buf == NULL and *length > 0`.
- The byte `protocolID != 0` and the corresponding protocol or `commandID` is not found within the current stack of protocols.

The Implementation detects any error which cannot be represented by any defined or Implementation defined error code.

5.3 Global commandCode Definitions for ioctl

In this version of the specification, no global `ioctl` commands are defined.

5.4 Example of a TEE_iSocket Protocol Implementation

This section provides a short abbreviated example of an implementation of the Foo protocol. It is only meant as a guideline for how to declare the protocol specific structures and functions required by the `TEE_iSocket` interface.

5.4.1 The Header File

```
/* Header file tee_foosocket.h */
#ifndef TEE_ISOCKET_PROTOCOLID_FOO
#include "tee_isocket.h"  /* provides definition for TEE_iSocket */

/* define the protocolID for FOO */
#define ISOCKET_PROTOCOLID_FOO 0x35

typedef struct TEE_fooSocket_Setup_s {
    /*
     * All things needed to setup the FOO protocol.
     */
} TEE_fooSocket_Setup;

extern TEE_iSocket * const TEE_fooSocket;
#endif
```

5.4.2 The C Implementation File

```
/* Implementation file tee_foosocket.c */
#include "tee_internal_api.h"
#include "tee_foosocket.h"

typedef struct fooSocket_Context_s {
    /*
     * All things needed to maintain the context
     */
    uint32_t         *protocolError;
} fooSocket_Context;


/*
 * FOO_Open
 */
static TEE_Result FOO_open(TEE_iSocketHandle *ctx,
                       void              *setup,
                       uint32_t          *protocolError)

{
    fooSocket_Context *context;
    TEE_fooSocket_Setup *mysetup;

    /*
     * Check for panic criteria.
     * NOTE that in real code the correct function ID and
     * document ID need to be returned by the panics.
     */
    if ((ctx == NULL) || (setup == NULL) || (protocolError == NULL) ) {
          TEE_Panic(TEE_ERROR_BAD_PARAMETERS);
    }

    mysetup = (TEE_fooSocket_Setup *)setup;
    /*
     * Here we should check the correctness of the mysetup struct
     * and MAY Panic if it's not correct
     */

    /*
     * Allocate memory for context, and get a POINTER
     * in this case the pointer also consitutues the handle
     * used by iSocketHandle.
     */
    context = (fooSocket_Context *) TEE_Malloc(sizeof(fooSocket_Context),
                                     TEE_MALLOC_FILL_ZERO);
    if (context == NULL) {
          *ctx = TEE_HANDLE_NULL;
        return TEE_ERROR_OUT_OF_MEMORY;
    }
```

```
     /*
      * Populate the fields in context to maintain the
      * communication channel.
      */
    context = (TEE_fooSocket_Context *) ctx;
    /* Check what is currently in the ctx by assigning it to context. */

    *ctx = (TEE_iSocketHandle) context;

    /* one example is to to store the address used to report protocol errors
     */
    context->protocolError = *protocolError;

    /*
     * Open the communication channel according to the
     * parameters in mysetup.

     *  [ Done here ]

     * There may be more context to be stored in relation
     * to the open channel before we:
     */
    return TEE_SUCCESS;
}

/*
 * FOO_Close
 */
static TEE_Result FOO_close(TEE_iSocketHandle *ctx)
{
    if (ctx == TEE_HANDLE_NULL)
          return TEE_SUCCESS;

    /*
     * Check for panic criteria using helper functions.
     * NOTE that in real code the correct function ID and
     * document ID need to be returned by the panics.
     */
    if (FOO_CtxInvalidInProtocol(ctx) || FOO_CtxNotInitialized(ctx)) {
          ~~TEE_Panic(TEE_ERROR_BAD_PARAMETERS);~~return TEE_SUCCESS;
    }

    /*
     * Code to clean up context goes here
     */

    TEE_Free(ctx);
    return TEE_SUCCESS;
}
```

```
/* Truncated definitions for the remaining functions */

static TEE_Result FOO_send(
             TEE_iSocketHandle    *ctx,
             const void           *buf,
             uint32_t             *length,
             uint32_t             timeout ) { /* body */ }

static TEE_Result FOO_recv(
             TEE_iSocketHandle    *ctx,
             void                 *buf,
             uint32_t             *length,
             uint32_t             timeout ) { /* body */ }

static uint32_t FOO_error(
             TEE_iSocketHandle    *ctx )  { /* body */ }

static TEE_Result FOO_ioctl(
                TEE_iSocketHandle *ctx,
                uint32_t          commandCode,
                void              *buf,
                uint32_t          *length )  { /* body */ }


/* Instance declaration of the FOO protocol functions */

TEE_iSocket fooSocketInstance =  {
    TEE_iSocketVersion,
    ISOCKET_PROTOCOLID_FOO,
    &FOO_open,
    &FOO_close,
    &FOO_send,
    &FOO_recv,
    &FOO_error,
    &FOO_ioctl
};

TEE_iSocket * const TEE_fooSocket = &fooSocketInstance;
```