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Trusted Execution Environment Provisioning (TEEP) Protocol
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Abstract

This document specifies a protocol that installs, updates, and deletes Trusted Applications (TAs) in a device with a Trusted Execution Environment (TEE). Due to its function it is called "Trusted Execution Environment Provisioning (TEEP) Protocol", which provides interoperability for mantaining the lifecycle of TAs.

Status of This Memo

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1. Introduction

The Trusted Execution Environment (TEE) concept has been designed to separate a regular operating system, also referred as a Rich Execution Environment (REE), from security-sensitive applications. In an TEE ecosystem, different device vendors may use different operating systems in the REE and may use different types of TEEs. When application providers or device administrators use Trusted Application Managers (TAMs) to install, update, and delete Trusted Applications (TAs) on a wide range of devices with potentially different TEEs then an interoperability need arises.

This document specifies the protocol for communicating between a TAM and a TEEP Agent, involving a TEEP Broker.

The Trusted Execution Environment Provisioning (TEEP) architecture document [I-D.ietf-teep-architecture] has set to provide a design guidance for such an interoperable protocol and introduces the necessary terminology. Note that the term Trusted Application may include more than code; it may also include configuration data and keys needed by the TA to operate correctly.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

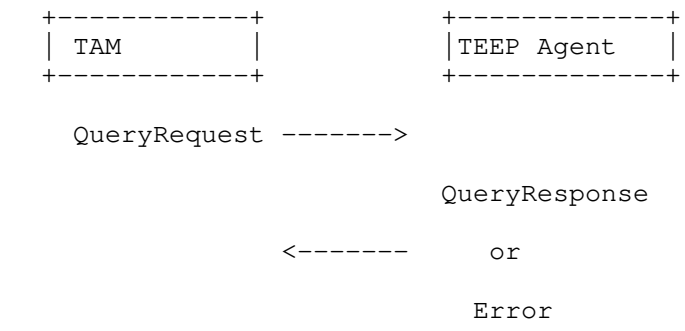
This specification re-uses the terminology defined in [I-D.ietf-teep-architecture].

3. Message Overview

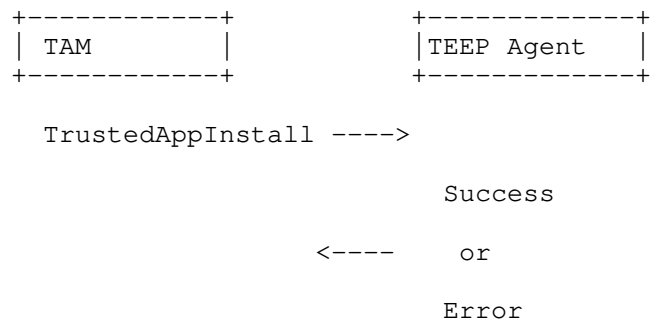
The TEEP protocol consists of a couple of messages exchanged between a TAM and a TEEP Agent via a TEEP Broker. The messages are encoded either in JSON or CBOR and designed to provide end-to-end security. TEEP protocol messages are signed and/or encrypted by the endpoints, i.e., the TAM and the TEEP Agent, but trusted applications may as well be encrypted and signed by the service provider. The TEEP protocol not only re-use JSON and CBOR but also the respective security wrappers, namely JOSE (JWS [RFC7515] and JWE [RFC7516], to be more specific) and COSE [RFC8152]. Furthermore, for attestation the Entity Attestation Token (EAT) [I-D.ietf-rats-eat] and for software updates the SUIT manifest format [I-D.ietf-suit-manifest] is re-used.

This specification defines six messages.

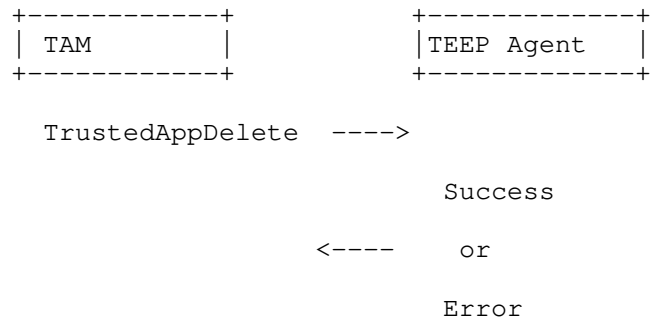
A TAM queries a device's current state with a QueryRequest message. A TEEP Agent will, after authenticating and authorizing the request, report attestation information, list all TAs, and provide information about supported algorithms and extensions in a QueryResponse message. An error message is returned if the request could not be processed. A TAM will process the QueryResponse message and determine whether subsequent message exchanges to install, update, or delete trusted applications shall be initiated.



With the TrustedAppInstall message a TAM can instruct a TEEP Agent to install a TA. The TEEP Agent will process the message, determine whether the TAM is authorized and whether the TA has been signed by an authorized SP. In addition to the binary, the TAM may also provide personalization data. If the TrustedAppInstall message was processed successfully then a Success message is returned to the TAM, an Error message otherwise.



With the TrustedAppDelete message a TAM can instruct a TEEP Agent to delete one or multiple TA(s). A Success message is returned when the operation has been completed successfully, and an Error message otherwise.



4. Detailed Messages Specification

For a CBOR-based encoding the following security wrapper is used (described in CDDL format [I-D.ietf-cbor-cddl]).

```
Outer_Wrapper = {
    msg-authenc-wrapper         => bstr .cbor
                                   Msg_AuthEnc_Wrapper / nil,
    teep-message                => (QueryRequest /
                                    QueryResponse /
                                    TrustedAppInstall /
                                    TrustedAppDelete /
                                    Error /
                                    Success ),
}

msg-authenc-wrapper = 1
teep-message = 2

Msg_AuthEnc_Wrapper = [ * (COSE_Mac_Tagged /
                           COSE_Sign_Tagged /
                           COSE_Mac0_Tagged /
                           COSE_Sign1_Tagged)]
```

A future version of this specification will also describe the security wrapper for JSON (in CDDL format).

```
suite = int

version = int

data_items = (
   attestation: 1,
   ta: 2,
   ext: 3
)

QueryRequest = (
     TYPE : int,
     TOKEN : bstr,
     REQUEST : [+data_items],
     ? CIPHER_SUITE : [+suite],
     ? NONCE : bstr,
     ? VERSION : [+version],
     ? OCSP_DATA : bstr,
     * $$extensions
)
```

A QueryRequest message is signed by the TAM and has the following fields:

TYPE TYPE = 1 corresponds to a QueryRequest message sent from the TAM to the TEEP Agent.

TOKEN The value in the TOKEN field is used to match requests to responses.

REQUEST The REQUEST field indicates what information the TAM requests from the TEEP Agent in form of a list of integer values. Each integer value corresponds to an IANA registered information element. This specification defines the initial set of information elements. With 'attestation' (1) the TAM requests the TEEP Agent to return an EAT entity attestation token in the response, with 'ta' (2) the TAM wants to query the TEEP Agent for all installed TAs, and with 'ext' (3) the TAM wants to query the TEEP Agent for supported extensions. Further values may be added in the future via IANA registration.

CIPHER_SUITE The CIPHER_SUITE field lists the ciphersuite(s) supported by the TAM.

NONCE NONCE is an optional field used for ensuring the refreshness of the Entity Attestation Token (EAT) contained in the response.

VERSION The VERSION field lists the version(s) supported by the TAM. For this version of the specification this field can be omitted.

OCSP_DATA The OCSP_DATA field contains a list of OCSP stapling data respectively for the TAM certificate and each of the CA certificates up to the root certificate. The TAM provides OCSP data so that the TEEP Agent can validate the status of the TAM certificate chain without making its own external OCSP service call.

```
ta_id = (
   Vendor_ID = bstr,
   Class_ID = bstr,
   Device_ID = bstr,
   * $$extensions
)

ext_info = int

QueryResponse = (
     TYPE : int,
     TOKEN : bstr,
     ? SELECTED_CIPHER_SUITE : suite,
     ? SELECTED_VERSION : version,
     ? EAT : bstr,
     ? TA_LIST  : [+ta_id],
     ? EXT_LIST : [+ext_info],
     * $$extensions
)
```

The QueryResponse message is signed and encrypted by the TEEP Agent and returned to the TAM. It has the following fields:

TYPE TYPE = 2 corresponds to a QueryResponse message sent from the TEEP Agent to the TAM.

TOKEN The value in the TOKEN field is used to match requests to responses. The value MUST correspond to the value received with the QueryRequest.

SELECTED_CIPHER_SUITE The SELECTED_CIPHER_SUITE field indicates the selected ciphersuite.

SELECTED_VERSION The SELECTED_VERSION field indicates the protocol version selected by the TEEP Agent.

EAT The EAT field contains an Entity Attestation Token following the encoding defined in [I-D.ietf-rats-eat].

TA_LIST The TA_LIST field enumerates the trusted applications installed on the device in form of ta_ids, i.e., a vendor id/class id/device id triple.

EXT_LIST The EXT_LIST field lists the supported extensions. This document does not define any extensions.

```
TrustedAppInstall = (
     TYPE : int,
     TOKEN : bstr,
     ? TA  : [+SUIT_Outer_Wrapper],
     * $$extensions
)
```

The TrustedAppInstall message is MACed and encrypted by the TAM and has the following fields:

TYPE TYPE = 3 corresponds to a TrustedAppInstall message sent from the TAM to the TEEP Agent. In case of successful processing, an Success message is returned by the TEEP Agent. In case of an error, an Error message is returned. Note that the TrustedAppInstall message is used for initial TA installation but also for TA updates.

TOKEN The value in the TOKEN field is used to match requests to responses.

TA The TA field is used to convey one or multiple SUIT manifests. The SUIT manifest contains the code for the trusted app but may also convey personalization data. TA binaries and personalization data is often signed and encrypted by the SP. Other combinations are, however, possible as well. For example, it is also possible for the TAM to sign and encrypt the personalization data and to let the SP sign and/or encrypt the TA binary.

```
TrustedAppDelete  = (
     TYPE : int,
     TOKEN : bstr,
     ? TA_LIST  : [+ta_id],
     * $$extensions
)
```

The TrustedAppDelete message is MACed and encrypted by the TAM and has the following fields:

TYPE TYPE = 4 corresponds to a TrustedAppDelete message sent from the TAM to the TEEP Agent. In case of successful processing, an Success message is returned by the TEEP Agent. In case of an error, an Error message is returned.

TOKEN The value in the TOKEN field is used to match requests to responses.

TA_LIST The TA_LIST field enumerates the TAs to be deleted.

```
Success = (
     TYPE : int,
     TOKEN : bstr,
     ? MSG : tstr,
     * $$extensions
)
```

The Success message is MACed and encrypted by the TEEP Agent and has the following fields:

TYPE TYPE = 5 corresponds to a Error message sent from the TEEP Agent to the TAM.

TOKEN The value in the TOKEN field is used to match requests to responses.

MSG The MSG field contains optional diagnostics information encoded in UTF-8 [RFC3629] returned by the TEEP Agent.

```
Error = (
     TYPE : int,
     TOKEN : bstr,
     ERR_CODE : int,
     ? ERR_MSG : tstr,
     ? CIPHER_SUITE : [+suite],
     ? VERSION : [+version],
     * $$extensions
)
```

If possible, the Error message is MACed and encrypted by the TEEP Agent. Unprotected Error messages MUST be handled with care by the TAM due to possible downgrading attacks. It has the following fields:

TYPE TYPE = 6 corresponds to a Error message sent from the TEEP Agent to the TAM.

TOKEN The value in the TOKEN field is used to match requests to responses.

ERR_CODE The ERR_CODE field is populated with values listed in a registry (with the initial set of error codes listed below). Only selected messages are applicable to each message.

ERR_MSG The ERR_MSG message is a human-readable diagnostic message that MUST be encoded using UTF-8 [RFC3629] using Net-Unicode form [RFC5198].

VERSION The VERSION field enumerates the protocol version(s) supported by the TEEP Agent. This field is optional but MUST be returned with the ERR_UNSUPPORTED_MSG_VERSION error message.

CIPHER_SUITE The CIPHER_SUITE field lists the ciphersuite(s) supported by the TEEP Agent. This field is optional but MUST be returned with the ERR_UNSUPPORTED_CRYPTO_ALG error message.

This specification defines the following initial error messages. Additional error code can be registered with IANA.

ERR_ILLEGAL_PARAMETER The TEEP Agent sends this error message when a request contains incorrect fields or fields that are inconsistent with other fields.

ERR_UNSUPPORTED_EXTENSION The TEEP Agent sends this error message when it recognizes an unsupported extension or unsupported message.

ERR_REQUEST_SIGNATURE_FAILED The TEEP Agent sends this error message when it fails to verify the signature of the message.

ERR_UNSUPPORTED_MSG_VERSION The TEEP Agent receives a message but does not support the indicated version.

ERR_UNSUPPORTED_CRYPTO_ALG The TEEP Agent receives a request message encoded with an unsupported cryptographic algorithm.

ERR_BAD_CERTIFICATE The TEEP Agent returns this error when processing of a certificate failed. For diagnosis purposes it is RECOMMMENDED to include information about the failing certificate in the error message.

ERR_UNSUPPORTED_CERTIFICATE The TEEP Agent returns this error when a certificate was of an unsupported type.

ERR_CERTIFICATE_REVOKED The TEEP Agent returns this error when a certificate was revoked by its signer.

ERR_CERTIFICATE_EXPIRED The TEEP Agent returns this error when a certificate has expired or is not currently valid.

ERR_INTERNAL_ERROR The TEEP Agent returns this error when a miscellaneous internal error occurred while processing the request.

ERR_RESOURCE_FULL This error is reported when a device resource isn’t available anymore, such as storage space is full.

ERR_TA_NOT_FOUND This error will occur when the target TA does not exist. This error may happen when the TAM has stale information and tries to delete a TA that has already been deleted.

ERR_TA_ALREADY_INSTALLED While installing a TA, a TEE will return this error if the TA has already been installed.

ERR_TA_UNKNOWN_FORMAT The TEEP Agent returns this error when it does not recognize the format of the TA binary.

ERR_TA_DECRYPTION_FAILED The TEEP Agent returns this error when it fails to decrypt the TA binary.

ERR_TA_DECOMPRESSION_FAILED The TEEP Agent returns this error when it fails to decompress the TA binary.

ERR_MANIFEST_PROCESSING_FAILED The TEEP Agent returns this error when manifest processing failures occur that are less specific than ERR_TA_UNKNOWN_FORMAT, ERR_TA_UNKNOWN_FORMAT, and ERR_TA_DECOMPRESSION_FAILED.

ERR_PD_PROCESSING_FAILED The TEEP Agent returns this error when it fails to process the provided personalization data.

5. Security Consideration

This section summarizes the security considerations discussed in this specification:

Cryptographic Algorithms This specification relies on the cryptographic algorithms provided by the security wrappers JOSE and COSE, respectively. A companion document makes algorithm recommendations but this document is written in an algorithm-agnostic way. TEEP protocol messages exchanged between the TAM and the TEEP Agent are protected using JWS and JWE (for JSON-encoded messages) and COSE (for CBOR-encoded messages). Public key based authentication is used to by the TEEP Agent to authenticate the TAM and vice versa.

Attestation A TAM may rely on the attestation information provided by the TEEP Agent and the Entity Attestation Token is re-used to convey this information. To sign the Entity Attestation Token it is necessary for the device to possess a public key (usually in the form of a certificate) along with the corresponding private key. Depending on the properties of the attestation mechanism it is possible to uniquely identify a device based on information in the attestation information or in the certificate used to sign the attestation token. This uniqueness may raise privacy concerns.

To lower the privacy implications the TEEP Agent MUST present its attestation information only to an authenticated and authorized TAM.

TA Binaries TA binaries are provided by the SP.It is the responsibility of the TAM to relay only verified TAs from authorized SPs. Delivery of that TA to the TEEP Agent is then the responsibility of the TAM and the TEEP Broker, using the security mechanisms provided by the TEEP protocol. To protect the TA binary the SUIT manifest is re-used and it offers a varity of security features, including digitial signatures and symmetric encryption.

Personalization Data An SP or a TAM can supply personalization data along with a TA. This data is also protected by a SUIT manifest. The personalization data may be itself is (or can be) opaque to the TAM.

TEEP Broker The TEEP protocol relies on the TEEP Broker to relay messages between the TAM and the TEEP Agent. When the TEEP Broker is compromised it can drop messages, delay the delivery of messages, and replay messages but it cannot modify those messages. (A replay would be, however, detected by the TEEP Agent.) A compromised TEEP Broker could reorder messages in an attempt to install an old version of a TA. Information in the manifest ensures that the TEEP Agents are protected against such downgrading attacks based on features offered by the manifest itself.

CA Compromise The QueryRequest message from a TAM to the TEEP Agent may include OCSP stapling data for the TAM's signer certificate and for intermediate CA certificates up to the root certificate so that the TEEP Agent can verify the certificate's revocation status.

A certificate revocation status check on a TA signer certificate is OPTIONAL by a TEEP Agent. A TAM is responsible for vetting a TA and before distributing them to TEEP Agents. TEEP Agents will trust a TA signer certificate's validation status done by a TAM.

CA Compromise The CA issuing certificates to a TAM or an SP may get compromised. A compromised intermediate CA certificates can be detected by a TEEP Agent by using OCSP information, assuming the revocation information is available. Additionally, it is RECOMMENDED to provide a way to update the trust anchor store used by the device, for example using a firmware update mechanism.

If the CA issuing certificates to devices gets compromised then these devices might be rejected by a TAM, if revocation is available to the TAM.

Compromised TAM The TEEP Agent SHOULD use OCSP information to verify the validity of the TAM-provided certificate (as well as the validity of intermediate CA certificates). The integrity and the accuracy of the clock within the TEE determines the ability to determine an expired or revoked certificate since OCSP stapling includes signature generation time, certificate validity dates are compared to the current time.

6. IANA Considerations

There are two IANA requests: a media type and list of error codes.

IANA is requested to assign a media type for application/otrpv2+json.

Type name: application

Subtype name: teep+json

Required parameters: none

Optional parameters: none

Encoding considerations: Same as encoding considerations of application/json as specified in Section 11 of [RFC7159]

Security considerations: See Security Considerations Section of this document.

Interoperability considerations: Same as interoperability considerations of application/json as specified in [RFC7159]

Published specification: This document.

Applications that use this media type: TEEP protocol implementations

Fragment identifier considerations: N/A

Additional information:

Deprecated alias names for this type: N/A

Magic number(s): N/A

File extension(s): N/A

Macintosh file type code(s): N/A

Person to contact for further information: teep@ietf.org

Intended usage: COMMON

Restrictions on usage: none

Author: See the "Authors' Addresses" section of this document

Change controller: IETF

IANA is requested to assign a media type for application/teep+cbor.

Type name: application

Subtype name: teep+cbor

Required parameters: none

Optional parameters: none

Encoding considerations: Same as encoding considerations of application/cbor

Security considerations: See Security Considerations Section of this document.

Interoperability considerations: Same as interoperability considerations of application/cbor as specified in [RFC7049]

Published specification: This document.

Applications that use this media type: TEEP protocol implementations

Fragment identifier considerations: N/A

Additional information:

Deprecated alias names for this type: N/A

Magic number(s): N/A

File extension(s): N/A

Macintosh file type code(s): N/A

Person to contact for further information: teep@ietf.org

Intended usage: COMMON

Restrictions on usage: none

Author: See the "Authors' Addresses" section of this document

Change controller: IETF

IANA is also requested to create a new registry for the error codes defined in Section 4.

Registration requests are evaluated after a three-week review period on the teep-reg-review@ietf.org mailing list, on the advice of one or more Designated Experts [RFC8126]. However, to allow for the allocation of values prior to publication, the Designated Experts may approve registration once they are satisfied that such a specification will be published.

Registration requests sent to the mailing list for review should use an appropriate subject (e.g., "Request to register an error code: example"). Registration requests that are undetermined for a period longer than 21 days can be brought to the IESG's attention (using the iesg@ietf.org mailing list) for resolution.

Criteria that should be applied by the Designated Experts includes determining whether the proposed registration duplicates existing functionality, whether it is likely to be of general applicability or whether it is useful only for a single extension, and whether the registration description is clear.

IANA must only accept registry updates from the Designated Experts and should direct all requests for registration to the review mailing list.

7. References

7.1. Normative References

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Appendix A. Acknowledgements

This work is based on the initial version of OTrP [I-D.ietf-teep-opentrustprotocol] and hence credits go to those who have contributed to it.

Appendix B. Contributors

We would like to thank the following individuals for their contributions to an earlier version of this specification.

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