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Trusted Execution Environment Provisioning (TEEP) Architecture
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Abstract

A Trusted Execution Environment (TEE) was designed to provide a hardware-isolation mechanism to separate a regular operating system from security-sensitive applications.

This architecture document motivates the design and standardization of a protocol for managing the lifecycle of trusted applications running inside a TEE.

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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. A TEE provides hardware-enforcement so that any data inside the TEE cannot be read by code outside of the TEE. Compromising a REE and normal applications in the REE do not affect code inside the TEE, which is called a Trusted Application (TA), running inside the TEE.

In an TEE ecosystem, a Trusted Application Manager (TAM) is commonly used to manage keys and TAs that run in a device. Different device vendors may use different TEE implementations. Different application providers or device administrators may choose to use different TAM providers.

To simplify the life of developers an interoperable protocol for managing TAs running in different TEEs of various devices is needed.

The protocol addresses the following problems.

1. A Device Administrator (DA) or Service Provider (SP) of the device users needs to determine security-relevant information of a device before provisioning the TA to the device with a TEE. Examples include the verification of the device 'root of trust' and the type of TEE included in a device.
2. A TEE in a device needs to determine whether a Device Administrator (DA) or a Service Provider (SP) that wants to manage an TA in the device is authorized to manage applications in the TEE.
3. Attestation must be able to ensure a TEE is genuine.

2. Terminology

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 RFC 2119 [RFC2119].

Client Application: An application running on a rich OS, such as an Android, Windows, or iOS application.

Device: A physical piece of hardware that hosts a TEE along with a rich OS.

Agent: An application running in the rich OS allowing the message protocol exchange between a TAM and a TEE in a device. A TEE is responsible to processing relayed messages and for returning an appropriate response.

Rich Execution Environment (REE) An environment that is provided and governed by a typical OS (Linux, Windows, Android, iOS, etc.), potentially in conjunction with other supporting operating systems and hypervisors; it is outside of the TEE. This environment and applications running on it are considered untrusted.

Secure Boot Module (SBM): A firmware in a device that delivers secure boot functionality. It is generally signed and can be verified whether it can be trusted.

Service Provider (SP): An entity that wishes to supply Trusted Applications to remote devices. A Service Provider requires the help of a TAM in order to provision the Trusted Applications to the devices.

Trust Anchor: A root certificate that can be used to validate its children certificates. It is usually embedded in a device or configured by a TAM for validating the trust of a remote entity's certificate.

Trusted Application (TA): An Application that runs in a TEE.

Trusted Execution Environment (TEE): An execution environment that runs alongside of, but is isolated from, an REE. A TEE has security capabilities and meets certain security-related

requirements. It protects TEE assets from general software attacks, defines rigid safeguards as to data and functions that a program can access, and resists a set of defined threats. It should have at least the following three properties:

- (a) A device unique credential that cannot be cloned;
- (b) Assurance that only authorized code can run in the TEE;
- (c) Memory that cannot be read by code outside of TEE.

There are multiple technologies that can be used to implement a TEE, and the level of security achieved varies accordingly.

Trusted Firmware (TFW): A signed SBM firmware that can be verified and is trusted by a TEE in a device.

This document uses the following abbreviations:

| | |
|-----|-------------------------------|
| CA | Certificate Authority |
| REE | Rich Execution Environment |
| SD | Security Domain |
| SP | Service Provider |
| SBM | Secure Boot Module |
| TA | Trusted Application |
| TEE | Trusted Execution Environment |
| TFW | Trusted Firmware |
| TAM | Trusted Application Manager |

3. Scope and Assumptions

This specification assumes that an applicable device is equipped with one or more TEEs and each TEE is pre-provisioned with a device-unique public/private key pair, which is securely stored. This key pair is referred to as the 'root of trust' for remote attestation of the associated TEE in a device by an TAM.

A Security Domain (SD) concept is used as the security boundary inside a TEE for trusted applications. Each SD is typically associated with one TA provider as the owner, which is a logical space that contains a SP's TAs. One TA provider may request to have multiple SDs in a TEE. One SD may contain multiple TAs. Each Security Domain requires the management operations of TAs in the form of installation, update and deletion.

A TA binary and configuration data can be from two sources:

1. A TAM supplies the signed and encrypted TA binary
2. A Client Application supplies the TA binary

The architecture covers the first case where the TA binary and configuration data are delivered from a TAM. The second case calls for an extension when a TAM is absent.

Messages exchange with a TAM require some transport and HTTPS is one commonly used transport.

4. Use Cases

4.1. Payment

A payment application in a mobile device requires high security and trust about the hosting device. Payments initiated from a mobile device can use a Trusted Application running inside TEE in the device to provide strong identification and proof of transaction.

For a mobile payment application, some biometric identification information could also be stored in the TEE. The mobile payment application can use such information for authentication.

A secure user interface (UI) may be used in a mobile device to prevent malicious software from stealing sensitive user input data. Such an application implementation often relies on TEE for user input protection.

4.2. Authentication

For better security of authentication, a devices may store its sensitive authentication keys inside a TEE of the device, providing hardware-protected security key strength and trusted execution code.

4.3. Internet of Things

Internet of Things (IoT) has been posing threats to networks and national infrastructures because of existing weak security in devices. It is very desirable that IoT devices can prevent a malware from stealing or modifying sensitive data such as authentication credentials in the device. A TEE can be the best way to implement such IoT security functions.

TEEs could be used to store variety of sensitive data for IoT devices. For example, a TEE could be used in smart door locks to store a user's biometric information for identification, and for protecting access the locking mechanism. Bike-sharing is another example that shares a similar usage scenario.

4.4. Confidential Cloud Computing

A tenant can store sensitive data in a TEE in a cloud computing server such that only the tenant can access the data, preventing the cloud host provider from accessing the data. A tenant can run TAs inside a server TEE for secure operation and enhanced data security. This provides benefits not only to tenants with better data security but also to cloud host provider for reduced liability and increased cloud adoption.

5. Architecture

5.1. System Components

The following are the main components in the system.

TAM: A TAM is responsible for originating and coordinating lifecycle management activity on a particular TEE on behalf of a Service Provider or a Device Administrator. For example, a payment application provider, which also provides payment service as a Service Provider using its payment TA, may choose to use a TAM that it runs or a third party TAM service to distribute and update its payment TA application in payment user devices. The payment SP isn't a device administrator of the user devices. A user who chooses to download the payment TA into its devices acts as the device administrator, authorizing the TA installation via the downloading consent. The device manufacturer is typically

responsible for embedding the TAM trust verification capability in its device TEE.

A TAM may be used by one SP or many SPs where a TAM may run as a Software-as-a-Service (SaaS). A TAM may provide Security Domain management and TA management in a device for the SD and TAs that a SP owns. In particular, a TAM typically offers over-the-air update to keep a SP's TAs up-to-date and clean up when a version should be removed. A TEE administrator or device administrator may decide TAMs that it trusts to manage its devices.

Certification Authority (CA): Certificate-based credentials used for authenticating a device, a TAM and an SP. A device embeds a list of root certificates (trust anchors), from trusted CAs that a TAM will be validated against. A TAM will remotely attest a device by checking whether a device comes with a certificate from a CA that the TAM trusts. The CAs do not need to be the same; different CAs can be chosen by each TAM, and different device CAs can be used by different device manufacturers.

TEE: A TEE in a device is responsible for protecting applications from attack, enabling the application to perform secure operations.

REE: The REE in a device is responsible for enabling off-device communications to be established between a TEE and TAM. The architecture does not assume or require that the REE or Client Applications is secure.

Agent: A Client Application is expected to communicate with a TAM to request TAs that it needs to use. The Client Application needs to pass the messages from the TAM to TEEs in the device. This calls for a component in REE that the Client Application can use to pass messages to TEEs. An Agent is this component to fill the role. In other words, an Agent is an application in the REE or software library that can simply relays messages from a Client Application to a TEE in the device. A device usually comes with only one active TEE. A TEE that supports may provide such an Agent to the device manufacturer to be bundled in devices. Such a compliant TEE must also include an Agent counterpart, namely, a processing module inside the TEE, to parse TAM messages sent through the Agent. An Agent is generally acting as a dummy relaying box with just the TEE interacting capability; it doesn't need and shouldn't parse protocol messages.

Device Administrator: A device owner or administrator may want to manage what TAs allowed to run in its devices. A default list of allowed TA trust root CA certificates is included in a device by

the device's manufacturer, which may be governed by the device carriers sometimes. There may be needs to expose overriding capability for a device owner to decide the list of allowed TAs by updating the list of trusted CA certificates.

Secure Boot: Secure boot must enable authenticity checking of TEEs by the TAM. Note that some TEE implementations do not require secure boot functionality.

5.2. Entity Relations

This architecture leverages asymmetric cryptography to authenticate a device towards a TAM. Additionally, a TEE in a device authenticates a TAM provider and TA signer. The provisioning of trust anchors to a device may differ from one use case to the other. The device administrator may want to have the capability to control what TAs are allowed. A device manufacturer enables verification of the TA signers and TAM providers; it may embed a list of default trust anchors that the signer of an allowed TA's signer certificate should chain to. A device administrator may choose to accept a subset of the allowed TAs via consent or action of downloading.

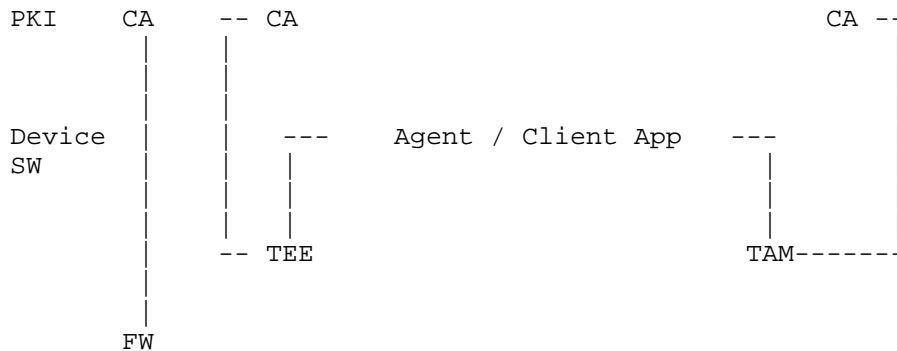


Figure 1: Entities

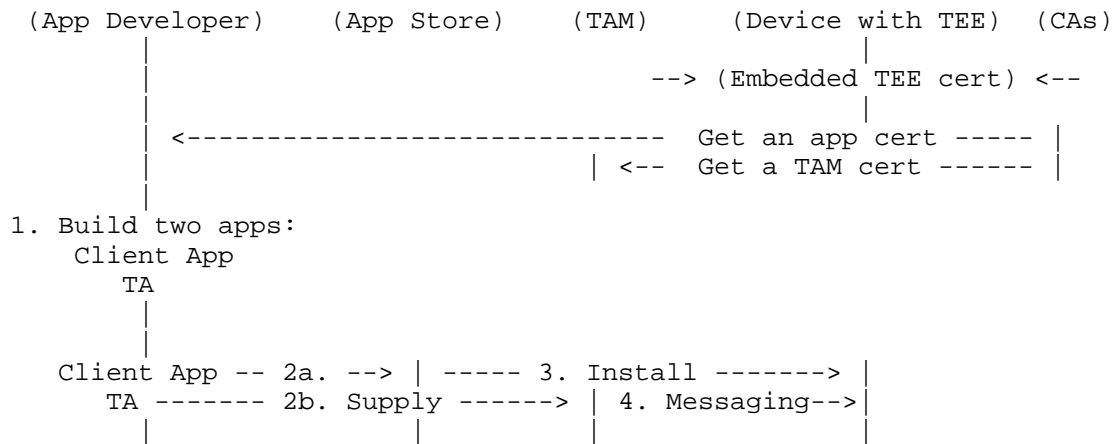


Figure 2: Developer Experience

Figure 2 shows an application developer building two applications: 1) a rich Client Application; 2) a TA that provides some security functions to be run inside a TEE. At step 2, the application developer uploads the Client Application (2a) to an Application Store. The Client Application may optionally bundle the TA binary. Meanwhile, the application developer may provide its TA to a TAM provider that will be managing the TA in various devices. 3. A user will go to an Application Store to download the Client Application. The Client Application will trigger TA installation by calling TAM. This is the step 4. The Client Application will get messages from TAM, and interacts with device TEE via an Agent.

The following diagram will show a system diagram about the entity relationships between CAs, TAM, SP and devices.

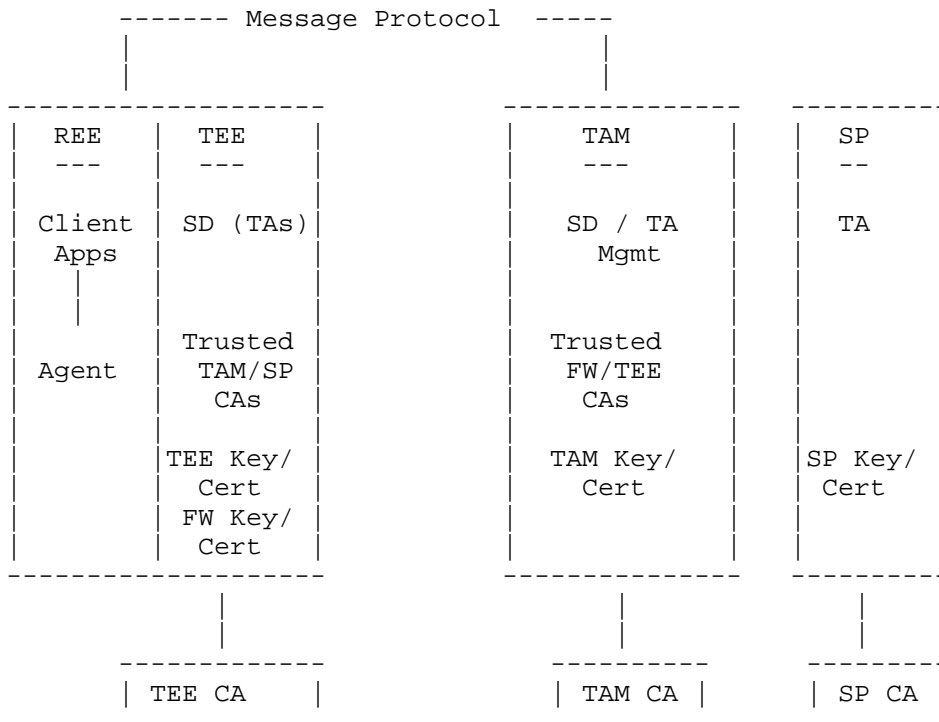


Figure 3: Keys

In the previous diagram, different CAs can be used for different types of certificates. Messages are always signed, where the signer key is the message originator's private key such as that of a TAM, the private key of a trusted firmware (TFW), or a TEE's private key.

The main components consist of a set of standard messages created by a TAM to deliver device SD and TA management commands to a device, and device attestation and response messages created by a TEE that responds to a TAM's message.

It should be noted that network communication capability is generally not available in TAs in today's TEE-powered devices. The networking functionality must be delegated to a rich Client Application. Client Applications will need to rely on an agent in the REE to interact with a TEE for message exchanges. Consequently, a TAM generally communicates with a Client Application about how it gets messages that originates from TEE inside a device. Similarly, a TA or TEE generally gets messages from a TAM via some Client Application, namely, an agent in this protocol architecture, not directly from the internet.

It is imperative to have an interoperable protocol to communicate with different TEEs in different devices that a Client Application needs to run and access a TA inside a TEE. This is the role of the agent, which is a software component that bridges communication between a TAM and a TEE. The agent does not need to know the actual content of messages except for the TEE routing information.

5.3. Trust Anchors in TEE

Each TEE comes with a trust store that contains a whitelist of root CA certificates that are used to validate a TAM's certificate. A TEE will accept a TAM to create new Security Domains and install new TAs on behalf of a SP only if the TAM's certificate is chained to one of the root CA certificates in the TEE's trust store.

A TEE's trust store is typically preloaded at manufacturing time. It is out of the scope in this document to specify how the trust store should be updated when a new root certificate should be added or existing one should be updated or removed. A device manufacturer is expected to provide its TEE trust store liveupdate or out-of-band update to devices.

Before a TAM can begin operation in the marketplace to support TEE-powered devices with a particular TEE, it must obtain a TAM certificate from a CA that is listed in the trust store of the TEE.

5.4. Trust Anchors in TAM

The trust anchor store in a TAM consists of a list of CA certificates that sign various device TEE certificates. A TAM decides what devices it will trust the TEE in.

5.5. Keys and Certificate Types

This architecture leverages the following credentials, which allow delivering end-to-end security without relying on any transport security.

| Key Entity Name | Location | Issuer | Checked Against | Cardinality |
|---------------------------------|-----------------------|------------------------|---|------------------------------------|
| 1. TFW key pair and certificate | Device secure storage | FW CA | A white list of FW root CA trusted by TAMs | 1 per device |
| 2. TEE key pair and certificate | Device TEE | TEE CA under a root CA | A white list of TEE root CA trusted by TAMs | 1 per device |
| 3. TAM key pair and certificate | TAM provider | TAM CA under a root CA | A white list of TAM root CA embedded in TEE | 1 or multiple can be used by a TAM |
| 4. SP key pair and certificate | SP | SP signer CA | A SP uses a TAM. TA is signed by a SP signer. TEE delegates trust of TA to TAM. SP signer is associated with a SD as the owner. | 1 or multiple can be used by a TAM |

Table 1: Key and Certificate Types

1. TFW key pair and certificate: A key pair and certificate for evidence of secure boot and trustworthy firmware in a device.
Location: Device secure storage
Supported Key Type: RSA and ECC
Issuer: OEM CA
Checked Against: A white list of FW root CA trusted by TAMs
Cardinality: One per device
2. TEE key pair and certificate: It is used for device attestation to a remote TAM and SP.

This key pair is burned into the device at device manufacturer. The key pair and its certificate are valid for the expected lifetime of the device.

Location: Device TEE

Supported Key Type: RSA and ECC

Issuer: A CA that chains to a TEE root CA

Checked Against: A white list of TEE root CA trusted by TAMs

Cardinality: One per device

3. TAM key pair and certificate: A TAM provider acquires a certificate from a CA that a TEE trusts.

Location: TAM provider

Supported Key Type: RSA and ECC.

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: TAM CA that chains to a root CA

Checked Against: A white list of TAM root CA embedded in TEE

Cardinality: One or multiple can be used by a TAM

4. SP key pair and certificate: an SP uses its own key pair and certificate to sign a TA.

Location: SP

Supported Key Type: RSA and ECC

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: an SP signer CA that chains to a root CA

Checked Against: A SP uses a TAM. A TEE trusts an SP by validating trust against a TAM that the SP uses. A TEE trusts TAM to ensure that a TA from the TAM is trustworthy.

Cardinality: One or multiple can be used by an SP

5.6. Scalability

This architecture uses a PKI. Trust anchors exist on the devices to enable the TEE to authenticate TAMs, and TAMs use trust anchors to authenticate TEEs. Since a PKI is used, many intermediate CAs certificates can chain to a root certificate, each of which can issue many certificates. This makes the protocol highly scalable. New factories that produce TEEs can join the ecosystem. In this case, such a factory can get an intermediate CA certificate from one of the existing roots without requiring that TAMs are updated with information about the new device factory. Likewise, new TAMs can join the ecosystem, providing they are issued a TAM certificate that chains to an existing root whereby existing TEEs will be allowed to be personalized by the TAM without requiring changes to the TEE itself. This enables the ecosystem to scale, and avoids the need for centralized databases of all TEEs produced or all TAMs that exist.

5.7. Message Security

Messages created by a TAM are used to deliver device SD and TA management commands to a device, and device attestation and response messages created by the TEE to respond to TAM messages.

These messages are signed end-to-end and are typically encrypted such that only the targeted device TEE or TAM is able to decrypt and view the actual content.

5.8. Security Domain Hierarchy and Ownership

The primary job of a TAM is to help an SP to manage its trusted applications. A TA is typically installed in an SD. An SD is commonly created for an SP.

When an SP delegates its SD and TA management to a TAM, an SD is created on behalf of a TAM in a TEE and the owner of the SD is assigned to the TAM. An SD may be associated with an SP but the TAM has full privilege to manage the SD for the SP.

Each SD for an SP is associated with only one TAM. When an SP changes TAM, a new SP SD must be created to associate with the new TAM. The TEE will maintain a registry of TAM ID and SP SD ID mapping.

From an SD ownership perspective, the SD tree is flat and there is only one level. An SD is associated with its owner. It is up to TEE implementation how it maintains SD binding information for a TAM and different SPs under the same TAM.

It is an important decision in this protocol specification that a TEE doesn't need to know whether a TAM is authorized to manage the SD for an SP. This authorization is implicitly triggered by an SP Client Application, which instructs what TAM it wants to use. An SD is always associated with a TAM in addition to its SP ID. A rogue TAM isn't able to do anything on an unauthorized SP's SD managed by another TAM.

Since a TAM may support multiple SPs, sharing the same SD name for different SPs creates a dependency in deleting an SD. An SD can be deleted only after all TAs associated with this SD is deleted. An SP cannot delete a Security Domain on its own with a TAM if a TAM decides to introduce such sharing. There are cases where multiple virtual SPs belong to the same organization, and a TAM chooses to use the same SD name for those SPs. This is totally up to the TAM implementation and out of scope of this specification.

5.9. SD Owner Identification and TAM Certificate Requirements

There is a need of cryptographically binding proof about the owner of an SD in a device. When an SD is created on behalf of a TAM, a future request from the TAM must present itself as a way that the TEE can verify it is the true owner. The certificate itself cannot reliably be used as the owner because TAM may change its certificate.

To this end, each TAM will be associated with a trusted identifier defined as an attribute in the TAM certificate. This field is kept the same when the TAM renews its certificates. A TAM CA is responsible to vet the requested TAM attribute value.

This identifier value must not collide among different TAM providers, and one TAM shouldn't be able to claim the identifier used by another TAM provider.

The certificate extension name to carry the identifier can initially use SubjectAltName:registeredID. A dedicated new extension name may be registered later.

One common choice of the identifier value is the TAM's service URL. A CA can verify the domain ownership of the URL with the TAM in the certificate enrollment process.

A TEE can assign this certificate attribute value as the TAM owner ID for the SDs that are created for the TAM.

An alternative way to represent an SD ownership by a TAM is to have a unique secret key upon SD creation such that only the creator TAM is able to produce a proof-of-possession (PoP) data with the secret.

5.10. Service Provider Container

A sample Security Domain hierarchy for the TEE is shown in Figure 4.

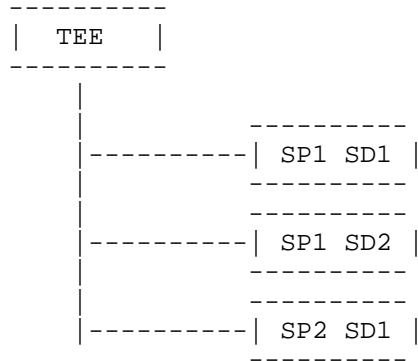


Figure 4: Security Domain Hierarchy

The architecture separates SDs and TAs such that a TAM can only manage or retrieve data for SDs and TAs that it previously created for the SPs it represents.

5.11. A Sample Device Setup Flow

Step 1: Prepare Images for Devices

1. [TEE vendor] Deliver TEE Image (CODE Binary) to device OEM
2. [CA] Deliver root CA Whitelist
3. [Soc] Deliver TFW Image

Step 2: Inject Key Pairs and Images to Devices

1. [OEM] Generate Secure Boot Key Pair (May be shared among multiple devices)
2. [OEM] Flash signed TFW Image and signed TEE Image onto devices (signed by Secure Boot Key)

Step 3: Setup attestation key pairs in devices

1. [OEM] Flash Secure Boot Public Key and eFuse Key (eFuse key is unique per device)

2. [TFW/TEE] Generate a unique attestation key pair and get a certificate for the device.

Step 4: Setup trust anchors in devices

1. [TFW/TEE] Store the key and certificate encrypted with the eFuse key
2. [TEE vendor or OEM] Store trusted CA certificate list into devices

6. Agent

A TEE and TAs do not generally have capability to communicate to the outside of the hosting device. For example, the Global Platform [GPTEE] specifies one such architecture. This calls for a software module in the REE world to handle the network communication. Each Client Application in REE may carry this communication functionality but it must also interact with the TEE for the message exchange. The TEE interaction will vary according to different TEEs. In order for a Client Application to transparently support different TEEs, it is imperative to have a common interface for a Client Application to invoke for exchanging messages with TEEs.

A shared agent comes to meet this need. An agent is an application running in the REE of the device or a SDK that facilitates communication between a TAM and TEE. It also provides interfaces for TAM SDK or Client Applications to query and trigger TA installation that the application needs to use.

This interface for Client Applications may be commonly an Android service call for an Android powered device. A Client Application interacts with a TAM, and turns around to pass messages received from TAM to agent.

In all cases, a Client Application needs to be able to identify an agent that it can use.

6.1. Role of the Agent

An agent abstracts the message exchanges with the TEE in a device. The input data is originated from a TAM that a Client Application connects. A Client Application may also directly call Agent for some TA query functions.

The agent may internally process a request from TAM. At least, it needs to know where to route a message, e.g., TEE instance. It does not need to process or verify message content.

The agent returns TEE / TFW generated response messages to the caller. The agent is not expected to handle any network connection with an application or TAM.

The agent only needs to return an agent error message if the TEE is not reachable for some reason. Other errors are represented as response messages returned from the TEE which will then be passed to the TAM.

6.2. Agent Implementation Consideration

A Provider should consider methods of distribution, scope and concurrency on device and runtime options when implementing an agent. Several non-exhaustive options are discussed below. Providers are encouraged to take advantage of the latest communication and platform capabilities to offer the best user experience.

6.2.1. Agent Distribution

The agent installation is commonly carried out at OEM time. A user can dynamically download and install an agent on-demand.

It is important to ensure a legitimate agent is installed and used. If an agent is compromised it may drop messages and thereby introducing a denial of service.

6.2.2. Number of Agents

We anticipate only one shared agent instance in a device. The device's TEE vendor will most probably supply one agent.

With one shared agent, the agent provider is responsible to allow multiple TAMs and TEE providers to achieve interoperability. With a standard agent interface, TAM can implement its own SDK for its SP Client Applications to work with this agent.

Multiple independent agent providers can be used as long as they have standard interface to a Client Application or TAM SDK. Only one agent is expected in a device.

TAM providers are generally expected to provide SDK for SP applications to interact with an agent for the TAM and TEE interaction.

7. Attestation

7.1. Attestation Hierarchy

The attestation hierarchy and seed required for TAM protocol operation must be built into the device at manufacture. Additional TEEs can be added post-manufacture using the scheme proposed, but it is outside of the current scope of this document to detail that.

It should be noted that the attestation scheme described is based on signatures. The only encryption that takes place may be the use of a so-called eFuse to release the SBM signing key and later during the protocol lifecycle management interchange with the TAM.

SBM attestation can be optional in TEEP architecture where the starting point of device attestation can be at TEE certificates. TAM can define its policies on what kind of TEE it trusts if TFW attestation isn't included during the TEE attestation.

7.1.1. Attestation Hierarchy Establishment: Manufacture

During manufacture the following steps are required:

1. A device-specific TFW key pair and certificate are burnt into the device, encrypted by eFuse. This key pair will be used for signing operations performed by the SBM.
2. TEE images are loaded and include a TEE instance-specific key pair and certificate. The key pair and certificate are included in the image and covered by the code signing hash.
3. The process for TEE images is repeated for any subordinate TEEs, which are additional TEEs after the root TEE that some devices have.

7.1.2. Attestation Hierarchy Establishment: Device Boot

During device boot the following steps are required:

1. Secure boot releases the TFW private key by decrypting it with eFuse.
2. The SBM verifies the code-signing signature of the active TEE and places its TEE public key into a signing buffer, along with its identifier for later access. For a TEE non-compliant to this architecture, the SBM leaves the TEE public key field blank.
3. The SBM signs the signing buffer with the TFW private key.

4. Each active TEE performs the same operation as the SBM, building up their own signed buffer containing subordinate TEE information.

7.1.3. Attestation Hierarchy Establishment: TAM

Before a TAM can begin operation in the marketplace to support devices of a given TEE, it must obtain a TAM certificate from a CA that is registered in the trust store of devices with that TEE. In this way, the TEE can check the intermediate and root CA and verify that it trusts this TAM to perform operations on the TEE.

8. Acknowledgements

The authors thank Dave Thaler for his very thorough review and many important suggestions. Most content of this document are split from a previously combined OTrP protocol document [I-D.ietf-teep-opentrustprotocol]. We thank the former co-authors Nick Cook and Minho Yoo for the initial document content, and contributors Brian Witten, Tyler Kim, and Alin Mutu.

9. Security Consideration

9.1. TA Trust Check at TEE

A TA binary is signed by a TA signer certificate. This TA signing certificate/private key belongs to the SP, and may be self-signed (i.e., it need not participate in a trust hierarchy). It is the responsibility of the TAM to only allow verified TAs from trusted SPs into the system. Delivery of that TA to the TEE is then the responsibility of the TEE, using the security mechanisms provided by the protocol.

We allow a way for an (untrusted) application to check the trustworthiness of a TA. An agent has a function to allow an application to query the information about a TA.

An application in the Rich O/S may perform verification of the TA by verifying the signature of the TA. The GetTAInformation function is available to return the TEE supplied TA signer and TAM signer information to the application. An application can do additional trust checks on the certificate returned for this TA. It might trust the TAM, or require additional SP signer trust chaining.

9.2. One TA Multiple SP Case

A TA for multiple SPs must have a different identifier per SP. A TA will be installed in a different SD for each respective SP.

9.3. Agent Trust Model

An agent could be malware in the vulnerable Rich OS. A Client Application will connect its TAM provider for required TA installation. It gets command messages from the TAM, and passes the message to the agent.

The architecture enables the TAM to communicate with the device's TEE to manage SDs and TAs. All TAM messages are signed and sensitive data is encrypted such that the agent cannot modify or capture sensitive data.

9.4. Data Protection at TAM and TEE

The TEE implementation provides protection of data on the device. It is the responsibility of the TAM to protect data on its servers.

9.5. Compromised CA

A root CA for TAM certificates might get compromised. Some TEE trust anchor update mechanism is expected from device OEM. A compromised intermediate CA is covered by OCSP stapling and OCSP validation check in the protocol. A TEE should validate certificate revocation about a TAM certificate chain.

If the root CA of some TEE device certificates is compromised, these devices might be rejected by a TAM, which is a decision of the TAM implementation and policy choice. Any intermediate CA for TEE device certificates SHOULD be validated by TAM with a Certificate Revocation List (CRL) or Online Certificate Status Protocol (OCSP) method.

9.6. Compromised TAM

The TEE SHOULD use validation of the supplied TAM certificates and OCSP stapled data to validate that the TAM is trustworthy.

Since PKI is used, the integrity of the clock within the TEE determines the ability of the TEE to reject an expired TAM certificate, or revoked TAM certificate. Since OCSP stapling includes signature generation time, certificate validity dates are compared to the current time.

9.7. Certificate Renewal

TFW and TEE device certificates are expected to be long lived, longer than the lifetime of a device. A TAM certificate usually has a moderate lifetime of 2 to 5 years. A TAM should get renewed or rekeyed certificates. The root CA certificates for a TAM, which are embedded into the trust anchor store in a device, should have long lifetimes that don't require device trust anchor update. On the other hand, it is imperative that OEMs or device providers plan for support of trust anchor update in their shipped devices.

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Trusted Execution Environment Provisioning (TEEP) Architecture
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Abstract

A Trusted Execution Environment (TEE) is an environment that enforces that any code within that environment cannot be tampered with, and that any data used by such code cannot be read or tampered with by any code outside that environment. This architecture document motivates the design and standardization of a protocol for managing the lifecycle of trusted applications running inside such a TEE.

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1. Introduction

Applications executing in a device are exposed to many different attacks intended to compromise the execution of the application or reveal the data upon which those applications are operating. These attacks increase with the number of other applications on the device, with such other applications coming from potentially untrustworthy sources. The potential for attacks further increases with the complexity of features and applications on devices, and the unintended interactions among those features and applications. The danger of attacks on a system increases as the sensitivity of the applications or data on the device increases. As an example, exposure of emails from a mail client is likely to be of concern to its owner, but a compromise of a banking application raises even greater concerns.

The Trusted Execution Environment (TEE) concept is designed to let applications execute in a protected environment that enforces that any code within that environment cannot be tampered with, and that any data used by such code cannot be read or tampered with by any code outside that environment, including by a commodity operating system (if present). In a system with multiple TEEs, this also means that code in one TEE cannot be read or tampered with by code in another TEE.

This separation reduces the possibility of a successful attack on application components and the data contained inside the TEE. Typically, application components are chosen to execute inside a TEE because those application components perform security sensitive operations or operate on sensitive data. An application component running inside a TEE is referred to as a Trusted Application (TA), while an application running outside any TEE, i.e., in the Rich Execution Environment (REE), is referred to as an Untrusted Application. In the example of a banking application, code that relates to the authentication protocol could reside in a TA while the application logic including HTTP protocol parsing could be contained in the Untrusted Application. In addition, processing of credit card numbers or account balances could be done in a TA as it is sensitive data. The precise code split is ultimately a decision of the developer based on the assets he or she wants to protect according to the threat model.

TEEs are typically used in cases where a software or data asset needs to be protected from unauthorized entities that may include the owner (or pwner) or possessor of a device. This situation arises for example in gaming consoles where anti-cheat protection is a concern, devices such as ATMs or IoT devices placed in locations where attackers might have physical access, cell phones or other devices used for mobile payments, and hosted cloud environments. Such environments can be thought of as hybrid devices where one user or administrator controls the REE and a different (remote) user or administrator controls a TEE in the same physical device. It may also be the case in some constrained devices that there is no REE (only a TEE) and there may be no local "user" per se, only a remote TEE administrator. For further discussion of such confidential computing use cases and threat model, see [CC-Overview] and [CC-Technical-Analysis].

TEEs use hardware enforcement combined with software protection to secure TAs and its data. TEEs typically offer a more limited set of services to TAs than is normally available to Untrusted Applications.

Not all TEEs are the same, however, and different vendors may have different implementations of TEEs with different security properties, different features, and different control mechanisms to operate on TAs. Some vendors may themselves market multiple different TEEs with different properties attuned to different markets. A device vendor may integrate one or more TEEs into their devices depending on market needs.

To simplify the life of TA developers interacting with TAs in a TEE, an interoperable protocol for managing TAs running in different TEEs of various devices is needed. This software update protocol needs to make sure that compatible trusted and untrusted components (if any) of an application are installed on the correct device. In this TEE ecosystem, there often arises a need for an external trusted party to verify the identity, claims, and rights of TA developers, devices, and their TEEs. This external trusted party is the Trusted Application Manager (TAM).

The Trusted Execution Environment Provisioning (TEEP) protocol addresses the following problems:

- * An installer of an Untrusted Application that depends on a given TA wants to request installation of that TA in the device's TEE so that the Untrusted Application can complete, but the TEE needs to verify whether such a TA is actually authorized to run in the TEE and consume potentially scarce TEE resources.

- * A TA developer providing a TA whose code itself is considered confidential wants to determine security-relevant information of a device before allowing their TA to be provisioned to the TEE within the device. An example is the verification of the type of TEE included in a device and that it is capable of providing the security protections required.
- * A TEE in a device wants to determine whether an entity that wants to manage a TA in the device is authorized to manage TAs in the TEE, and what TAs the entity is permitted to manage.
- * A Device Administrator wants to determine if a TA exists (is installed) on a device (in the TEE), and if not, install the TA in the TEE.
- * A Device Administrator wants to check whether a TA in a device's TEE is the most up-to-date version, and if not, update the TA in the TEE.
- * A Device Administrator wants to remove a TA from a device's TEE if the TA developer is no longer maintaining that TA, when the TA has been revoked, or is not used for other reasons anymore (e.g., due to an expired subscription).

For TEEs that simply verify and load signed TA's from an untrusted filesystem, classic application distribution protocols can be used without modification. The problems in the bullets above, on the other hand, require a new protocol, i.e., the TEEP protocol. The TEEP protocol is a solution for TEEs that can install and enumerate TAs in a TEE-secured location where another domain-specific protocol standard (e.g., [GSMA], [OTRP]) that meets the needs is not already in use.

2. Terminology

The following terms are used:

- * App Store: An online location from which Untrusted Applications can be downloaded.
- * Device: A physical piece of hardware that hosts one or more TEEs, often along with an REE.
- * Device Administrator: An entity that is responsible for administration of a device, which could be the Device Owner. A Device Administrator has privileges on the device to install and remove Untrusted Applications and TAs, approve or reject Trust Anchors, and approve or reject TA developers, among possibly other

privileges on the device. A Device Administrator can manage the list of allowed TAMs by modifying the list of Trust Anchors on the device. Although a Device Administrator may have privileges and device-specific controls to locally administer a device, the Device Administrator may choose to remotely administer a device through a TAM.

- * **Device Owner:** A device is always owned by someone. In some cases, it is common for the (primary) device user to also own the device, making the device user/owner also the Device Administrator. In enterprise environments it is more common for the enterprise to own the device, and any device user has no or limited administration rights. In this case, the enterprise appoints a Device Administrator that is not the device owner.
- * **Device User:** A human being that uses a device. Many devices have a single device user. Some devices have a primary device user with other human beings as secondary device users (e.g., a parent allowing children to use their tablet or laptop). Other devices are not used by a human being and hence have no device user. Relates to Device Owner and Device Administrator.
- * **Personalization Data:** A set of configuration data that is specific to the device or user. The Personalization Data may depend on the type of TEE, a particular TEE instance, the TA, and even the user of the device; an example of Personalization Data might be a secret symmetric key used by a TA to communicate with some service.
- * **Raw Public Key:** A raw public key consists of only the algorithm identifier (type) of the key and the cryptographic public key material, such as the SubjectPublicKeyInfo structure of a PKIX certificate [RFC5280]. Other serialization formats that do not rely on ASN.1 may also be used.
- * **Rich Execution Environment (REE):** An environment that is provided and governed by a typical OS (e.g., Linux, Windows, Android, iOS), potentially in conjunction with other supporting operating systems and hypervisors; it is outside of the TEE(s) managed by the TEEP protocol. This environment and applications running on it are considered untrusted (or more precisely, less trusted than a TEE).
- * **Trust Anchor:** As defined in [RFC6024] and [I-D.ietf-suit-architecture], "A trust anchor represents an authoritative entity via a public key and associated data. The public key is used to verify digital signatures, and the associated data is used to constrain the types of information for which the trust anchor is authoritative." The Trust Anchor may be

a certificate, a raw public key or other structure, as appropriate. It can be a non-root certificate when it is a certificate.

- * **Trust Anchor Store:** As defined in [RFC6024], "A trust anchor store is a set of one or more trust anchors stored in a device... A device may have more than one trust anchor store, each of which may be used by one or more applications." As noted in [I-D.ietf-suit-architecture], a Trust Anchor Store must resist modification against unauthorized insertion, deletion, and modification.
- * **Trusted Application (TA):** An application (or, in some implementations, an application component) that runs in a TEE.
- * **Trusted Application Manager (TAM):** An entity that manages Trusted Applications and other Trusted Components running in TEEs of various devices.
- * **Trusted Component:** A set of code and/or data in a TEE managed as a unit by a Trusted Application Manager. Trusted Applications and Personalization Data are thus managed by being included in Trusted Components. Trusted OS code or trusted firmware can also be expressed as Trusted Components that a Trusted Component depends on.
- * **Trusted Component Developer:** An entity that develops one or more Trusted Components.
- * **Trusted Component Signer:** An entity that signs a Trusted Component with a key that a TEE will trust. The signer might or might not be the same entity as the Trusted Component Developer. For example, a Trusted Component might be signed (or re-signed) by a Device Administrator if the TEE will only trust the Device Administrator. A Trusted Component might also be encrypted, if the code is considered confidential.
- * **Trusted Execution Environment (TEE):** An execution environment that enforces that only authorized code can execute within the TEE, and data used by that code cannot be read or tampered with by code outside the TEE. A TEE also generally has a device unique credential that cannot be cloned. There are multiple technologies that can be used to implement a TEE, and the level of security achieved varies accordingly. In addition, TEEs typically use an isolation mechanism between Trusted Applications to ensure that one TA cannot read, modify or delete the data and code of another TA.

- * **Untrusted Application:** An application running in an REE. An Untrusted Application might depend on one or more TAs.

3. Use Cases

3.1. Payment

A payment application in a mobile device requires high security and trust in the hosting device. Payments initiated from a mobile device can use a Trusted Application to provide strong identification and proof of transaction.

For a mobile payment application, some biometric identification information could also be stored in a TEE. The mobile payment application can use such information for unlocking the device and for local identification of the user.

A trusted user interface (UI) may be used in a mobile device to prevent malicious software from stealing sensitive user input data. Such an implementation often relies on a TEE for providing access to peripherals, such as PIN input or a trusted display, so that the REE cannot observe or tamper with the user input or output.

3.2. Authentication

For better security of authentication, a device may store its keys and cryptographic libraries inside a TEE limiting access to cryptographic functions via a well-defined interface and thereby reducing access to keying material.

3.3. Internet of Things

Weak security in Internet of Things (IoT) devices has been posing threats to critical infrastructure, i.e., assets that are essential for the functioning of a society and economy. It is desirable that IoT devices can prevent malware from manipulating actuators (e.g., unlocking a door), or stealing or modifying sensitive data, such as authentication credentials in the device. A TEE can be the best way to implement such IoT security functions.

3.4. Confidential Cloud Computing

A tenant can store sensitive data, such as customer details or credit card numbers, in a TEE in a cloud computing server such that only the tenant can access the data, preventing the cloud hosting provider from accessing the data. A tenant can run TAs inside a server TEE for secure operation and enhanced data security. This provides benefits not only to tenants with better data security but also to

cloud hosting providers for reduced liability and increased cloud adoption.

4. Architecture

4.1. System Components

Figure 1 shows the main components in a typical device with an REE and a TEE. Full descriptions of components not previously defined are provided below. Interactions of all components are further explained in the following paragraphs.

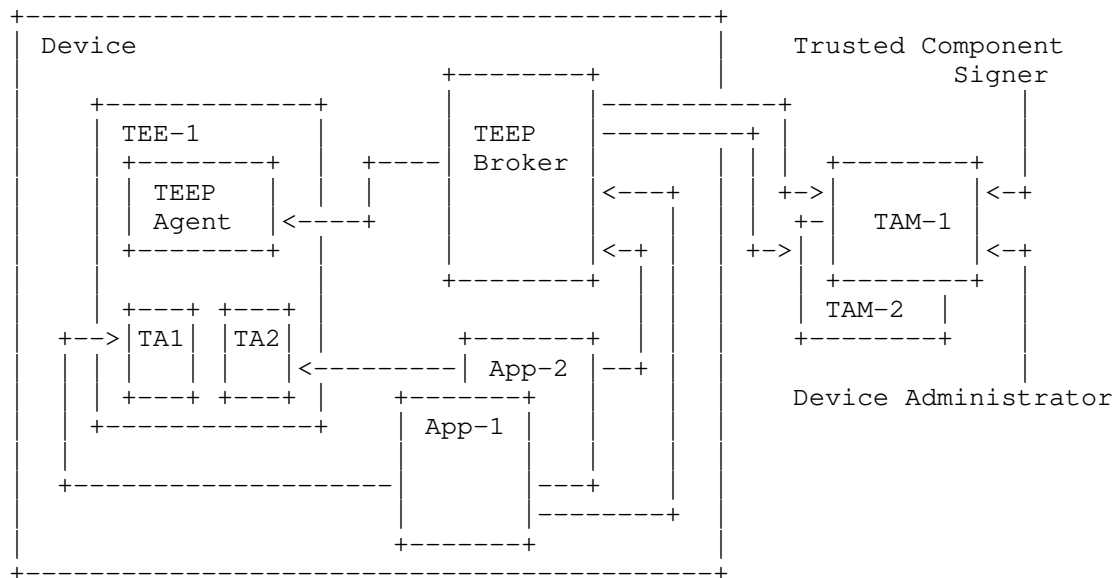


Figure 1: Notional Architecture of TEEP

- * Trusted Component Signers and Device Administrators utilize the services of a TAM to manage TAs on devices. Trusted Component Signers do not directly interact with devices. Device Administrators may elect to use a TAM for remote administration of TAs instead of managing each device directly.
- * Trusted Application Manager (TAM): A TAM is responsible for performing lifecycle management activity on Trusted Components on behalf of Trusted Component Signers and Device Administrators. This includes installation and deletion of Trusted Components, and may include, for example, over-the-air updates to keep Trusted Components up-to-date and clean up when Trusted Components should be removed. TAMs may provide services that make it easier for

Trusted Component Signers or Device Administrators to use the TAM's service to manage multiple devices, although that is not required of a TAM.

The TAM performs its management of Trusted Components on the device through interactions with a device's TEEP Broker, which relays messages between a TAM and a TEEP Agent running inside the TEE. TEEP authentication is performed between a TAM and a TEEP Agent.

As shown in Figure 1, the TAM cannot directly contact a TEEP Agent, but must wait for the TEEP Broker to contact the TAM requesting a particular service. This architecture is intentional in order to accommodate network and application firewalls that normally protect user and enterprise devices from arbitrary connections from external network entities.

A TAM may be publicly available for use by many Trusted Component Signers, or a TAM may be private, and accessible by only one or a limited number of Trusted Component Signers. It is expected that many enterprises, manufacturers, and network carriers will run their own private TAM.

A Trusted Component Signer or Device Administrator chooses a particular TAM based on whether the TAM is trusted by a device or set of devices. The TAM is trusted by a device if the TAM's public key is, or chains up to, an authorized Trust Anchor in the device. A Trusted Component Signer or Device Administrator may run their own TAM, but the devices they wish to manage must include this TAM's public key or certificate, or a certificate it chains up to, in the Trust Anchor Store.

A Trusted Component Signer or Device Administrator is free to utilize multiple TAMs. This may be required for managing Trusted Components on multiple different types of devices from different manufacturers, or mobile devices on different network carriers, since the Trust Anchor Store on these different devices may contain keys for different TAMs. A Device Administrator may be able to add their own TAM's public key or certificate, or a certificate it chains up to, to the Trust Anchor Store on all their devices, overcoming this limitation.

Any entity is free to operate a TAM. For a TAM to be successful, it must have its public key or certificate installed in a device's Trust Anchor Store. A TAM may set up a relationship with device manufacturers or network carriers to have them install the TAM's keys in their device's Trust Anchor Store. Alternatively, a TAM may publish its certificate and allow Device Administrators to install the TAM's certificate in their devices as an after-market action.

- * **TEEP Broker:** A TEEP Broker is an application component running in a Rich Execution Environment (REE) that enables the message protocol exchange between a TAM and a TEE in a device. A TEEP Broker does not process messages on behalf of a TEE, but merely is responsible for relaying messages from the TAM to the TEE, and for returning the TEE's responses to the TAM. In devices with no REE (e.g., a microcontroller where all code runs in an environment that meets the definition of a Trusted Execution Environment in Section 2), the TEEP Broker would be absent and instead the TEEP protocol transport would be implemented inside the TEE itself.
- * **TEEP Agent:** The TEEP Agent is a processing module running inside a TEE that receives TAM requests (typically relayed via a TEEP Broker that runs in an REE). A TEEP Agent in the TEE may parse requests or forward requests to other processing modules in a TEE, which is up to a TEE provider's implementation. A response message corresponding to a TAM request is sent back to the TAM, again typically relayed via a TEEP Broker.
- * **Certification Authority (CA):** A CA is an entity that issues digital certificates (especially X.509 certificates) and vouches for the binding between the data items in a certificate [RFC4949]. Certificates are then used for authenticating a device, a TAM, or a Trusted Component Signer, as discussed in Section 5. The CAs do not need to be the same; different CAs can be chosen by each TAM, and different device CAs can be used by different device manufacturers.

4.2. Multiple TEEs in a Device

Some devices might implement multiple TEEs. In these cases, there might be one shared TEEP Broker that interacts with all the TEEs in the device. However, some TEEs (for example, SGX [SGX]) present themselves as separate containers within memory without a controlling manager within the TEE. As such, there might be multiple TEEP Brokers in the REE, where each TEEP Broker communicates with one or more TEEs associated with it.

It is up to the REE and the Untrusted Applications how they select the correct TEEP Broker. Verification that the correct TA has been reached then becomes a matter of properly verifying TA attestations, which are unforgeable.

The multiple TEEP Broker approach is shown in the diagram below. For brevity, TEEP Broker 2 is shown interacting with only one TAM and Untrusted Application and only one TEE, but no such limitations are intended to be implied in the architecture.

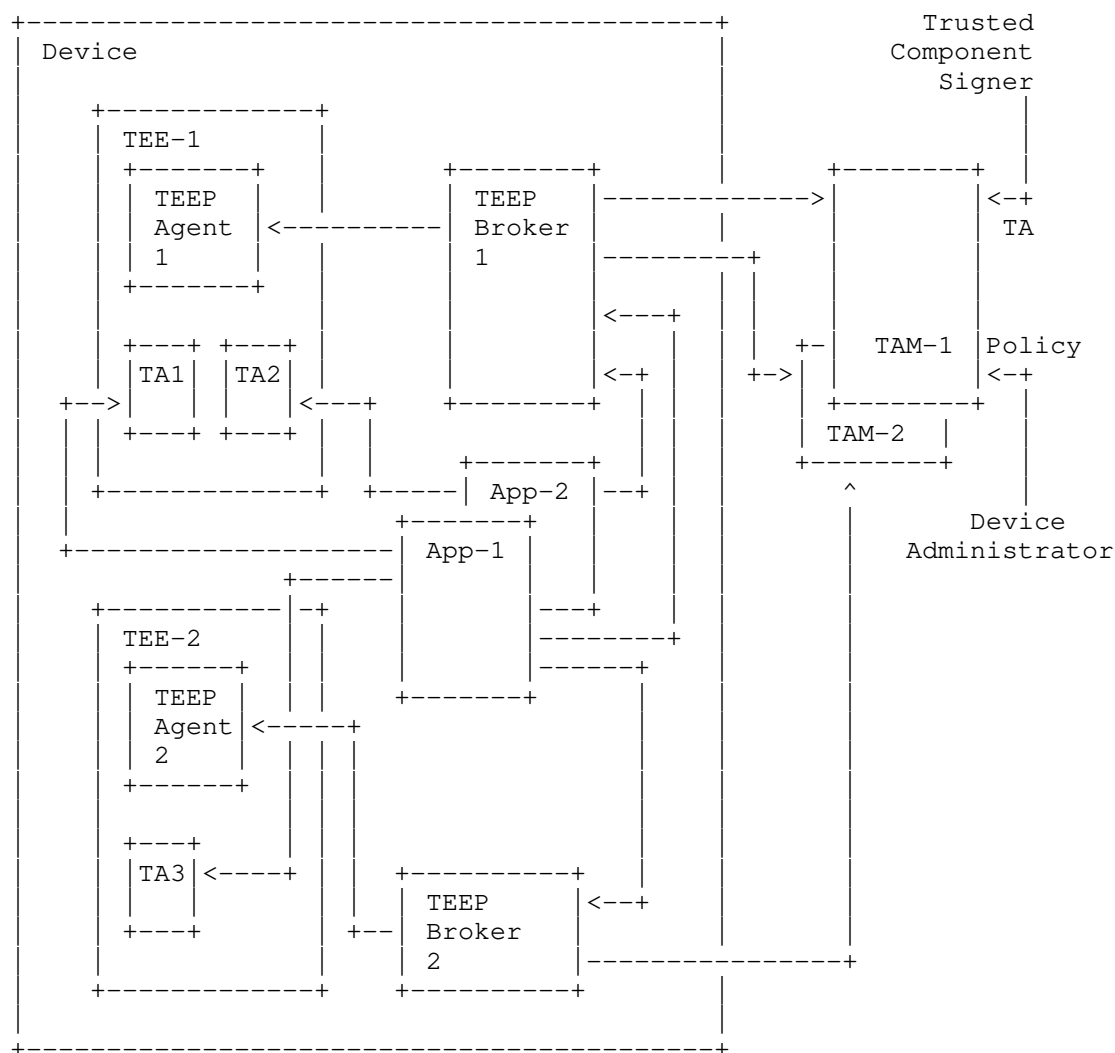


Figure 2: Notional Architecture of TEEP with multiple TEEs

In the diagram above, TEEP Broker 1 controls interactions with the TAs in TEE-1, and TEEP Broker 2 controls interactions with the TAs in TEE-2. This presents some challenges for a TAM in completely managing the device, since a TAM may not interact with all the TEEP Brokers on a particular platform. In addition, since TEEs may be physically separated, with wholly different resources, there may be no need for TEEP Brokers to share information on installed Trusted Components or resource usage.

4.3. Multiple TAMs and Relationship to TAs

As shown in Figure 2, a TEEP Broker provides communication between one or more TEEP Agents and one or more TAMs. The selection of which TAM to interact with might be made with or without input from an Untrusted Application, but is ultimately the decision of a TEEP Agent.

A TEEP Agent is assumed to be able to determine, for any given Trusted Component, whether that Trusted Component is installed (or minimally, is running) in a TEE with which the TEEP Agent is associated.

Each Trusted Component is digitally signed, protecting its integrity, and linking the Trusted Component back to the Trusted Component Signer. The Trusted Component Signer is often the Trusted Component Developer, but in some cases might be another party such as a Device Administrator or other party to whom the code has been licensed (in which case the same code might be signed by multiple licensees and distributed as if it were different TAs).

A Trusted Component Signer selects one or more TAMs and communicates the Trusted Component(s) to the TAM. For example, the Trusted Component Signer might choose TAMs based upon the markets into which the TAM can provide access. There may be TAMs that provide services to specific types of devices, or device operating systems, or specific geographical regions or network carriers. A Trusted Component Signer may be motivated to utilize multiple TAMs in order to maximize market penetration and availability on multiple types of devices. This means that the same Trusted Component will often be available through multiple TAMs.

When the developer of an Untrusted Application that depends on a Trusted Component publishes the Untrusted Application to an app store or other app repository, the developer optionally binds the Untrusted Application with a manifest that identifies what TAMs can be contacted for the Trusted Component. In some situations, a Trusted Component may only be available via a single TAM - this is likely the case for enterprise applications or Trusted Component Signers serving

a closed community. For broad public apps, there will likely be multiple TAMs in the Untrusted Application's manifest - one servicing one brand of mobile device and another servicing a different manufacturer, etc. Because different devices and different manufacturers trust different TAMs, the manifest can include multiple TAMs that support the required Trusted Component.

When a TEEP Broker receives a request (see the RequestTA API in Section 6.2.1) from an Untrusted Application to install a Trusted Component, a list of TAM URIs may be provided for that Trusted Component, and the request is passed to the TEEP Agent. If the TEEP Agent decides that the Trusted Component needs to be installed, the TEEP Agent selects a single TAM URI that is consistent with the list of trusted TAMs provisioned in the TEEP Agent, invokes the HTTP transport for TEEP to connect to the TAM URI, and begins a TEEP protocol exchange. When the TEEP Agent subsequently receives the Trusted Component to install and the Trusted Component's manifest indicates dependencies on any other trusted components, each dependency can include a list of TAM URIs for the relevant dependency. If such dependencies exist that are prerequisites to install the Trusted Component, then the TEEP Agent recursively follows the same procedure for each dependency that needs to be installed or updated, including selecting a TAM URI that is consistent with the list of trusted TAMs provisioned on the device, and beginning a TEEP exchange. If multiple TAM URIs are considered trusted, only one needs to be contacted and they can be attempted in some order until one responds.

Separate from the Untrusted Application's manifest, this framework relies on the use of the manifest format in [I-D.ietf-suit-manifest] for expressing how to install a Trusted Component, as well as any dependencies on other TEE components and versions. That is, dependencies from Trusted Components on other Trusted Components can be expressed in a SUIT manifest, including dependencies on any other TAs, trusted OS code (if any), or trusted firmware. Installation steps can also be expressed in a SUIT manifest.

For example, TEEs compliant with GlobalPlatform [GPTEE] may have a notion of a "security domain" (which is a grouping of one or more TAs installed on a device, that can share information within such a group) that must be created and into which one or more TAs can then be installed. It is thus up to the SUIT manifest to express a dependency on having such a security domain existing or being created first, as appropriate.

Updating a Trusted Component may cause compatibility issues with any Untrusted Applications or other components that depend on the updated Trusted Component, just like updating the OS or a shared library could impact an Untrusted Application. Thus, an implementation needs to take into account such issues.

4.4. Untrusted Apps, Trusted Apps, and Personalization Data

In TEEP, there is an explicit relationship and dependence between an Untrusted Application in an REE and one or more TAs in a TEE, as shown in Figure 2. For most purposes, an Untrusted Application that uses one or more TAs in a TEE appears no different from any other Untrusted Application in the REE. However, the way the Untrusted Application and its corresponding TAs are packaged, delivered, and installed on the device can vary. The variations depend on whether the Untrusted Application and TA are bundled together or are provided separately, and this has implications to the management of the TAs in a TEE. In addition to the Untrusted Application and TA(s), the TA(s) and/or TEE may also require additional data to personalize the TA to the device or a user. Implementations must support encryption to preserve the confidentiality and integrity of such Personalized Data, which may potentially contain sensitive data. Other than the requirement to support confidentiality and integrity protection, the TEEP architecture places no limitations or requirements on the Personalization Data.

There are multiple possible cases for bundling of an Untrusted Application, TA(s), and Personalization Data. Such cases include (possibly among others):

1. The Untrusted Application, TA(s), and Personalization Data are all bundled together in a single package by a Trusted Component Signer and either provided to the TEEP Broker through the TAM, or provided separately (with encrypted Personalization Data), with key material needed to decrypt and install the Personalization Data and TA provided by a TAM.
2. The Untrusted Application and the TA(s) are bundled together in a single package, which a TAM or a publicly accessible app store maintains, and the Personalization Data is separately provided by the Personalization Data provider's TAM.
3. All components are independent packages. The Untrusted Application is installed through some independent or device-specific mechanism, and one or more TAMs provide (directly or indirectly by reference) the TA(s) and Personalization Data.

4. The TA(s) and Personalization Data are bundled together into a package provided by a TAM, while the Untrusted Application is installed through some independent or device-specific mechanism such as an app store.
5. Encrypted Personalization Data is bundled into a package distributed with the Untrusted Application, while the TA(s) and key material needed to decrypt and install the Personalization Data are in a separate package provided by a TAM.

The TEEP protocol can treat each TA, any dependencies the TA has, and Personalization Data as separate Trusted Components with separate installation steps that are expressed in SUIT manifests, and a SUIT manifest might contain or reference multiple binaries (see [I-D.ietf-suit-manifest] for more details). The TEEP Agent is responsible for handling any installation steps that need to be performed inside the TEE, such as decryption of private TA binaries or Personalization Data.

In order to better understand these cases, it is helpful to review actual implementations of TEEs and their application delivery mechanisms.

4.4.1. Example: Application Delivery Mechanisms in Intel SGX

In Intel Software Guard Extensions (SGX), the Untrusted Application and TA are typically bundled into the same package (Case 2). The TA exists in the package as a shared library (.so or .dll). The Untrusted Application loads the TA into an SGX enclave when the Untrusted Application needs the TA. This organization makes it easy to maintain compatibility between the Untrusted Application and the TA, since they are updated together. It is entirely possible to create an Untrusted Application that loads an external TA into an SGX enclave, and use that TA (Cases 3-5). In this case, the Untrusted Application would require a reference to an external file or download such a file dynamically, place the contents of the file into memory, and load that as a TA. Obviously, such file or downloaded content must be properly formatted and signed for it to be accepted by the SGX TEE.

In SGX, any Personalization Data is normally loaded into the SGX enclave (the TA) after the TA has started. Although it is possible with SGX to include the Untrusted Application in an encrypted package along with Personalization Data (Cases 1 and 5), there are no instances of this known to be in use at this time, since such a construction would require a special installation program and SGX TA (which might or might not be the TEEP Agent itself based on the implementation) to receive the encrypted package, decrypt it,

separate it into the different elements, and then install each one. This installation is complex because the Untrusted Application decrypted inside the TEE must be passed out of the TEE to an installer in the REE which would install the Untrusted Application. Finally, the Personalization Data would need to be sent out of the TEE (encrypted in an SGX enclave-to-enclave manner) to the REE's installation app, which would pass this data to the installed Untrusted Application, which would in turn send this data to the SGX enclave (TA). This complexity is due to the fact that each SGX enclave is separate and does not have direct communication to other SGX enclaves.

As long as signed files (TAs and/or Personalization Data) are installed into an untrusted filesystem and trust is verified by the TEE at load time, classic distribution mechanisms can be used. Some uses of SGX, however, allow a model where a TA can be dynamically installed into an SGX enclave that provides a runtime platform. The TEEP protocol can be used in such cases, where the runtime platform could include a TEEP Agent.

4.4.2. Example: Application Delivery Mechanisms in Arm TrustZone

In Arm TrustZone [TrustZone] for A-class devices, the Untrusted Application and TA may or may not be bundled together. This differs from SGX since in TrustZone the TA lifetime is not inherently tied to a specific Untrusted Application process lifetime as occurs in SGX. A TA is loaded by a trusted OS running in the TEE such as a GlobalPlatform [GPTEE] compliant TEE, where the trusted OS is separate from the OS in the REE. Thus Cases 2-4 are equally applicable. In addition, it is possible for TAs to communicate with each other without involving any Untrusted Application, and so the complexity of Cases 1 and 5 are lower than in the SGX example, though still more complex than Cases 2-4.

A trusted OS running in the TEE (e.g., OP-TEE) that supports loading and verifying signed TAs from an untrusted filesystem can, like SGX, use classic file distribution mechanisms. If secure TA storage is used (e.g., a Replay-Protected Memory Block device) on the other hand, the TEEP protocol can be used to manage such storage.

4.5. Entity Relations

This architecture leverages asymmetric cryptography to authenticate a device to a TAM. Additionally, a TEEP Agent in a device authenticates a TAM. The provisioning of Trust Anchors to a device may be different from one use case to the other. A Device Administrator may want to have the capability to control what TAs are allowed. A device manufacturer enables verification by one or more

TAMs and by Trusted Component Signers; it may embed a list of default Trust Anchors into the TEEP Agent and TEE for TAM trust verification and TA signature verification.

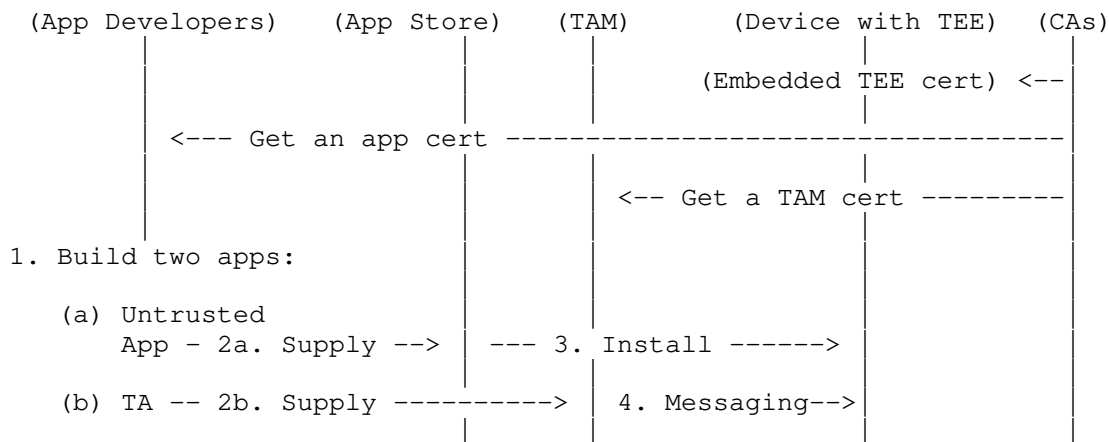


Figure 3: Example Developer Experience

Figure 3 shows an example where the same developer builds and signs two applications: (a) an Untrusted Application; (b) a TA that provides some security functions to be run inside a TEE. This example assumes that the developer, the TEE, and the TAM have previously been provisioned with certificates.

At step 1, the developer authors the two applications.

At step 2, the developer uploads the Untrusted Application (2a) to an Application Store. In this example, the developer is also the Trusted Component Signer, and so generates a signed TA. The developer can then either bundle the signed TA with the Untrusted Application, or the developer can provide a signed Trusted Component containing the TA to a TAM that will be managing the TA in various devices.

At step 3, a user will go to an Application Store to download the Untrusted Application (where the arrow indicates the direction of data transfer).

At step 4, since the Untrusted Application depends on the TA, installing the Untrusted Application will trigger TA installation via communication with a TAM. The TEEP Agent will interact with the TAM via a TEEP Broker that facilitates communications between the TAM and the TEEP Agent.

Some Trusted Component installation implementations might ask for a user's consent. In other implementations, a Device Administrator might choose what Untrusted Applications and related Trusted Components to be installed. A user consent flow is out of scope of the TEEP architecture.

The main components of the TEEP protocol consist of a set of standard messages created by a TAM to deliver Trusted Component management commands to a device, and device attestation and response messages created by a TEE that responds to a TAM's message.

It should be noted that network communication capability is generally not available in TAs in today's TEE-powered devices. Consequently, Trusted Applications generally rely on a broker in the REE to provide access to network functionality in the REE. A broker does not need to know the actual content of messages to facilitate such access.

Similarly, since the TEEP Agent runs inside a TEE, the TEEP Agent generally relies on a TEEP Broker in the REE to provide network access, and relay TAM requests to the TEEP Agent and relay the responses back to the TAM.

5. Keys and Certificate Types

This architecture leverages the following credentials, which allow achieving end-to-end security between a TAM and a TEEP Agent.

Figure 4 summarizes the relationships between various keys and where they are stored. Each public/private key identifies a Trusted Component Signer, TAM, or TEE, and gets a certificate that chains up to some trust anchor. A list of trusted certificates is used to check a presented certificate against.

Different CAs can be used for different types of certificates. TEEP messages are always signed, where the signer key is the message originator's private key, such as that of a TAM or a TEE. In addition to the keys shown in Figure 4, there may be additional keys used for attestation or encryption. Refer to the RATS Architecture [I-D.ietf-rats-architecture] for more discussion.

| Purpose | Cardinality & Location of Private Key | Private Key Signs | Location of Trust Anchor Store |
|------------------------------|---|----------------------|--------------------------------------|
| Authenticating TEEP Agent | 1 per TEE | TEEP responses | TAM |
| Authenticating TAM | 1 per TAM | TEEP requests | TEEP Agent |
| Code Signing | 1 per Trusted Component Signer | TA binary | TEE |

Figure 4: Signature Keys

Note that Personalization Data is not included in the table above. The use of Personalization Data is dependent on how TAs are used and what their security requirements are.

TEEP requests from a TAM to a TEEP Agent are signed with the TAM private key (for authentication and integrity protection). Personalization Data and TA binaries can be encrypted with a key that is established with a content-encryption key established with the TEE public key (to provide confidentiality). Conversely, TEEP responses from a TEEP Agent to a TAM can be signed with the TEE private key.

The TEE key pair and certificate are thus used for authenticating the TEE to a remote TAM, and for sending private data to the TEE. Often, the key pair is burned into the TEE by the TEE manufacturer and the key pair and its certificate are valid for the expected lifetime of the TEE. A TAM provider is responsible for configuring the TAM's Trust Anchor Store with the manufacturer certificates or CAs that are used to sign TEE keys. This is discussed further in Section 5.3 below. Typically the same key TEE pair is used for both signing and encryption, though separate key pairs might also be used in the future, as the joint security of encryption and signature with a single key remains to some extent an open question in academic cryptography.

The TAM key pair and certificate are used for authenticating a TAM to a remote TEE, and for sending private data to the TAM (separate key pairs for authentication vs. encryption could also be used in the future). A TAM provider is responsible for acquiring a certificate from a CA that is trusted by the TEEs it manages. This is discussed further in Section 5.1 below.

The Trusted Component Signer key pair and certificate are used to sign Trusted Components that the TEE will consider authorized to execute. TEEs must be configured with the certificates or keys that it considers authorized to sign TAs that it will execute. This is discussed further in Section 5.2 below.

5.1. Trust Anchors in a TEEP Agent

A TEEP Agent's Trust Anchor Store contains a list of Trust Anchors, which are typically CA certificates that sign various TAM certificates. The list is typically preloaded at manufacturing time, and can be updated using the TEEP protocol if the TEE has some form of "Trust Anchor Manager TA" that has Trust Anchors in its configuration data. Thus, Trust Anchors can be updated similarly to the Personalization Data for any other TA.

When Trust Anchor update is carried out, it is imperative that any update must maintain integrity where only an authentic Trust Anchor list from a device manufacturer or a Device Administrator is accepted. Details are out of scope of the architecture and can be addressed in a protocol document.

Before a TAM can begin operation in the marketplace to support a device with a particular TEE, it must be able to get its raw public key, or its certificate, or a certificate it chains up to, listed in the Trust Anchor Store of the TEEP Agent.

5.2. Trust Anchors in a TEE

The Trust Anchor Store in a TEE contains a list of Trust Anchors (raw public keys or certificates) that are used to determine whether TA binaries are allowed to execute by checking if their signatures can be verified. The list is typically preloaded at manufacturing time, and can be updated using the TEEP protocol if the TEE has some form of "Trust Anchor Manager TA" that has Trust Anchors in its configuration data. Thus, Trust Anchors can be updated similarly to the Personalization Data for any other TA, as discussed in Section 5.1.

5.3. Trust Anchors in a TAM

The Trust Anchor Store in a TAM consists of a list of Trust Anchors, which are certificates that sign various device TEE certificates. A TAM will accept a device for Trusted Component management if the TEE in the device uses a TEE certificate that is chained to a certificate or raw public key that the TAM trusts, is contained in an allow list, is not found on a block list, and/or fulfills any other policy criteria.

5.4. Scalability

This architecture uses a PKI (including self-signed certificates). Trust Anchors exist on the devices to enable the TEEP Agent to authenticate TAMs and the TEE to authenticate Trusted Component Signers, and TAMs use Trust Anchors to authenticate TEEP Agents. When a PKI is used, many intermediate CA certificates can chain to a root certificate, each of which can issue many certificates. This makes the protocol highly scalable. New factories that produce TEEs can join the ecosystem. In this case, such a factory can get an intermediate CA certificate from one of the existing roots without requiring that TAMs are updated with information about the new device factory. Likewise, new TAMs can join the ecosystem, providing they are issued a TAM certificate that chains to an existing root whereby existing TEEs will be allowed to be personalized by the TAM without requiring changes to the TEE itself. This enables the ecosystem to scale, and avoids the need for centralized databases of all TEEs produced or all TAMs that exist or all Trusted Component Signers that exist.

5.5. Message Security

Messages created by a TAM are used to deliver Trusted Component management commands to a device, and device attestation and messages are created by the device TEE to respond to TAM messages.

These messages are signed end-to-end between a TEEP Agent and a TAM. Confidentiality is provided by encrypting sensitive payloads (such as Personalization Data and attestation evidence), rather than encrypting the messages themselves. Using encrypted payloads is important to ensure that only the targeted device TEE or TAM is able to decrypt and view the actual content.

6. TEEP Broker

A TEE and TAs often do not have the capability to directly communicate outside of the hosting device. For example, GlobalPlatform [GPTEE] specifies one such architecture. This calls for a software module in the REE world to handle network communication with a TAM.

A TEEP Broker is an application component running in the REE of the device or an SDK that facilitates communication between a TAM and a TEE. It also provides interfaces for Untrusted Applications to query and trigger installation of Trusted Components that the application needs to use.

An Untrusted Application might communicate with a TEEP Broker at runtime to trigger Trusted Component installation itself, or an Untrusted Application might simply have a metadata file that describes the Trusted Components it depends on and the associated TAM(s) for each Trusted Component, and an REE Application Installer can inspect this application metadata file and invoke the TEEP Broker to trigger Trusted Component installation on behalf of the Untrusted Application without requiring the Untrusted Application to run first.

6.1. Role of the TEEP Broker

A TEEP Broker abstracts the message exchanges with a TEE in a device. The input data is originated from a TAM or the first initialization call to trigger a Trusted Component installation.

The Broker doesn't need to parse TEEP message content received from a TAM that should be processed by a TEE (see the `ProcessTeepMessage` API in Section 6.2.1). When a device has more than one TEE, one TEEP Broker per TEE could be present in the REE or a common TEEP Broker could be used by multiple TEEs where the transport protocol (e.g., [I-D.ietf-teep-otrp-over-http]) allows the TEEP Broker to distinguish which TEE is relevant for each message from a TAM.

The TEEP Broker interacts with a TEEP Agent inside a TEE, and relays the response messages generated from the TEEP Agent back to the TAM.

The Broker only needs to return a (transport) error message to the TAM if the TEE is not reachable for some reason. Other errors are represented as TEEP response messages returned from the TEE which will then be passed to the TAM.

6.2. TEEP Broker Implementation Consideration

As depicted in Figure 5, there are multiple ways in which a TEEP Broker can be implemented, with more or fewer layers being inside the TEE. For example, in model A, the model with the smallest TEE footprint, only the TEEP implementation is inside the TEE, whereas the TEEP/HTTP implementation is in the TEEP Broker outside the TEE.

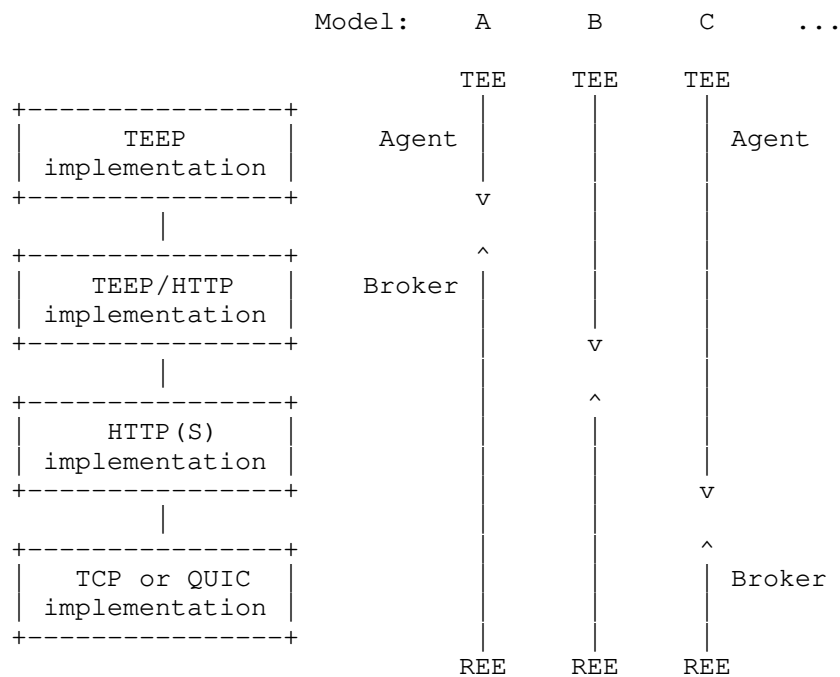


Figure 5: TEEP Broker Models

In other models, additional layers are moved into the TEE, increasing the TEE footprint, with the Broker either containing or calling the topmost protocol layer outside of the TEE. An implementation is free to choose any of these models.

TEEP Broker implementers should consider methods of distribution, scope and concurrency on devices and runtime options.

6.2.1. TEEP Broker APIs

The following conceptual APIs exist from a TEEP Broker to a TEEP Agent:

1. RequestTA: A notification from an REE application (e.g., an installer, or an Untrusted Application) that it depends on a given Trusted Component, which may or may not already be installed in the TEE.

2. **UnrequestTA:** A notification from an REE application (e.g., an installer, or an Untrusted Application) that it no longer depends on a given Trusted Component, which may or may not already be installed in the TEE. For example, if the Untrusted Application is uninstalled, the uninstaller might invoke this conceptual API.
3. **ProcessTeepMessage:** A message arriving from the network, to be delivered to the TEEP Agent for processing.
4. **RequestPolicyCheck:** A hint (e.g., based on a timer) that the TEEP Agent may wish to contact the TAM for any changes, without the device itself needing any particular change.
5. **ProcessError:** A notification that the TEEP Broker could not deliver an outbound TEEP message to a TAM.

For comparison, similar APIs may exist on the TAM side, where a Broker may or may not exist, depending on whether the TAM uses a TEE or not:

1. **ProcessConnect:** A notification that a new TEEP session is being requested by a TEEP Agent.
2. **ProcessTeepMessage:** A message arriving on an existing TEEP session, to be delivered to the TAM for processing.

For further discussion on these APIs, see [I-D.ietf-teep-otrp-over-http].

6.2.2. TEEP Broker Distribution

The Broker installation is commonly carried out at OEM time. A user can dynamically download and install a Broker on-demand.

7. Attestation

Attestation is the process through which one entity (an Attester) presents "evidence", in the form of a series of claims, to another entity (a Verifier), and provides sufficient proof that the claims are true. Different Verifiers may require different degrees of confidence in attestation proofs and not all attestations are acceptable to every verifier. A third entity (a Relying Party) can then use "attestation results", in the form of another series of claims, from a Verifier to make authorization decisions. (See [I-D.ietf-rats-architecture] for more discussion.)

In TEEP, as depicted in Figure 6, the primary purpose of an attestation is to allow a device (the Attester) to prove to a TAM (the Relying Party) that a TEE in the device has particular properties, was built by a particular manufacturer, and/or is executing a particular TA. Other claims are possible; TEEP does not limit the claims that may appear in evidence or attestation results, but defines a minimal set of attestation result claims required for TEEP to operate properly. Extensions to these claims are possible. Other standards or groups may define the format and semantics of extended claims.

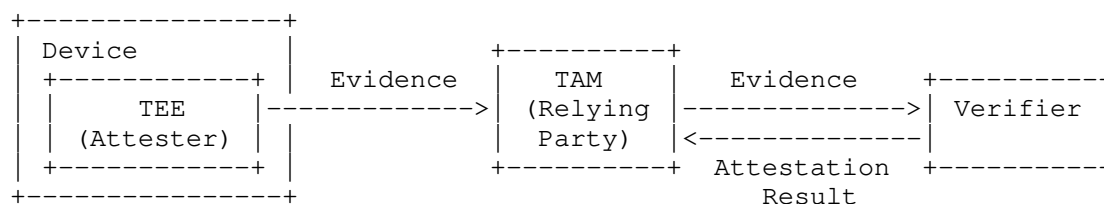


Figure 6: TEEP Attestation Roles

As of the writing of this specification, device and TEE attestations have not been standardized across the market. Different devices, manufacturers, and TEEs support different attestation protocols. In order for TEEP to be inclusive, it is agnostic to the format of evidence, allowing proprietary or standardized formats to be used between a TEE and a verifier (which may or may not be colocated in the TAM), as long as the format supports encryption of any information that is considered sensitive.

However, it should be recognized that not all Verifiers may be able to process all proprietary forms of attestation evidence. Similarly, the TEEP protocol is agnostic as to the format of attestation results, and the protocol (if any) used between the TAM and a verifier, as long as they convey at least the required set of claims in some format. Note that the respective attestation algorithms are not defined in the TEEP protocol itself; see [I-D.ietf-rats-architecture] and [I-D.ietf-teep-protocol] for more discussion.

There are a number of considerations that need to be considered when appraising evidence provided by a TEE, including:

- * What security measures a manufacturer takes when provisioning keys into devices/TEEs;
- * What hardware and software components have access to the attestation keys of the TEE;

- * The source or local verification of claims within an attestation prior to a TEE signing a set of claims;
- * The level of protection afforded to attestation keys against exfiltration, modification, and side channel attacks;
- * The limitations of use applied to TEE attestation keys;
- * The processes in place to discover or detect TEE breaches; and
- * The revocation and recovery process of TEE attestation keys.

Some TAMs may require additional claims in order to properly authorize a device or TEE. The specific format for these additional claims are outside the scope of this specification, but the TEEP protocol allows these additional claims to be included in the attestation messages.

For more discussion of the attestation and appraisal process, see the RATS Architecture [I-D.ietf-rats-architecture].

The following information is required for TEEP attestation:

- * **Device Identifying Information:** Attestation information may need to uniquely identify a device to the TAM. Unique device identification allows the TAM to provide services to the device, such as managing installed TAs, and providing subscriptions to services, and locating device-specific keying material to communicate with or authenticate the device. In some use cases it may be sufficient to identify only the class of the device. The security and privacy requirements regarding device identification will vary with the type of TA provisioned to the TEE.
- * **TEE Identifying Information:** The type of TEE that generated this attestation must be identified. This includes version identification information for hardware, firmware, and software version of the TEE, as applicable by the TEE type. TEE manufacturer information for the TEE is required in order to disambiguate the same TEE type created by different manufacturers and address considerations around manufacturer provisioning, keying and support for the TEE.
- * **Freshness Proof:** A claim that includes freshness information must be included, such as a nonce or timestamp.

8. Algorithm and Attestation Agility

RFC 7696 [RFC7696] outlines the requirements to migrate from one mandatory-to-implement cryptographic algorithm suite to another over time. This feature is also known as crypto agility. Protocol evolution is greatly simplified when crypto agility is considered during the design of the protocol. In the case of the TEEP protocol the diverse range of use cases, from trusted app updates for smart phones and tablets to updates of code on higher-end IoT devices, creates the need for different mandatory-to-implement algorithms already from the start.

Crypto agility in TEEP concerns the use of symmetric as well as asymmetric algorithms. In the context of TEEP, symmetric algorithms are used for encryption and integrity protection of TA binaries and Personalization Data whereas the asymmetric algorithms are used for signing messages and managing symmetric keys.

In addition to the use of cryptographic algorithms in TEEP, there is also the need to make use of different attestation technologies. A device must provide techniques to inform a TAM about the attestation technology it supports. For many deployment cases it is more likely for the TAM to support one or more attestation techniques whereas the device may only support one.

9. Security Considerations

9.1. Broker Trust Model

The architecture enables the TAM to communicate, via a TEEP Broker, with the device's TEE to manage Trusted Components. Since the TEEP Broker runs in a potentially vulnerable REE, the TEEP Broker could, however, be (or be infected by) malware. As such, all TAM messages are signed and sensitive data is encrypted such that the TEEP Broker cannot modify or capture sensitive data, but the TEEP Broker can still conduct DoS attacks as discussed in Section 9.3.

A TEEP Agent in a TEE is responsible for protecting against potential attacks from a compromised TEEP Broker or rogue malware in the REE. A rogue TEEP Broker might send corrupted data to the TEEP Agent, or launch a DoS attack by sending a flood of TEEP protocol requests, or simply drop or delay notifications to a TEE. The TEEP Agent validates the signature of each TEEP protocol request and checks the signing certificate against its Trust Anchors. To mitigate DoS attacks, it might also add some protection scheme such as a threshold on repeated requests or number of TAs that can be installed.

Some implementations might rely on (due to lack of any available alternative) the use of an untrusted timer or other event to call the RequestPolicyCheck API (Section 6.2.1), which means that a compromised REE can cause a TEE to not receive policy changes and thus be out of date with respect to policy. The same can potentially be done by any other man-in-the-middle simply by blocking communication with a TAM. Ultimately such outdated compliance could be addressed by using attestation in secure communication, where the attestation evidence reveals what state the TEE is in, so that communication (other than remediation such as via TEEP) from an out-of-compliance TEE can be rejected.

Similarly, in most implementations the REE is involved in the mechanics of installing new TAs. However, the authority for what TAs are running in a given TEE is between the TEEP Agent and the TAM. While a TEEP Broker broker can in effect make suggestions, it cannot decide or enforce what runs where. The TEEP Broker can also control which TEE a given installation request is directed at, but a TEEP Agent will only accept TAs that are actually applicable to it and where installation instructions are received by a TAM that it trusts.

The authorization model for the UnrequestTA operation is, however, weaker in that it expresses the removal of a dependency from an application that was untrusted to begin with. This means that a compromised REE could remove a valid dependency from an Untrusted Application on a TA. Normal REE security mechanisms should be used to protect the REE and Untrusted Applications.

9.2. Data Protection

It is the responsibility of the TAM to protect data on its servers. Similarly, it is the responsibility of the TEE implementation to provide protection of data against integrity and confidentiality attacks from outside the TEE. TEEs that provide isolation among TAs within the TEE are likewise responsible for protecting TA data against the REE and other TAs. For example, this can be used to protect one user's or tenant's data from compromise by another user or tenant, even if the attacker has TAs.

The protocol between TEEP Agents and TAMs similarly is responsible for securely providing integrity and confidentiality protection against adversaries between them. It is a design choice at what layers to best provide protection against network adversaries. As discussed in Section 6, the transport protocol and any security mechanism associated with it (e.g., the Transport Layer Security protocol) under the TEEP protocol may terminate outside a TEE. If it does, the TEEP protocol itself must provide integrity protection and confidentiality protection to secure data end-to-end. For example,

confidentiality protection for payloads may be provided by utilizing encrypted TA binaries and encrypted attestation information. See [I-D.ietf-teepp-protocol] for how a specific solution addresses the design question of how to provide integrity and confidentiality protection.

9.3. Compromised REE

It is possible that the REE of a device is compromised. We have already seen examples of attacks on the public Internet with billions of compromised devices being used to mount DDoS attacks. A compromised REE can be used for such an attack but it cannot tamper with the TEE's code or data in doing so. A compromised REE can, however, launch DoS attacks against the TEE.

The compromised REE may terminate the TEEP Broker such that TEEP transactions cannot reach the TEE, or might drop, replay, or delay messages between a TAM and a TEEP Agent. However, while a DoS attack cannot be prevented, the REE cannot access anything in the TEE if the TEE is implemented correctly. Some TEEs may have some watchdog scheme to observe REE state and mitigate DoS attacks against it but most TEEs don't have such a capability.

In some other scenarios, the compromised REE may ask a TEEP Broker to make repeated requests to a TEEP Agent in a TEE to install or uninstall a Trusted Component. An installation or uninstallation request constructed by the TEEP Broker or REE will be rejected by the TEEP Agent because the request won't have the correct signature from a TAM to pass the request signature validation.

This can become a DoS attack by exhausting resources in a TEE with repeated requests. In general, a DoS attack threat exists when the REE is compromised, and a DoS attack can happen to other resources. The TEEP architecture doesn't change this.

A compromised REE might also request initiating the full flow of installation of Trusted Components that are not necessary. It may also repeat a prior legitimate Trusted Component installation request. A TEEP Agent implementation is responsible for ensuring that it can recognize and decline such repeated requests. It is also responsible for protecting the resource usage allocated for Trusted Component management.

9.4. CA Compromise or Expiry of CA Certificate

A root CA for TAM certificates might get compromised or its certificate might expire, or a Trust Anchor other than a root CA certificate may also expire or be compromised. TEEs are responsible for validating the entire TAM certificate path, including the TAM certificate and any intermediate certificates up to the root certificate. See Section 6 of [RFC5280] for details. Such validation generally includes checking for certificate revocation, but certificate status check protocols may not scale down to constrained devices that use TEEP.

To address the above issues, a certificate path update mechanism is expected from TAM operators, so that the TAM can get a new certificate path that can be validated by a TEEP Agent. In addition, the Trust Anchor in the TEEP Agent's Trust Anchor Store may need to be updated. To address this, some TEE Trust Anchor update mechanism is expected from device OEMs, such as using the TEEP protocol to distribute new Trust Anchors.

Similarly, a root CA for TEE certificates might get compromised or its certificate might expire, or a Trust Anchor other than a root CA certificate may also expire or be compromised. TAMs are responsible for validating the entire TEE certificate path, including the TEE certificate and any intermediate certificates up to the root certificate. Such validation includes checking for certificate revocation.

If a TEE certificate path validation fails, the TEE might be rejected by a TAM, subject to the TAM's policy. To address this, some certificate path update mechanism is expected from device OEMs, so that the TEE can get a new certificate path that can be validated by a TAM. In addition, the Trust Anchor in the TAM's Trust Anchor Store may need to be updated.

9.5. Compromised TAM

Device TEEs are responsible for validating the supplied TAM certificates to determine that the TAM is trustworthy.

9.6. Malicious TA Removal

It is possible that a rogue developer distributes a malicious Untrusted Application and intends to get a malicious TA installed. Such a TA might be able to escape from malware detection by the REE, or access trusted resources within the TEE (but could not access other TEEs, or access other TA's if the TEE provides isolation between TAs).

It is the responsibility of the TAM to not install malicious TAs in the first place. The TEEP architecture allows a TEEP Agent to decide which TAMs it trusts via Trust Anchors, and delegates the TA authenticity check to the TAMs it trusts.

It may happen that a TA was previously considered trustworthy but is later found to be buggy or compromised. In this case, the TAM can initiate the removal of the TA by notifying devices to remove the TA (and potentially the REE or Device Owner to remove any Untrusted Application that depend on the TA). If the TAM does not currently have a connection to the TEEP Agent on a device, such a notification would occur the next time connectivity does exist. That is, to recover, the TEEP Agent must be able to reach out to the TAM, for example whenever the RequestPolicyCheck API (Section 6.2.1) is invoked by a timer or other event.

Furthermore the policy in the Verifier in an attestation process can be updated so that any evidence that includes the malicious TA would result in an attestation failure. There is, however, a time window during which a malicious TA might be able to operate successfully, which is the validity time of the previous attestation result. For example, if the Verifier in Figure 6 is updated to treat a previously valid TA as no longer trustworthy, any attestation result it previously generated saying that the TA is valid will continue to be used until the attestation result expires. As such, the TAM's Verifier should take into account the acceptable time window when generating attestation results. See [I-D.ietf-rats-architecture] for further discussion.

9.7. TEE Certificate Expiry and Renewal

TEE device certificates are expected to be long lived, longer than the lifetime of a device. A TAM certificate usually has a moderate lifetime of 2 to 5 years. A TAM should get renewed or rekeyed certificates. The root CA certificates for a TAM, which are embedded into the Trust Anchor Store in a device, should have long lifetimes that don't require device Trust Anchor updates. On the other hand, it is imperative that OEMs or device providers plan for support of Trust Anchor update in their shipped devices.

For those cases where TEE devices are given certificates for which no good expiration date can be assigned the recommendations in Section 4.1.2.5 of [RFC5280] are applicable.

9.8. Keeping Secrets from the TAM

In some scenarios, it is desirable to protect the TA binary or Personalization Data from being disclosed to the TAM that distributes them. In such a scenario, the files can be encrypted end-to-end between a Trusted Component Signer and a TEE. However, there must be some means of provisioning the decryption key into the TEE and/or some means of the Trusted Component Signer securely learning a public key of the TEE that it can use to encrypt. The Trusted Component Signer cannot necessarily even trust the TAM to report the correct public key of a TEE for use with encryption, since the TAM might instead provide the public key of a TEE that it controls.

One way to solve this is for the Trusted Component Signer to run its own TAM that is only used to distribute the decryption key via the TEEP protocol, and the key file can be a dependency in the manifest of the encrypted TA. Thus, the TEEP Agent would look at the Trusted Component manifest, determine there is a dependency with a TAM URI of the Trusted Component Signer's TAM. The Agent would then install the dependency, and then continue with the Trusted Component installation steps, including decrypting the TA binary with the relevant key.

9.9. REE Privacy

The TEEP architecture is applicable to cases where devices have a TEE that protects data and code from the REE administrator. In such cases, the TAM administrator, not the REE administrator, controls the TEE in the devices. As some examples:

- * a cloud hoster may be the REE administrator where a customer administrator controls the TEE hosted in the cloud.
- * a device manufacturer might control the TEE in a device purchased by a customer

The privacy risk is that data in the REE might be susceptible to disclosure to the TEE administrator. This risk is not introduced by the TEEP architecture, but is inherent in most uses of TEEs. This risk can be mitigated by making sure the REE administrator is aware of and explicitly chooses to have a TEE that is managed by another party. In the cloud hoster example, this choice is made by explicitly offering a service to customers to provide TEEs for them to administer. In the device manufacturer example, this choice is made by the customer choosing to buy a device made by a given manufacturer.

10. IANA Considerations

This document does not require actions by IANA.

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The Open Trust Protocol (OTrP)
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Abstract

This document specifies the Open Trust Protocol (OTrP), a protocol that follows the Trust Execution Environment Provisioning (TEEP) architecture and provides a message protocol that provisions and manages Trusted Applications into a device with a Trusted Execution Environment (TEE).

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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 TEE implementations. Different application providers or device administrators may choose to use different TAM providers. There calls for an interoperable protocol for managing TAs running in different TEEs of various devices is needed.

The Trusted Execution Environment Provisioning (TEEP) architecture document [TEEPArch] has set to provide a design guidance for such an interoperable protocol. This document specifies an Open Trust Protocol (OTrP) that follows the architecture guidance.

OTrP defines a mutual trust message protocol between a TAM and a TEE and relies on IETF-defined end-to-end security mechanisms, namely JSON Web Encryption (JWE), JSON Web Signature (JWS), and JSON Web Key (JWK). Other message encoding methods may be supported.

This specification defines message payloads exchanged between devices and a TAM. The messages are designed in anticipation of the use of the most common transport methods such as HTTPS.

A TA binary and personalization data can be from two sources:

1. A TAM supplies the signed and encrypted TA binary
2. A Client Application supplies the TA binary

This specification considers the first case where TA binary and personalization data are encrypted by recipient's public key that TAM has to be involved. The second case will be addressed separately.

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].

3. Terminology

3.1. Definitions

The definitions provided below are defined as used in this document. All the terms defined in the TEEP Architecture document [TEEPArch] will be used, which are not repeated in this document.

OTrP Agent: It is the Agent as defined in the TEEP Architecture document [TEEPArch].

3.2. Abbreviations

| | |
|------|-------------------------------|
| CA | Certificate Authority |
| OTrP | Open Trust Protocol |
| REE | Rich Execution Environment |
| SD | Security Domain |
| SP | Service Provider |
| SBM | Secure Boot Module |
| TA | Trusted Application |
| TEE | Trusted Execution Environment |
| TFW | Trusted Firmware |
| TAM | Trusted Application Manager |

4. OTrP Entities and Trust Model

4.1. System Components

The same system components as defined in the TEEP Architecture document [TEEPArch] are used in OTrP, including TAM, CA, TEE, REE, and OTrP Agent (a.k.a Agent).

Secure boot (for the purposes of OTrP) is optional in enabling authenticity checking of TEEs by the TAM. A TAM provider can choose its policy whether it trusts a TEE if the underlying firmware attestation information isn't included.

OTrP uses trust anchors to establish trust between TEEs and TAMs and verifies that they communicate in a trusted way when performing lifecycle management transactions.

4.2. Trust Anchors in TEE

This assumes the Trust Anchor specification defined in the TEEP Architecture document [TEEPArch].

Each TEE comes with a trust store that contains a whitelist of root CA certificates that are used to validate a TAM's certificate. A TEE will accept a TAM to create new Security Domains and install new TAs on behalf of a SP only if the TAM's certificate is chained to one of the root CA certificates in the TEE's trust store.

4.3. Trust Anchors in TAM

The Trust Anchor set in a TAM consists of a list of Certificate Authority certificates that signs various device TEE certificates. A TAM decides what TEE and optionally TFW it will trust when TFW signature data is present in an attestation.

4.4. Keys and Certificate Types

OTrP leverages the following list of trust anchors and identities in generating signed and encrypted command messages that are exchanged between a device's TEE and a TAM. With these security artifacts, OTrP Messages are able to deliver end-to-end security without relying on any transport security.

| Key Entity Name | Location | Issuer | Trust Implication | Cardinality |
|---------------------------------|-----------------------|------------------------|--|------------------------------------|
| 1. TFW key pair and certificate | Device secure storage | FW CA | A white list of FW root CA trusted by TAMs | 1 per device |
| 2. TEE key pair and certificate | Device TEE | TEE CA under a root CA | A white list of TEE root CA trusted by TAMs | 1 per device |
| 3. TAM key pair and certificate | TAM provider | TAM CA under a root CA | A white list of TAM root CA embedded in TEE | 1 or multiple can be used by a TAM |
| 4. SP key pair and certificate | SP | SP signer CA | TAM manages SP. TA trust is delegated to TAM. TEE trusts TAM to ensure that a TA is trustworthy. | 1 or multiple can be used by a TAM |

Table 1: Key and Certificate Types

1. TFW key pair and certificate: A key pair and certificate for evidence of secure boot and trustworthy firmware in a device.

Location: Device secure storage

Supported Key Type: RSA and ECC

Issuer: OEM CA

Trust Implication: A white list of FW root CA trusted by TAMs

Cardinality: One per device
2. TEE key pair and certificate: It is used for device attestation to a remote TAM and SP.

This key pair is burned into the device at device manufacturer. The key pair and its certificate are valid for the expected lifetime of the device.

Location: Device TEE

Supported Key Type: RSA and ECC

Issuer: A CA that chains to a TEE root CA

Trust Implication: A white list of TEE root CA trusted by TAMs

Cardinality: One per device

3. TAM key pair and certificate: A TAM provider acquires a certificate from a CA that a TEE trusts.

Location: TAM provider

Supported Key Type: RSA and ECC.

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: TAM CA that chains to a root CA

Trust Implication: A white list of TAM root CA embedded in TEE

Cardinality: One or multiple can be used by a TAM

4. SP key pair and certificate: an SP uses its own key pair and certificate to sign a TA.

Location: SP

Supported Key Type: RSA and ECC

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: an SP signer CA that chains to a root CA

Trust Implication: TAM manages SP. TA trusts an SP by validating trust against a TAM that the SP uses. A TEE trusts TAM to ensure that a TA from the TAM is trustworthy.

Cardinality: One or multiple can be used by an SP

5. Protocol Scope and Entity Relations

This document specifies messages and key properties that can establish mutual trust between a TEE and a TAM. The protocol provides specifications for the following three entities:

1. Key and certificate types required for device firmware, TEEs, TAs, SPs, and TAMs
2. Data message formats that should be exchanged between a TEE in a device and a TAM
3. An OTrP Agent application in the REE that can relay messages between a Client Application and TEE

Figure 1: Protocol Scope and Entity Relationship

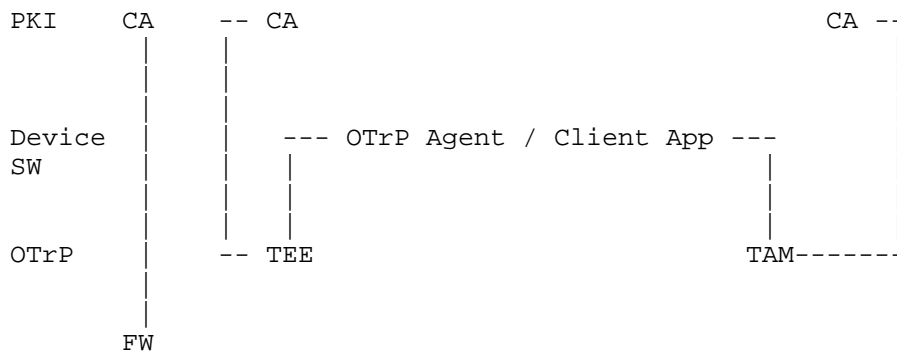
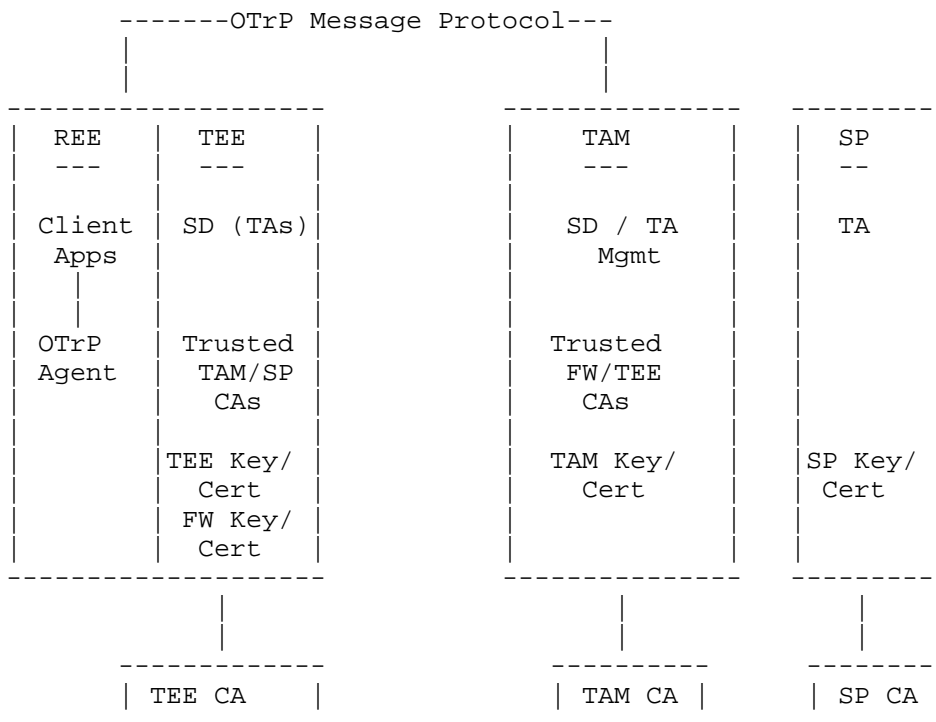


Figure 2: OTrP System Diagram



In the previous diagram, different Certificate Authorities can be used respectively for different types of certificates. OTrP Messages are always signed, where the signer keys is the message creator's private key such as a FW's private key, a TEE's private key, or a TAM's private key.

The main OTrP component consists of a set of standard JSON messages created by a TAM to deliver device SD and TA management commands to a device, and device attestation and response messages created by a TEE that responds to a TAM's OTrP message.

The communication method of OTrP Messages between a TAM and TEE in a device may vary between TAM and TEE providers. A mandatory transport protocol is specified for a compliant TAM and a device TEE.

An OTrP Agent is used to bridge communication between a TAM and a TEE. The OTrP Agent doesn't need to know the actual content of OTrP Messages except for the TEE routing information.

5.1. A Sample Device Setup Flow

Step 1: Prepare Images for Devices

1. [TEE vendor] Deliver TEE Image (CODE Binary) to device OEM
2. [CA] Deliver root CA Whitelist
3. [Soc] Deliver TFW Image

Step 2: Inject Key Pairs and Images to Devices

1. [OEM] Generate Secure Boot Key Pair (May be shared among multiple devices)
2. [OEM] Flash signed TFW Image and signed TEE Image onto devices (signed by Secure Boot Key)

Step 3: Setup attestation key pairs in devices

1. [OEM] Flash Secure Boot Public Key and eFuse Key (eFuse key is unique per device)
2. [TFW/TEE] Generate a unique attestation key pair and get a certificate for the device.

Step 4: Setup trust anchors in devices

1. [TFW/TEE] Store the key and certificate encrypted with the eFuse key
2. [TEE vendor or OEM] Store trusted CA certificate list into devices

5.2. Derived Keys in The Protocol

The protocol generates one key pair in run time to assist message communication and anonymous verification between a TAM and a TEE.

TEE SP Anonymous Key (AIK): one derived key pair per SP in a device

The purpose of the key pair is to sign data by a TEE without using its TEE device key for anonymous attestation to a Client Application. This key pair is generated in the first SD creation for an SP. It is deleted when all SDs are removed for a SP in a device. The public key of the key pair is given to the caller Client Application and TAM for future TEE returned data validation. The public key of this AIK

is also used by a TAM to encrypt TA binary data and personalization data when it sends a TA to a device for installation.

5.3. Security Domain Hierarchy and Ownership

The primary job of a TAM is to help an SP to manage its trusted applications. A TA is typically installed in an SD. An SD is commonly created for an SP.

When an SP delegates its SD and TA management to a TAM, an SD is created on behalf of a TAM in a TEE and the owner of the SD is assigned to the TAM. An SD may be associated with an SP but the TAM has full privilege to manage the SD for the SP.

Each SD for an SP is associated with only one TAM. When an SP changes TAM, a new SP SD must be created to associate with the new TAM. The TEE will maintain a registry of TAM ID and SP SD ID mapping.

From an SD ownership perspective, the SD tree is flat and there is only one level. An SD is associated with its owner. It is up to TEE implementation how it maintains SD binding information for a TAM and different SPs under the same TAM.

It is an important decision in this protocol specification that a TEE doesn't need to know whether a TAM is authorized to manage the SD for an SP. This authorization is implicitly triggered by an SP Client Application, which instructs what TAM it wants to use. An SD is always associated with a TAM in addition to its SP ID. A rogue TAM isn't able to do anything on an unauthorized SP's SD managed by another TAM.

Since a TAM may support multiple SPs, sharing the same SD name for different SPs creates a dependency in deleting an SD. An SD can be deleted only after all TAs associated with this SD is deleted. An SP cannot delete a Security Domain on its own with a TAM if a TAM decides to introduce such sharing. There are cases where multiple virtual SPs belong to the same organization, and a TAM chooses to use the same SD name for those SPs. This is totally up to the TAM implementation and out of scope of this specification.

5.4. SD Owner Identification and TAM Certificate Requirements

There is a need of cryptographically binding proof about the owner of an SD in a device. When an SD is created on behalf of a TAM, a future request from the TAM must present itself as a way that the TEE can verify it is the true owner. The certificate itself cannot reliably used as the owner because TAM may change its certificate.

To this end, each TAM will be associated with a trusted identifier defined as an attribute in the TAM certificate. This field is kept the same when the TAM renew its certificates. A TAM CA is responsible to vet the requested TAM attribute value.

This identifier value must not collide among different TAM providers, and one TAM shouldn't be able to claim the identifier used by another TAM provider.

The certificate extension name to carry the identifier can initially use SubjectAltName:registeredID. A dedicated new extension name may be registered later.

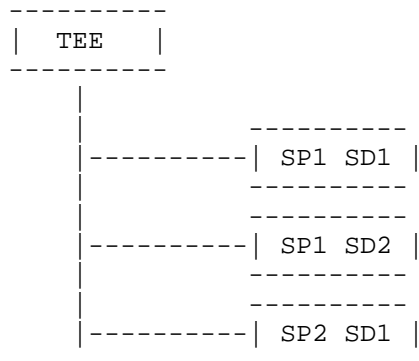
One common choice of the identifier value is the TAM's service URL. A CA can verify the domain ownership of the URL with the TAM in the certificate enrollment process.

A TEE can assign this certificate attribute value as the TAM owner ID for the SDs that are created for the TAM.

An alternative way to represent an SD ownership by a TAM is to have a unique secret key upon SD creation such that only the creator TAM is able to produce a Proof-of-Possession (POP) data with the secret.

5.5. Service Provider Container

A sample Security Domain hierarchy for the TEE is shown below.



OTrP segregates SDs and TAs such that a TAM can only manage or retrieve data for SDs and TAs that it previously created for the SPs it represents.

6. OTrP Agent

A TEE and TAs that run inside the TEE don't generally have capability to communicate to the outside of the hosting device, for example, the TEE specified by Global Platform groups [GPTEE]. This calls for a software module in the REE world to handle the network communication. Each Client Application in REE may carry this communication functionality but it must also interact with the TEE for the message exchange. The TEE interaction will vary according to different TEEs. In order for a Client Application to transparently support different TEEs, it is imperative to have a common interface for a Client Application to invoke for exchanging messages with TEEs.

A shared OTrP Agent comes to meet this need. An OTrP Agent is a Rich Application or SDK that facilitates communication between a TAM and TEE. It also provides interfaces for TAM SDK or Client Applications to query and trigger TA installation that the application needs to use.

This interface for Client Applications may be commonly an Android service call for an Android powered device. A Client Application interacts with a TAM, and turns around to pass messages received from TAM to OTrP Agent.

In all cases, a Client Application needs to be able to identify an OTrP Agent that it can use.

6.1. Role of OTrP Agent

An OTrP Agent abstracts the message exchanges with the TEE in a device. The input data is originated from a TAM that a Client Application connects. A Client Application may also directly call OTrP Agent for some TA query functions.

OTrP Agent may internally process a request from TAM. At least, it needs to know where to route a message, e.g. TEE instance. It doesn't need to process or verify message content.

OTrP Agent returns TEE / TFW generated response messages to the caller. OTrP Agent isn't expected to handle any network connection with an application or TAM.

OTrP Agent only needs to return an OTrP Agent error message if the TEE is not reachable for some reason. Other errors are represented as response messages returned from the TEE which will then be passed to the TAM.

6.2. OTrP Agent and Global Platform TEE Client API

A Client Application may use Global Platform (GP) TEE API for TA communication. OTrP may use the GP TEE Client API but it is internal to OTrP implementation that converts given messages from TAM. More details can be found at [GPTEECLAPI].

6.3. OTrP Agent Implementation Consideration

A Provider should consider methods of distribution, scope and concurrency on device and runtime options when implementing an OTrP Agent. Several non-exhaustive options are discussed below. Providers are encouraged to take advantage of the latest communication and platform capabilities to offer the best user experience.

6.3.1. OTrP Agent Distribution

OTrP Agent installation is commonly carried out at OEM time. A user can dynamically download and install an OTrP Agent on-demand.

It is important to ensure a legitimate OTrP Agent is installed and used. If an OTrP Agent is compromised it may send rogue messages to TAM and TEE and introduce additional risks.

6.3.2. Number of OTrP Agent

We anticipate only one shared OTrP Agent instance in a device. The device's TEE vendor will most probably supply one OTrP Agent. Potentially we expect some open source.

With one shared OTrP Agent, the OTrP Agent provider is responsible to allow multiple TAMs and TEE providers to achieve interoperability. With a standard OTrP Agent interface, TAM can implement its own SDK for its SP Client Applications to work with this OTrP Agent.

Multiple independent OTrP Agent providers can be used as long as they have standard interface to a Client Application or TAM SDK. Only one OTrP Agent is expected in a device.

TAM providers are generally expected to provide SDK for SP applications to interact with an OTrP Agent for the TAM and TEE interaction.

6.4. OTrP Agent Interfaces for Client Applications

A Client Application shall be responsible for relaying messages between the OTrP agent and the TAM.

If a failure occurs during calling OTrP Agent, an error message described in "Common Errors" section (see Section 7.6) will be returned.

6.4.1. ProcessOTrPMessage call

Description

A Client Application will use this method of the OTrP Agent in a device to pass OTrP messages from a TAM. The method is responsible for interacting with the TEE and for forwarding the input message to the TEE. It also returns TEE generated response message back to the Client Application.

Inputs:

TAMInMsg - OTrP message generated in a TAM that is passed to this method from a Client Application.

Outputs:

A TEE-generated OTrP response message (which may be a successful response or be a response message containing an error raised within the TEE) for the client application to forward to the TAM. In the event of the OTrP agent not being able to communicate with the TEE, a OTrPAgentException shall be thrown.

6.4.2. GetTAInformation call

Description

A Client Application may quickly query local TEE about a previously installed TA without requiring TAM each time if it has had the TA's identifier and previously saved TEE SP AIK public key for TA information integrity verification.

Inputs:

```
{
  "TAQuery": {
    "spid": "<SP identifier value of the TA>",
    "taid": "<The identifier value of the TA>"
  }
}
```

Outputs:

The OTrP Agent is expected to return TA signer and TAM signer certificate along with other metadata information about the TA associated with the given identifier. It follows the underlying TEE trust model for authoring the local TA query from a Client Application.

The output is a JSON message that is generated by the TEE. It contains the following information:

- * tamid
- * SP ID
- * TA signer certificate
- * TAM certificate

The message is signed with TEE SP AIK private key.

The Client Application is expected to consume the response as follows.

The Client Application gets signed TA metadata, in particular, the TA signer certificate. It is able to verify that the result is from device by checking signer against TEE SP AIK public key it gets in some earlier interaction with TAM.

If this is a new Client Application in the device that hasn't had TEE SP AIK public key for the response verification, the application can contact the TAM first to do GetDeviceState, and TAM will return TEE SP AIK public key to the app for this operation to proceed.

Output Message:

```

{
  "TAInformationTBS": {
    "taid": "<TA Identifier from the input>",
    "tamid": "<TAM ID for the Security Domain where this TA
              resides>",
    "spid": "<The service provider identifier of this TA>",
    "signercert": "<The BASE64 encoded certificate data of the
                  TA binary application's signer certificate>",
    "signercacerts": [ // the full list of CA certificate chain
                      // including the root CA
    ],
    "cacert": "<The BASE64 encoded CA certificate data of the TA
              binary application's signer certificate>"
  ],
  "tamcert": "<The BASE64 encoded certificate data of the TAM
              that manages this TA.>",
  "tamcacerts": [ // the full list of CA certificate chain
                 // including the root CA
  ],
  "cacert": "<The BASE64 encoded CA certificate data of the TAM
            that manages this TA>"
  ]
}
}

{
  "TAInformation": {
    "payload": "<The BASE64URL encoding of the TAInformationTBS
              JSON above>",
    "protected": "<BASE64URL encoded signing algorithm>",
    "header": {
      "signer": { "<JWK definition of the TEE SP AIK public
                  key>" }
    },
    "signature": "<signature contents signed by TEE SP AIK
                  private key BASE64URL encoded>"
  }
}

```

where the definitions of BASE64 and BASE64URL refer to [RFC4648].

A sample JWK public key representation refers to an example in [RFC7517].

6.5. Sample End-to-End Client Application Flow

6.5.1. Case 1: A New Client Application Uses a TA

1. During the Client Application installation time, the Client Application calls TAM to initialize the device preparation step.
 - A. The Client Application knows it wants to use a Trusted Application TA1 but the application doesn't know whether TA1 has been installed or not. It can use GP TEE Client API [GPTEECLAPI] to check the existence of TA1 first. If it detects that TA1 doesn't exist, it will contact TAM to initiate the installation of TA1. Note that TA1 could have been previously installed by other Client Applications from the same service provider in the device.
 - B. The Client Application sends the TAM the TA list that it depends on. The TAM will query a device for the Security Domains and TAs that have been installed, and instructs the device to install any dependent TAs that have not been installed.
 - C. In general, the TAM has the latest TA list and their status in a device because all operations are instructed by TAM. TAM has such visibility because all Security Domain deletion and TA deletion are managed by the TAM; the TAM could have stored the state when a TA is installed, updated and deleted. There is also the possibility that an update command is carried out inside TEE but a response is never received in TAM. There is also possibility that some manual local reset is done in a device that the TAM isn't aware of the changes.
2. The TAM generates message: GetDeviceStateRequest
3. The Client Application passes the JSON message GetDeviceStateRequest to OTrP Agent call ProcessOTrPMessage. The communication between a Client Application and an OTrP Agent is up to the implementation of the OTrP Agent.
4. The OTrP Agent routes the message to the active TEE. Multiple TEE case: it is up to OTrP Agent to figure this out. This specification limits the support to only one active TEE, which is the typical case today.
5. The target active TEE processes the received OTrP message, and returns a JSON message GetDeviceStateResponse.

6. The OTrP Agent passes the GetDeviceStateResponse to the Client Application.
 7. The Client Application sends GetDeviceStateResponse to the TAM.
 8. The TAM processes the GetDeviceStateResponse.
 - A. Extract TEEspaik for the SP, signs TEEspaik with TAM signer key
 - B. Examine SD list and TA list
 9. The TAM continues to carry out other actions based on the need. The next call could be instructing the device to install a dependent TA.
 - A. Assume a dependent TA isn't in the device yet, the TAM may do the following: (1) create an SD in which to install the TA by sending a CreateSDRequest message. The message is sent back to the Client Application, and then the OTrP Agent and TEE to process; (2) install a TA with an InstallTARrequest message.
 - B. If a Client Application depends on multiple TAs, the Client Application should expect multiple round trips of the TA installation message exchanges.
 10. At the last TAM and TEE operation, the TAM returns the signed TEE SP AIK public key to the application.
 11. The Client Application stores the TEEspaik for future loaded TA trust check.
 12. If the TAM finds that this is a fresh device that does not have any SD for the SP yet, then the TAM may next create an SD for the SP.
 13. During Client Application installation, the application checks whether required Trusted Applications are already installed, which may have been provided by the TEE. If needed, it will contact its TAM service to determine whether the device is ready or install TA list that this application needs.
- 6.5.2. Case 2: A Previously Installed Client Application Calls a TA
1. The Client Application checks the device readiness: (a) whether it has a TEE; (b) whether it has TA that it depends. It may happen that TAM has removed the TA this application depends on.

2. The Client Application calls the OTrP Agent to query the TA.
3. The OTrP Agent queries the TEE to get TA information. If the given TA doesn't exist, an error is returned.
4. The Client Application parses the TAInformation message.
5. If the TA doesn't exist, the Client Application calls its TAM to install the TA. If the TA exists, the Client Application proceeds to call the TA.

7. OTrP Messages

The main OTrP component is the set of standard JSON messages created by a TAM to deliver device SD and TA management commands to a device, and device attestation and response messages created by TEE to respond to TAM OTrP Messages.

An OTrP Message is designed to provide end-to-end security. It is always signed by its creator. In addition, an OTrP Message is typically encrypted such that only the targeted device TEE or TAM is able to decrypt and view the actual content.

7.1. Message Format

OTrP Messages use the JSON format for JSON's simple readability and moderate data size in comparison with alternative TLV and XML formats. More compact CBOR format may be used as an alternative choice.

JSON Message security has developed JSON Web Signing and JSON Web Encryption standard in the IETF Workgroup JOSE, see JWS [RFC7515] and JWE [RFC7516]. The OTrP Messages in this protocol will leverage the basic JWS and JWE to handle JSON signing and encryption.

7.2. Message Naming Convention

For each TAM command "xyz", OTrP use the following naming convention to represent its raw message content and complete request and response messages:

| Purpose | Message Name | Example |
|-----------------------|----------------|---------------------|
| Request to be signed | xyzTBSRequest | CreateSDTBSRequest |
| Request message | xyzRequest | CreateSDRequest |
| Response to be signed | xyzTBSResponse | CreateSDTBSResponse |
| Response message | xyzResponse | CreateSDResponse |

7.3. Request and Response Message Template

An OTrP Request message uses the following format:

```
{
  "<name>TBSRequest": {
    <request message content>
  }
}
```

A corresponding OTrP Response message will be as follows.

```
{
  "<name>TBSResponse": {
    <response message content>
  }
}
```

7.4. Signed Request and Response Message Structure

A signed request message will generally include only one signature, and uses the flattened JWS JSON Serialization Syntax, see Section 7.2.2 in [RFC7515].

A general JWS object looks like the following.

```
{
  "payload": "<payload contents>",
  "protected": "<integrity-protected header contents>",
  "header": {
    <non-integrity-protected header contents>,
  },
  "signature": "<signature contents>"
}
```

OTrP signed messages only require the signing algorithm as the mandate header in the property "protected". The "non-integrity-protected header contents" is optional.

OTrP signed message will be given an explicit Request or Response property name. In other words, a signed Request or Response uses the following template.

A general JWS object looks like the following.

```
{
  "<name>[Request | Response]": {
    <JWS Message of <name>TBS[Request | Response]
  }
}
```

With the standard JWS message format, a signed OTrP Message looks like the following.

```
{
  "<name>[Request | Response]": {
    "payload": "<payload contents of <name>TBS[Request | Response]>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents>"
  }
}
```

The top element " <name>[Signed][Request | Response]" cannot be fully trusted to match the content because it doesn't participate in the signature generation. However, a recipient can always match it with the value associated with the property "payload". It purely serves to provide a quick reference for reading and method invocation.

Furthermore, most properties in an unsigned OTrP messages are encrypted to provide end-to-end confidentiality. The only OTrP message that isn't encrypted is the initial device query message that asks for the device state information.

Thus a typical OTrP Message consists of an encrypted and then signed JSON message. Some transaction data such as transaction ID and TEE information may need to be exposed to the OTrP Agent for routing purpose. Such information is excluded from JSON encryption. The device's signer certificate itself is encrypted. The overall final message is a standard signed JSON message.

As required by JSW/JWE, those JWE and JWS related elements will be BASE64URL encoded. Other binary data elements specific to the OTrP

specification are BASE64-encoded. This specification indicates elements that should be BASE64 and those elements that are to be BASE64URL encoded.

7.4.1. Identifying Signing and Encryption Keys for JWS/JWE Messaging

JWS and JWE messaging allow various options for identifying the signing and encryption keys, for example, it allows optional elements including "x5c", "x5t" and "kid" in the header to cover various possibilities.

To protect privacy, it is important that the device's certificate is released only to a trusted TAM, and that it is encrypted. The TAM will need to know the device certificate, but untrusted parties must not be able to get the device certificate. All OTrP messaging conversations between a TAM and device begin with `GetDeviceStateRequest` / `GetDeviceStateResponse`. These messages have elements built into them to exchange signing certificates, described in the section Section 9. Any subsequent messages in the conversation that follow on from this implicitly use the same certificates for signing/encryption, and as a result the certificates or references may be omitted in those subsequent messages.

In other words, the signing key identifier in the use of JWS and JWE here may be absent in the subsequent messages after the initial `GetDeviceState` query.

This has an implication on the TEE and TAM implementation: they have to cache the signer certificates for the subsequent message signature validation in the session. It may be easier for a TAM service to cache transaction session information but not so for a TEE in a device. A TAM can get a device's capability by checking the response message from a TEE to decide whether it should include its TAM signer certificate and OCSP data in each subsequent request message. The device's caching capability is reported in `GetDeviceStateResponse` `signerreq` parameter.

7.5. JSON Signing and Encryption Algorithms

The OTrP JSON signing algorithm shall use SHA256 or a stronger hash method with respective key type. JSON Web Algorithm RS256 or ES256 [RFC7518] SHALL be used for RSA with SHA256 and ECDSA with SHA256. If RSA with SHA256 is used, the JSON web algorithm representation is as follows.

```
{"alg": "RS256"}
```

The (BASE64URL encoded) "protected" header property in a signed message looks like the following:

```
"protected": "eyJhbGciOiJSUzI1NiJ9"
```

If ECSDA with P-256 curve and SHA256 are used for signing, the JSON signing algorithm representation is as follows.

```
{"alg": "ES256"}
```

The value for the "protected" field will be the following.

```
eyJhbGciOiJFUzI1NiJ9
```

Thus, a common OTrP signed message with ES256 looks like the following.

```
{
  "payload": "<payload contents>",
  "protected": "eyJhbGciOiJFUzI1NiJ9",
  "signature": "<signature contents>"
}
```

The OTrP JSON message encryption algorithm SHOULD use one of the supported algorithms defined in the later chapter of this document. JSON encryption uses a symmetric key as its "Content Encryption Key (CEK)". This CEK is encrypted or wrapped by a recipient's key. The OTrP recipient typically has an asymmetric key pair. Therefore, the CEK will be encrypted by the recipient's public key.

A compliant implementation shall support the following symmetric encryption algorithm and anticipate future new algorithms.

```
{"enc": "A128CBC-HS256"}
```

This algorithm represents encryption with AES 128 in CBC mode with HMAC SHA 256 for integrity. The value of the property "protected" in a JWE message will be

```
eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

An encrypted JSON message looks like the following.

```
{
  "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
  "recipients": [
    {
      "header": {
        "alg": "<RSA1_5 etc.>"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON plaintext
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

OTrP doesn't use JWE AAD (Additional Authenticated Data) because each message is always signed after the message is encrypted.

7.5.1. Supported JSON Signing Algorithms

The following JSON signature algorithm is mandatory support in the TEE and TAM:

- o RS256

ES256 is optional to support.

7.5.2. Support JSON Encryption Algorithms

The following JSON authenticated encryption algorithm is mandatory support in TEE and TAM.

- o A128CBC-HS256

A256CBC-HS512 is optional to support.

7.5.3. Supported JSON Key Management Algorithms

The following JSON key management algorithm is mandatory support in TEE and TAM.

- o RSA1_5

ECDH-ES+A128KW and ECDH-ES+A256KW are optional to support.

7.6. Common Errors

An OTrP Response message typically needs to report the operation status and error causes if an operation fails. The following JSON message elements should be used across all OTrP Messages.

```
"status": "pass | fail"

"reason": {
  "error-code": "<error code if there is any>",
  "error-message": "<error message>"
}

"ver": "<version string>"
```

7.7. OTrP Message List

The following table lists the OTrP commands and therefore corresponding Request and Response messages defined in this specification. Additional messages may be added in the future when new task messages are needed.

GetDeviceState -

A TAM queries a device's current state with a message GetDeviceStateRequest. A device TEE will report its version, its FW version, and list of all SDs and TAs in the device that is managed by the requesting TAM. TAM may determine whether the device is trustworthy and decide to carry out additional commands according to the response from this query.

CreateSD -

A TAM instructs a device TEE to create an SD for an SP. The recipient TEE will check whether the requesting TAM is trustworthy.

UpdateSD -

A TAM instructs a device TEE to update an existing SD. A typical update need comes from SP certificate change, TAM certificate change and so on. The recipient TEE will verify whether the TAM is trustworthy and owns the SD.

DeleteSD -

A TAM instructs a device TEE to delete an existing SD. A TEE conditionally deletes TAs loaded in the SD according to a request parameter. An SD cannot be deleted until all TAs in this SD are deleted. If this is the last SD for an SP, TEE MAY also delete TEE SP AIK key for this SP.

InstallTA -

A TAM instructs a device to install a TA into an SD for a SP. The TEE in a device will check whether the TAM and TA are trustworthy.

UpdateTA -

A TAM instructs a device to update a TA into an SD for an SP. The change may commonly be bug fix for a previously installed TA.

DeleteTA -

A TAM instructs a device to delete a TA. The TEE in a device will check whether the TAM and TA are trustworthy.

7.8. OTrP Request Message Routing Rules

For each command that a TAM wants to send to a device, the TAM generates a request message. This is typically triggered by a Client Application that uses the TAM. The Client Application initiates contact with the TAM and receives TAM OTrP Request messages according to the TAM's implementation. The Client Application forwards the OTrP message to an OTrP Agent in the device, which in turn sends the message to the active TEE in the device.

The current version of this specification assumes that each device has only one active TEE, and the OTrP Agent is responsible to connect to the active TEE. This is the case today with devices in the market.

When the TEE responds to a request, the OTrP Agent gets the OTrP response messages back to the Client Application that sent the request. In case the target TEE fails to respond to the request, the OTrP Agent will be responsible to generate an error message to reply the Client Application. The Client Application forwards any data it received to its TAM.

7.8.1. SP Anonymous Attestation Key (SP AIK)

When the first new Security Domain is created in a TEE for an SP, a new key pair is generated and associated with this SP. This key pair is used for future device attestation to the service provider instead of using the device's TEE key pair.

8. Transport Protocol Support

The OTrP message exchange between a TEE device and TAM generally takes place between a Client Application in REE and TAM. A device that is capable to run a TEE and PKI based cryptographic attestation

isn't generally resource constraint to carry out standard HTTPS connections. A compliant device and TAM SHOULD support HTTPS.

9. Detailed Messages Specification

For each message in the following sections all JSON elements are mandatory if not explicitly indicated as optional.

9.1. GetDeviceState

This is the first command that a TAM will send to a device. This command is triggered when an SP's Client Application contacts its TAM to check whether the underlying device is ready for TA operations.

This command queries a device's current TEE state. A device TEE will report its version, its FW version, and list of all SDs and TAs in the device that is managed by the requesting TAM. TAM may determine whether the device is trustworthy and decide to carry out additional commands according to the response from this query.

The request message of this command is signed by the TAM. The response message from the TEE is encrypted. A random message encryption key (MK) is generated by TEE, and this encrypted key is encrypted by the TAM's public key such that only the TAM that sent the request is able to decrypt and view the response message.

9.1.1. GetDeviceStateRequest message

```
{
  "GetDeviceStateTBSRequest": {
    "ver": "1.0",
    "rid": "<Unique request ID>",
    "tid": "<transaction ID>",
    "ocspdat": [<a list of OCSP stapling data>],
    "supportedsigalgs": [<array of supported signing algorithms>]
  }
}
```

The request message consists of the following data elements:

ver - version of the message format

rid - a unique request ID generated by the TAM

tid - a unique transaction ID to trace request and response. This can be from a prior transaction's tid field, and can be used in subsequent message exchanges in this TAM session. The combination of rid and tid MUST be made unique.

ocspdat - 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 such that a recipient TEE can validate the TAM certificate chain revocation status without making its own external OCSP service call. A TEE MAY cache the CA OCSP data such that the array may contain only the OCSP stapling data for the TAM certificate in subsequent exchanges. This is a mandatory field.

supportedsigalgs - an optional property to list the signing algorithms that the TAM is able to support. A recipient TEE MUST choose an algorithm in this list to sign its response message if this property is present in a request. If it is absent, the TEE may use any compliant signing algorithm that is listed as mandatory support in this specification.

The final request message is JSON signed message of the above raw JSON data with TAM's certificate.

```
{
  "GetDeviceStateRequest": {
    "payload": "<BASE64URL encoding of the GetDeviceStateTBSRequest
               JSON above>",
    "protected": "<BASE64URL encoded signing algorithm>",
    "header": {
      "x5c": "<BASE64 encoded TAM certificate chain up to the
             root CA certificate>"
    },
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

The signing algorithm SHOULD use SHA256 with respective key type. The mandatory algorithm support is the RSA signing algorithm. The signer header "x5c" is used to include the TAM signer certificate up to the root CA certificate.

9.1.2. Request processing requirements at a TEE

Upon receiving a request message GetDeviceStateRequest at a TEE, the TEE MUST validate a request:

1. Validate JSON message signing. If it doesn't pass, an error message is returned.
2. Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor.

- * Cache the CA OCSP stapling data and certificate revocation check status for other subsequent requests.
- * A TEE can use its own clock time for the OCSP stapling data validation.

3. Optionally collect Firmware signed data

- * This is a capability in ARM architecture that allows a TEE to query Firmware to get FW signed data. It isn't required for all TEE implementations. When TFW signed data is absent, it is up to a TAM's policy how it will trust a TEE.

4. Collect SD information for the SD owned by this TAM

9.1.3. Firmware Signed Data

Firmware isn't expected to process or produce JSON data. It is expected to just sign some raw bytes of data.

The data to be signed by TFW key needs be some unique random data each time. The (UTF-8 encoded) "tid" value from the `GetDeviceStateTBSRequest` shall be signed by the firmware. TAM isn't expected to parse TFW data except the signature validation and signer trust path validation.

It is possible that a TEE can get some valid TFW signed data from another device. The TEE is responsible to validate TFW integrity to ensure that the underlying device firmware is trustworthy. In some cases, a TEE isn't able to get a TFW signed data, in which case the TEE trust validation is up to a TAM to decide. A TAM may opt to trust a TEE basing on the TEE signer and additional information about a TEE out-of-band.

When TFW signed data is available, a TAM validates the TEE and trusts that a trusted TEE has carried out appropriate trust check about a TFW.

```
TfwData: {  
  "tbs": "<TFW to be signed data, BASE64 encoded>",  
  "cert": "<BASE64 encoded TFW certificate>",  
  "sigalg": "Signing method",  
  "sig": "<TFW signed data, BASE64 encoded>"  
}
```

It is expected that a FW uses standard signature methods for maximal interoperability with TAM providers. The mandatory support list of signing algorithm is RSA with SHA256.

The JSON object above is constructed by a TEE with data returned from the FW. It isn't a standard JSON signed object. The signer information and data to be signed must be specially processed by a TAM according to the definition given here. The data to be signed is the raw data.

9.1.3.1. Supported Firmware Signature Methods

TAM providers shall support the following signature methods. A firmware provider can choose one of the methods in signature generation.

- o RSA with SHA256
- o ECDSA with SHA 256

The value of "sigalg" in the TfwData JSON message SHOULD use one of the following:

- o RS256
- o ES256

9.1.4. Post Conditions

Upon successful request validation, the TEE information is collected. There is no change in the TEE in the device.

The response message shall be encrypted where the encryption key shall be a symmetric key that is wrapped by TAM's public key. The JSON Content Encryption Key (CEK) is used for this purpose.

9.1.5. GetDeviceStateResponse Message

The message has the following structure.

```
{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass | fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "signerreq": true | false // about whether TAM needs to send
                          signer data again in subsequent messages,
    "edsi": "<Encrypted JSON DSI information>"
  }
}
```

where

signerreq - true if the TAM should send its signer certificate and OSCP data again in the subsequent messages. The value may be "false" if the TEE caches the TAM's signer certificate and OSCP status.

rid - the request ID from the request message

tid - the tid from the request message

edsi - the main data element whose value is JSON encrypted message over the following Device State Information (DSI).

The Device State Information (DSI) message consists of the following.

```

{
  "dsi": {
    "tfwdata": {
      "tbs": "<TFW to be signed data is the tid>",
      "cert": "<BASE64 encoded TFW certificate>",
      "sigalg": "Signing method",
      "sig": "<TFW signed data, BASE64 encoded>"
    },
    "tee": {
      "name": "<TEE name>",
      "ver": "<TEE version>",
      "cert": "<BASE64 encoded TEE cert>",
      "cacert": "<JSON array value of CA certificates up to
                  the root CA>",
      "sdlist": {
        "cnt": "<Number of SD owned by this TAM>",
        "sd": [
          {
            "name": "<SD name>",
            "spid": "<SP owner ID of this SD>",
            "talist": [
              {
                "taid": "<TA application identifier>",
                "taname": "<TA application friendly
                           name>" // optional
              }
            ]
          }
        ]
      },
      "teeaiklist": [
        {
          "spaik": "<SP AIK public key, BASE64 encoded>",
          "spaiktype": "<RSA | ECC>",
          "spid": "<sp id>"
        }
      ]
    }
  }
}

```

The encrypted JSON message looks like the following.

```
{
  "protected": "<BASE64URL encoding of encryption algorithm header
                JSON data>",
  "recipients": [
    {
      "header": {
        "alg": "RSA1_5"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON object of dsi
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

Assume we encrypt plaintext with AES 128 in CBC mode with HMAC SHA 256 for integrity, the encryption algorithm header is:

```
{ "enc": "A128CBC-HS256" }
```

The value of the property "protected" in the above JWE message will be

```
eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

In other words, the above message looks like the following:

```
{
  "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
  "recipients": [
    {
      "header": {
        "alg": "RSA1_5"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON object of dsi
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

The full response message looks like the following:


```

{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass | fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "signerreq": "true | false",
    "edsi": {
      "protected": "<BASE64URL encoding of encryption algorithm
                    header JSON data>",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key": "<encrypted value of CEK>"
        }
      ],
      "iv": "<BASE64URL encoded IV data>",
      "ciphertext": "<Encrypted data over the JSON object of dsi
                    (BASE64URL)>",
      "tag": "<JWE authentication tag (BASE64URL)>"
    }
  }
}

```

The CEK will be encrypted by the TAM public key in the device. The TEE signed message has the following structure.

```

{
  "GetDeviceTEESStateResponse": {
    "payload": "<BASE64URL encoding of the JSON message
               GetDeviceTEESStateTBSResponse>",
    "protected": "<BASE64URL encoding of signing algorithm>",
    "signature": "<BASE64URL encoding of the signature value>"
  }
}

```

The signing algorithm shall use SHA256 with respective key type, see Section 7.5.1.

The final GetDeviceStateResponse response message consists of an array of TEE responses.

```
{
  "GetDeviceStateResponse": [ // JSON array
    {"GetDeviceTEEStateResponse": ...},
    ...
    {"GetDeviceTEEStateResponse": ...}
  ]
}
```

9.1.6. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible error conditions is the following.

ERR_REQUEST_INVALID The TEE meets the following conditions with a request message: (1) The request from a TAM has an invalid message structure; mandatory information is absent in the message; or an undefined member or structure is included. (2) TEE fails to verify the signature of the message or fails to decrypt its contents.

ERR_UNSUPPORTED_MSG_VERSION The TEE receives a version of message that the TEE can't deal with.

ERR_UNSUPPORTED_CRYPTO_ALG The TEE receives a request message encoded with a cryptographic algorithm that the TEE doesn't support.

ERR_TFW_NOT_TRUSTED The TEE considers the underlying device firmware be not trustworthy.

ERR_TAM_NOT_TRUSTED The TEE needs to make sure whether the TAM is trustworthy by checking the validity of the TAM certificate and OCSP stapling data and so on. If the TEE finds the TAM is not reliable, it returns this error code.

ERR_TEE_FAIL If the TEE fails to process a request because of its internal error but is able to sign an error response message, it will return this error code.

ERR_AGENT_TEE_FAIL The TEE failed to respond to a TAM request. The OTrP Agent will construct an error message in responding to the TAM's request. The error message will not be signed.

The response message will look like the following if the TEE signing can work to sign the error response message.

```
{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "reason": {"error-code": "<error code>"}
    "supportedsigalgs": [<an array of signature algorithms that
                        the TEE supports>]
  }
}
```

where

supportedsigalgs - an optional property to list the JWS signing algorithms that the active TEE supports. When a TAM sends a signed message that the TEE isn't able to validate, it can include signature algorithms that it is able to consume in this status report. A TAM can generate a new request message to retry the management task with a TEE-supported signing algorithm.

If the TEE isn't able to sign an error message due to an internal device error, a general error message should be returned by the OTrP Agent.

9.1.1.7. TAM Processing Requirements

Upon receiving a GetDeviceStateResponse message at a TAM, the TAM MUST validate the following.

- o Parse to get list of GetDeviceTEESStateResponse JSON objects
- o Parse the JSON "payload" property and decrypt the JSON element "edsi". The decrypted message contains the TEE signer certificate.
- o Validate the GetDeviceTEESStateResponse JSON signature. The signer certificate is extracted from the decrypted message in the last step.
- o Extract TEE information and check it against its TEE acceptance policy.
- o Extract the TFW signed element, and check the signer and data integration against its TFW policy.
- o Check the SD list and TA list and prepare for a subsequent command such as "CreateSD" if it needs to have a new SD for an SP.

9.2. Security Domain Management

9.2.1. CreateSD

This command is typically preceded with a GetDeviceState command that has acquired the device information of the target device by the TAM. The TAM sends such a command to instruct a TEE to create a new Security Domain for an SP.

A TAM sends an OTrP CreateSDRequest Request message to a device TEE to create a Security Domain for an SP. Such a request is signed by the TAM where the TAM signer may or may not be the same as the SP's TA signer certificate. The resulting SD is associated with two identifiers for future management:

- o TAM as the owner. The owner identifier is a registered unique TAM ID that is stored in the TAM certificate.
- o SP identified by its TA signer certificate as the authorization. A TAM can add more than one SP certificate to an SD.

A Trusted Application that is signed by a matching SP signer certificate for an SD is eligible to be installed into that SD. The TA installation into an SD by a subsequent InstallTARrequest message may be instructed from a TAM.

9.2.1.1. CreateSDRequest Message

The request message for CreateSD has the following JSON format.

```
{
  "CreateSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON data will be
                        // encrypted
      "spid": "<SP ID value>",
      "sdname": "<SD name for the domain to be created>",
      "spcert": "<BASE64 encoded SP certificate>",
      "tamid": "<An identifiable attribute of the TAM
                certificate>",
      "did": "<SHA256 hash of the TEE cert>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse.

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is expected in the response from the TEE to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD creation. The encryption key is TAMmk that is encrypted by the target TEE's public key. The entire message is signed by the TAM private key TAMpriv. A separate TAMmk isn't used in the latest specification because JSON encryption will use a content encryption key for exactly the same purpose.

spid - A unique id assigned by the TAM for its SP. It should be unique within a TAM namespace.

sdname - a name unique to the SP. TAM should ensure it is unique for each SP.

spcert - The SP's TA signer certificate is included in the request. This certificate will be stored by the device TEE which uses it to check against TA installation. Only if a TA is signed by a matching spcert associated with an SD will the TA be installed into the SD.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate. TEE will be responsible to assign this ID to the SD. The TAM certificate attribute for this attribute tamid MUST be vetted by the TAM signer issuing CA. With this trusted identifier, the SD query at TEE can be fast upon TAM signer verification.

did - The SHA256 hash of the binary-encoded device TEE certificate. The encryption key CEK will be encrypted the recipient TEE's public key. This hash value in the "did" property allows the recipient TEE to check whether it is the expected target to receive such a request. If this isn't given, an OTrP message for device 2 could be sent to device 1. It is optional for the TEE to check because the successful decryption of the request message with this device's TEE private key already proves it is the target. This explicit hash value makes the protocol not dependent on message encryption method in future.

A CreateSDTBSRequest message is signed to generate a final CreateSDRequest message as follows.

```
{
  "CreateSDRequest": {
    "payload": "<CreateSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

The TAM signer certificate is included in the "header" property.

9.2.1.2. Request Processing Requirements at a TEE

Upon receiving a CreateSDRequest request message at a TEE, the TEE MUST do the following:

1. Validate the JSON request message as follows
 - * Validate JSON message signing.
 - * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor.
 - * Compare dsihash with its current state to make sure nothing has changed since this request was sent.
 - * Decrypt to get the plaintext of the content: (a) spid, (b) sd name, (c) did.
 - * Check that an SPID is supplied.
 - * spcert check: check it is a valid certificate (signature and format verification only).
 - * Check "did" is the SHA256 hash of its TEEcert BER raw binary data.
 - * Check whether the requested SD already exists for the SP.
 - * Check that the tamid in the request matches the TAM certificate's TAM ID attribute.
2. If the request was valid, create action
 - * Create an SD for the SP with the given name.
 - * Assign the tamid from the TAMCert to this SD.
 - * Assign the SPID and SPCert to this SD.
 - * Check whether a TEE SP AIK key pair already exists for the given SP ID.
 - * Create TEE SP AIK key pair if it doesn't exist for the given SP ID.
 - * Generate new DSI data if the request asks for updated DSI.
3. Construct a CreateSDResponse message

- * Create raw content
 - + Operation status
 - + "did" or full signer certificate information,
 - + TEE SP AIK public key if DSI isn't going to be included
 - + Updated DSI data if requested
 - * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver the response message. (a) The OTrP Agent returns this to the Client Application; (b) The Client App passes this back to the TAM.
 5. TAM processing. (a) The TAM processes the response message; (b) the TAM can look up signer certificate from the device ID "did".

If a request is illegitimate or signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.1.3. CreateSDResponse Message

The response message for a CreateSDRequest contains the following content.

```
{
  "CreateSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id received from the request>",
      "sdname": "<SD name for the domain created>",
      "teespaik": "<TEE SP AIK public key, BASE64 encoded>",
      "dsi": "<Updated TEE state, including all SDs owned by
        this TAM>"
    }
  }
}
```


In the response message, the following fields MUST be supplied.

did - The SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

teespaik - The newly generated SP AIK public key for the given SP. This is an optional value if the device has had another domain for the SP that has triggered TEE SP AIK key pair for this specific SP.

There is a possible extreme error case where the TEE isn't reachable or the TEE final response generation itself fails. In this case, the TAM might still receive a response from the OTrP Agent if the OTrP Agent is able to detect such error from TEE. In this case, a general error response message should be returned by the OTrP Agent, assuming OTrP Agent even doesn't know any content and information about the request message.

In other words, the TAM should expect to receive a TEE successfully signed JSON message, a general "status" message, or none when a client experiences a network error.

```
{
  "CreateSDResponse": {
    "payload": "<CreateSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by the TEE device private
                  key (BASE64URL)>"
  }
}
```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```
{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "TEE fails to respond"
  }
}
```

9.2.1.4. Error Conditions

An error might occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_ALREADY_EXIST

ERR_SD_NOT_FOUND

ERR_SPCERT_INVALID

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.2.2. UpdateSD

This TAM initiated command can update an SP's SD that it manages for any of the following needs: (a) Update an SP signer certificate; (b) Add an SP signer certificate when an SP uses multiple to sign TA binaries; (c) Update an SP ID.

The TAM presents the proof of the SD ownership to the TEE, and includes related information in its signed message. The entire request is also encrypted for end-to-end confidentiality.

9.2.2.1. UpdateSDRequest Message

The UpdateSD request message has the following JSON format.

```
{
  "UpdateSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON will be encrypted
      "tamid": "<tamid associated with this SD>",
      "spid": "<SP ID>",
      "sdname": "<SD name for the domain to be updated>",
      "changes": {
        "newsdname": "<Change the SD name to this new name>",
          // Optional
        "newspid": "<Change SP ID of the domain to this new value>",
          // Optional
        "spcert": ["<BASE64 encoded new SP signer cert to be added>"],
          // Optional
        "deloldspcert": ["<The SHA256 hex value of an old SP cert
          assigned into this SD that should be deleted >"],
          // Optional
        "renewteespaik": true | false
      }
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value as the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is expected to be returned in the response from the TEE to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It

helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - the identifier of the SP whose SD will be updated. This value is still needed because the SD name is considered unique only within an SP.

sdname - the name of the target SD to be updated.

changes - its content consists of changes are to be updated in the given SD.

newsdname - the new name of the target SD to be assigned if this value is present.

newspid - the new SP ID of the target SD to be assigned if this value is present.

spcert - a new TA signer certificate of this SP to be added to the SD if this is present.

deloldspcert - an SP certificate assigned into the SD is to be deleted if this is present. The value is the SHA256 fingerprint of the old SP certificate.

renewteespaik - the value should be true or false. If it is present and the value is true, the TEE MUST regenerate TEE SP AIK for this SD's owner SP. The newly generated TEE SP AIK for the SP must be returned in the response message of this request. If there is more than one SD for the SP, a new SPID for one of the domains will always trigger a new teespaik generation as if a new SP were introduced to the TEE.

The UpdateSDTBSRequest message is signed to generate the final UpdateSDRequest message.

```
{
  "UpdateSDRequest": {
    "payload": "<UpdateSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

TAM signer certificate is included in the "header" property.

9.2.2.2. Request Processing Requirements at a TEE

Upon receiving a request message UpdateSDRequest at a TEE, the TEE must validate a request:

1. Validate the JSON request message

- * Validate JSON message signing
- * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor. The TAM certificate status check is generally not needed anymore in this request. The prior request should have validated the TAM certificate's revocation status.
- * Compare dsihash with the TEE cached last response DSI data to this TAM.
- * Decrypt to get the plaintext of the content.
- * Check that the target SD name is supplied.
- * Check whether the requested SD exists.
- * Check that the TAM owns this TAM by verifying tamid in the SD matches TAM certificate's TAM ID attribute.
- * Now the TEE is ready to carry out update listed in the "content" message.

2. If the request is valid, update action

- * If "newsdname" is given, replace the SD name for the SD to the new value

- * If "newspid" is given, replace the SP ID assigned to this SD with the given new value
 - * If "spcert" is given, add this new SP certificate to the SD.
 - * If "deloldspcert" is present in the content, check previously assigned SP certificates to this SD, and delete the one that matches the given certificate hash value.
 - * If "renewteespaik" is given and has a value of 'true', generate a new TEE SP AIK key pair, and replace the old one with this.
 - * Generate new DSI data if the request asks for updated DSI
 - * Now the TEE is ready to construct the response message
3. Construct UpdateSDResponse message
- * Create raw content
 - + Operation status
 - + "did" or full signer certificate information,
 - + TEE SP AIK public key if DSI isn't going to be included
 - + Updated DSI data if requested
 - * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver response message. (a) The OTrP Agent returns this to the app; (b) The app passes this back to the TAM.
5. TAM processing. (a) The TAM processes the response message; (b) The TAM can look up the signer certificate from the device ID "did".

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.2.3. UpdateSDResponse Message

The response message for a UpdateSDRequest contains the following content.

```
{
  "UpdateSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "cert": "<TEE certificate>", // optional
      "teespaik": "<TEE SP AIK public key, BASE64 encoded>",
      "teespaiktype": "<TEE SP AIK key type: RSA or ECC>",
      "dsi": "<Updated TEE state, including all SD owned by
        this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - The request should have known the signer certificate of this device from a prior request. This hash value of the device TEE certificate serves as a quick identifier only. A full device certificate isn't necessary.

teespaik - the newly generated SP AIK public key for the given SP if the TEE SP AIK for the SP is asked to be renewed in the request. This is an optional value if "dsi" is included in the response, which will contain all up-to-date TEE SP AIK key pairs.

Similar to the template for the creation of the encrypted and signed CreateSDResponse, the final UpdateSDResponse looks like the following.

```
{
  "UpdateSDResponse": {
    "payload": "<UpdateSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device private
                  key (BASE64URL)>"
  }
}
```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```
{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "<TEE fails to respond message>"
  }
}
```

9.2.2.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_SDNAME_ALREADY_USED

ERR_SPCERT_INVALID

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.2.3. DeleteSD

A TAM sends a DeleteSDRequest message to a TEE to delete a specified SD that it owns. An SD can be deleted only if there is no TA associated with this SD in the device. The request message can contain a flag to instruct the TEE to delete all related TAs in an SD and then delete the SD.

The target TEE will operate with the following logic.

1. Look up the given SD specified in the request message
2. Check that the TAM owns the SD
3. Check that the device state hasn't changed since the last operation
4. Check whether there are TAs in this SD
5. If TA exists in an SD, check whether the request instructs whether the TA should be deleted. If the request instructs the TEE to delete TAs, delete all TAs in this SD. If the request doesn't instruct the TEE to delete TAs, return an error "ERR_SD_NOT_EMPTY".
6. Delete the SD
7. If this is the last SD of this SP, delete the TEE SP AIK key.

9.2.3.1. DeleteSDRequest Message

The request message for DeleteSD has the following JSON format.

```
{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON will be encrypted
      "tamid": "<tamid associated with this SD>",
      "sdname": "<SD name for the domain to be updated>",
      "deleteta": true | false
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous response
GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

sdname - the name of the target SD to be updated.

deleteta - the value should be boolean 'true' or 'false'. If it is present and the value is 'true', the TEE should delete all TAs associated with the SD in the device.

According to the OTrP message template, the full request DeleteSDRequest is a signed message over the DeleteSDTBSRequest as follows.

```
{
  "DeleteSDRequest": {
    "payload": "<DeleteSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

TAM signer certificate is included in the "header" property.

9.2.3.2. Request Processing Requirements at a TEE

Upon receiving a request message DeleteSDRequest at a TEE, the TEE must validate a request:

1. Validate the JSON request message

- * Validate JSON message signing
- * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor. The TAM certificate status check is generally not needed anymore in this request. The prior request should have validated the TAM certificate's revocation status.
- * Compare dsihash with the TEE cached last response DSI data to this TAM
- * Decrypt to get the plaintext of the content
- * Check that the target SD name is supplied
- * Check whether the requested SD exists
- * Check that the TAM owns this TAM by verifying that the tamid in the SD matches the TAM certificate's TAM ID attribute
- * Now the TEE is ready to carry out the update listed in the "content" message

2. If the request is valid, deletion action
 - * Check TA existence in this SD
 - * If "deleteta" is "true", delete all TAs in this SD. If the value of "deleteta" is false and some TA exists, return an error "ERR_SD_NOT_EMPTY"
 - * Delete the SD
 - * Delete the TEE SP AIK key pair if this SD is the last one for the SP
 - * Now the TEE is ready to construct the response message
3. Construct a DeleteSDResponse message
 - * Create response content
 - + Operation status
 - + "did" or full signer certificate information,
 - + Updated DSI data if requested
 - * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver response message. (a) The OTrP Agent returns this to the app; (b) The app passes this back to the TAM
5. TAM processing. (a) The TAM processes the response message; (b) The TAM can look up signer certificate from the device ID "did".

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.3.3. DeleteSDResponse Message

The response message for a DeleteSDRequest contains the following content.

```

{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
              this TAM>"
    }
  }
}

```

In the response message, the following fields MUST be supplied.

did - The request should have known the signer certificate of this device from a prior request. This hash value of the device TEE certificate serves as a quick identifier only. A full device certificate isn't necessary.

The final DeleteSDResponse looks like the following.

```

{
  "DeleteSDResponse": {
    "payload": "<DeleteSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                  private key (BASE64URL)>"
  }
}

```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```

{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "TEE fails to respond"
  }
}

```

9.2.3.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors is as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_EMPTY

ERR_SD_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3. Trusted Application Management

This protocol doesn't introduce a TA container concept. All TA authorization and management will be up to the TEE implementation.

The following three TA management commands are supported.

- o InstallTA - provision a TA by TAM
- o UpdateTA - update a TA by TAM
- o DeleteTA - remove TA registration information with an SD, remove the TA binary and all TA-related data in a TEE

9.3.1. InstallTA

TA binary data and related personalization data if there is any can be from two sources:

1. A TAM supplies the signed and encrypted TA binary
2. A Client Application supplies the TA binary

This specification primarily considers the first case where a TAM supplies a TA binary. This is to ensure that a TEE can properly validate whether a TA is trustworthy. Further, TA personalization data will be encrypted by the TEE device's SP public key for end-to-end protection. A Client Application bundled TA case will be addressed separately later.

A TAM sends the following information in a InstallTAREquest message to a target TEE:

- o The target SD information: SP ID and SD name
- o Encrypted TA binary data. TA data is encrypted with the TEE SP AIK.
- o TA metadata. It is optional to include the SP signer certificate for the SD to add if the SP has changed signer since the SD was created.

The TEE processes the command given by the TAM to install a TA into an SP's SD. It does the following:

- o Validation
 - * The TEE validates the TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD with the SD name
 - * Checks that the TAM owns the SD
 - * Checks that the DSI hash matches which shows that the device state hasn't changed
- o If the request is valid, continue to do the TA validation
 - * Decrypt to get the TA binary data and any personalization data with the "TEE SP AIK private key"

- * Check that SP ID is the one that is registered with the SP SD
- * Check that the TA signer is either a newly given SP certificate or the one that is already trusted by the SD from the previous TA installation. The TA signing method is specific to a TEE. This specification doesn't define how a TA should be signed; a TAM should support TEE specific TA signing when it supports that TEE.
- * If a TA signer is given in the request, add this signer into the SD.
- o If the above validation passed, continue to do TA installation
 - * The TEE re-encrypts the TA binary and its personalization data with its own method.
 - * The TEE enrolls and stores the TA in a secure storage.
- o Construct a response message. This involves signing encrypted status information for the requesting TAM.

9.3.1.1. InstallTAResponse Message

The request message for InstallTA has the following JSON format.

```
{
  "InstallTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "spid": "<SPID value>",
      "sdname": "<SD name for the domain to install the TA>",
      "spcert": "<BASE64 encoded SP certificate >", // optional
      "taid": "<TA identifier>"
    },
    "encrypted_ta": {
      "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
      "iv": "<hex of 16 random bytes>",
      "alg": "<encryption algorithm. AESCBC by default.>",
      "ciphertadata": "<BASE64 encoded encrypted TA binary data>",
      "cipherpdata": "<BASE64 encoded encrypted TA personalization
        data>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - An SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - SP identifier of the TA owner SP

sdname - the name of the target SD where the TA is to be installed

spcert - an optional field to specify the SP certificate that signed the TA. This is sent if the SP has a new certificate that hasn't been previously registered with the target SD where the TA should be installed.

taid - the identifier of the TA application to be installed

encrypted_ta - the message portion contains encrypted TA binary data and personalization data. The TA data encryption key is placed in "key", which is encrypted by the recipient's public key, using JWE enveloped structure. The TA data encryption uses symmetric key based encryption such as AESCBC.

According to the OTrP message template, the full request InstallTARrequest is a signed message over the InstallTATBSRequest as follows.

```
{
  "InstallTARrequest": {
    "payload": "<InstallTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

9.3.1.2. InstallTARresponse Message

The response message for a InstallTARrequest contains the following content.

```

{
  "InstallTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
              this TAM>"
    }
  }
}

```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message InstallTAResponse looks like the following.

```

{
  "InstallTAResponse": {
    "payload": "<InstallTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                  private key (BASE64URL)>"
  }
}

```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```

{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "TEE fails to respond"
  }
}

```

9.3.1.3. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPT_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_INVALID

ERR_TA_ALREADY_INSTALLED

ERR_TEE_FAIL

ERR_TEE_RESOURCE_FULL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3.2. UpdateTA

This TAM-initiated command can update a TA and its data in an SP's SD that it manages for the following purposes.

1. Update TA binary
2. Update TA's personalization data

The TAM presents the proof of the SD ownership to a TEE, and includes related information in its signed message. The entire request is also encrypted for end-to-end confidentiality.

The TEE processes the command from the TAM to update the TA of an SP SD. It does the following:

- o Validation
 - * The TEE validates the TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD with the SD name
 - * Checks that the TAM owns the SD
 - * Checks DSI hash matches that the device state hasn't changed
- o TA validation
 - * Both TA binary and personalization data are optional, but at least one of them shall be present in the message
 - * Decrypt to get the TA binary and any personalization data with the "TEE SP AIK private key"
 - * Check that SP ID is the one that is registered with the SP SD
 - * Check that the TA signer is either a newly given SP certificate or the one in SD.
 - * If a TA signer is given in the request, add this signer into the SD.
- o If the above validation passes, continue to do TA update
 - * The TEE re-encrypts the TA binary and its personalization data with its own method
 - * The TEE replaces the existing TA binary and its personalization data with the new binary and data.
- o Construct a response message. This involves signing a encrypted status information for the requesting TAM.

9.3.2.1. UpdateTARquest Message

The request message for UpdateTA has the following JSON format.

```
{
  "UpdateTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "spid": "<SPID value>",
      "sdname": "<SD name for the domain to be created>",
      "spcert": "<BASE64 encoded SP certificate >", // optional
      "taid": "<TA identifier>"
    },
    "encrypted_ta": {
      "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
      "iv": "<hex of 16 random bytes>",
      "alg": "<encryption algorithm. AESCBC by default.>",
      "ciphernewtadata": "<Change existing TA binary to this new TA
        binary data(BASE64 encoded and encrypted)>",
      "ciphernewpdata": "<Change the existing data to this new TA
        personalization data(BASE64 encoded and encrypted)>"
      // optional
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It

helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - SP identifier of the TA owner SP

spcert - an optional field to specify the SP certificate that signed the TA. This is sent if the SP has a new certificate that hasn't been previously registered with the target SD where the TA is to be installed.

sdname - the name of the target SD where the TA should be updated

taid - an identifier for the TA application to be updated

encrypted_ta - the message portion contains newly encrypted TA binary data and personalization data.

According to the OTrP message template, the full request UpdateTARequest is a signed message over the UpdateTATBSRequest as follows.

```
{
  "UpdateTARequest": {
    "payload": "<UpdateTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

9.3.2.2. UpdateTAResponse Message

The response message for a UpdateTARequest contains the following content.

```
{
  "UpdateTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
             this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message UpdateTAResponse looks like the following.

```
{
  "UpdateTAResponse": {
    "payload": "<UpdateTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                 private key (BASE64URL)>"
  }
}
```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```
{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "TEE fails to respond"
  }
}
```


9.3.2.3. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_INVALID

ERR_TA_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3.3. DeleteTA

This operation defines OTrP messages that allow a TAM to instruct a TEE to delete a TA for an SP in a given SD. A TEE will delete a TA from an SD and also TA data in the TEE. A Client Application cannot directly access TEE or OTrP Agent to delete a TA.

9.3.3.1. DeleteTAResponse Message

The request message for DeleteTA has the following JSON format.

```
{
  "DeleteTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "sdname": "<SD name of the TA>",
      "taid": "<the identifier of the TA to be deleted from the
              specified SD>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - The TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

sdname - the name of the target SD where the TA is installed

taid - an identifier for the TA application to be deleted

According to the OTrP message template, the full request DeleteTARequest is a signed message over the DeleteTATBSRequest as follows.

```
{
  "DeleteTARequest": {
    "payload": "<DeleteTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM
                  private key>"
  }
}
```

9.3.3.2. Request Processing Requirements at a TEE

A TEE processes a command from a TAM to delete a TA of an SP SD. It does the following:

1. Validate the JSON request message
 - * The TEE validates TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD and the TA with the given SD name and TA ID
 - * Checks that the TAM owns the SD, and TA is installed in the SD
 - * Checks that the DSI hash matches and the the device state hasn't changed
2. Deletion action
 - * If all the above validation points pass, the TEE deletes the TA from the SD
 - * The TEE SHOULD also delete all personalization data for the TA
3. Construct DeleteTAResponse message.

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.3.3.3. DeleteTAResponse Message

The response message for a DeleteTAResponse contains the following content.

```
{
  "DeleteTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
              this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message DeleteTAResponse looks like the following.

```
{
  "DeleteTAResponse": {
    "payload": "<DeleteTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                  private key (BASE64URL)>"
  }
}
```

A response message type "status" will be returned when the TEE fails to respond. The OTrP Agent is responsible to create this message.

```
{
  "status": {
    "result": "fail",
    "error-code": "ERR_AGENT_TEE_FAIL",
    "error-message": "TEE fails to respond"
  }
}
```

9.3.3.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_AGENT_TEE_BUSY

ERR_AGENT_TEE_FAIL

ERR_AGENT_TEE_UNKNOWN

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPT_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

10. Response Messages a TAM May Expect

A TAM expects some feedback from a remote device when a request message is delivered to a device. The following three types of responses SHOULD be supplied.

Type 1: Expect a valid TEE-generated response message

A valid TEE signed response may contain errors detected by a TEE, e.g. a TAM is trusted but some TAM-supplied data is missing, for

example, SP ID doesn't exist. TEE MUST be able to sign and encrypt.

If a TEE isn't able to sign a response, the TEE returns an error to the OTrP Agent without giving any other internal information. The OTrP Agent will be generating the response.

Type 2: The OTrP Agent generated error message when TEE fails. OTrP Agent errors will be defined in this document.

A Type 2 message has the following format.

```
{
  "OTrPAgentError": {
    "ver": "1.0",
    "rid": "",
    "tid": "",
    "errcode": "ERR_AGENT_TEE_UNKNOWN | ERR_AGENT_TEE_BUSY"
  }
}
```

Type 3: OTrP Agent itself isn't reachable or fails. A Client Application is responsible to handle error and respond the TAM in its own way. This is out of scope for this specification.

11. Basic Protocol Profile

This section describes a baseline for interoperability among the protocol entities, mainly, the TAM and TEE.

A TEE MUST support RSA algorithms. It is optional to support ECC algorithms. A TAM SHOULD use a RSA certificate for TAM message signing. It may use an ECC certificate if it detects that the TEE supports ECC according to the field "supportedsigalgs" in a TEE response.

A TAM MUST support both RSA 2048-bit algorithm and ECC P-256 algorithms. With this, a TEE and TFW certificate can be either RSA or ECC type.

JSON signing algorithms

- o RSA PKCS#1 with SHA256 signing : "RS256"
- o ECDSA with SHA256 signing : "ES256"

JSON asymmetric encryption algorithms (describes key-exchange or key-agreement algorithm for sharing symmetric key with TEE):

- o RSA PKCS#1 : "RSA1_5"
- o ECDH using TEE ECC P-256 key and ephemeral ECC key generated by TAM : "ECDH-ES+A128W"

JSON symmetric encryption algorithms (describes symmetric algorithm for encrypting body of data, using symmetric key transferred to TEE using asymmetric encryption):

- o Authenticated encryption AES 128 CBC with SHA256 :
{"enc": "A128CBC-HS256"}

12. Attestation Implementation Consideration

It is important to know that the state of a device is appropriate before trusting that a device is what it says it is. The attestation scheme for OTrP must also be able to cope with different TEEs, including those that are OTrP compliant and those that use another mechanism. In the initial version, only one active TEE is assumed.

It is out of scope how the TAM and the device implement the trust hierarchy verification. However, it is helpful to understand what each system provider should do in order to properly implement an OTrP trust hierarchy.

In this section, we provide some implementation reference consideration.

12.1. OTrP Secure Boot Module

12.1.1. Attestation signer

It is proposed that attestation for OTrP is based on the SBM secure boot layer, and that further attestation is not performed within the TEE itself during Security Domain operations. The rationale is that the device boot process will be defined to start with a secure boot approach that, using eFuse, only releases attestation signing capabilities into the SBM once a secure boot has been established. In this way the release of the attestation signer can be considered the first "platform configuration metric", using Trust Computing Group (TCG) terminology.

12.1.2. SBM Initial Requirements

- R1 The SBM must be possible to load securely into the secure boot flow

- R2 The SBM must allow a public / private key pair to be generated during device manufacture
- R3 The public key and certificate must be possible to store securely
- R4 The private key must be possible to store encrypted at rest
- R5 The private key must only be visible to the SBM when it is decrypted
- R6 The SBM must be able to read a list of root and intermediate certificates that it can use to check certificate chains with. The list must be stored such that it cannot be tampered with
- R7 Need to allow a TEE to access its unique TEE specific private key

12.2. TEE Loading

During boot, the SBM is required to start all of the root TEEs. Before loading them, the SBM must first determine whether the code sign signature of the TEE is valid. If TEE integrity is confirmed, the TEE may be started. The SBM must then be able to receive the identity certificate from the TEE (if that TEE is OTrP compliant). The identity certificate and keys will need to be baked into the TEE image, and therefore also covered by the code signer hash during the manufacturing process. The private key for the identity certificate must be securely protected. The private key for a TEE identity must never be released no matter how the public key and certificate are released to the SBM.

Once the SBM has successfully booted a TEE and retrieved the identity certificate, the SBM will commit this to the platform configuration register (PCR) set, for later use during attestation. At minimum, the following data must be committed to the PCR for each TEE:

1. Public key and certificate for the TEE
2. TEE identifier that can be used later by a TAM to identify this TEE

12.3. Attestation Hierarchy

The attestation hierarchy and seed required for TAM protocol operation must be built into the device at manufacture. Additional TEEs can be added post-manufacture using the scheme proposed, but it is outside of the current scope of this document to detail that.

It should be noted that the attestation scheme described is based on signatures. The only encryption that takes place is with eFuse to release the SBM signing key and later during the protocol lifecycle management interchange with the TAM.

12.3.1. Attestation Hierarchy Establishment: Manufacture

During manufacture the following steps are required:

1. A device-specific TFW key pair and certificate are burnt into the device, encrypted by eFuse. This key pair will be used for signing operations performed by the SBM.
2. TEE images are loaded and include a TEE instance-specific key pair and certificate. The key pair and certificate are included in the image and covered by the code signing hash.
3. The process for TEE images is repeated for any subordinate TEEs, which are additional TEEs after the root TEE that some devices have.

12.3.2. Attestation Hierarchy Establishment: Device Boot

During device boot the following steps are required:

1. Secure boot releases the TFW private key by decrypting it with eFuse
2. The SBM verifies the code-signing signature of the active TEE and places its TEE public key into a signing buffer, along with its identifier for later access. For a non-OTrP TEE, the SBM leaves the TEE public key field blank.
3. The SBM signs the signing buffer with the TFW private key.
4. Each active TEE performs the same operation as the SBM, building up their own signed buffer containing subordinate TEE information.

12.3.3. Attestation Hierarchy Establishment: TAM

Before a TAM can begin operation in the marketplace to support devices of a given TEE, it must obtain a TAM certificate from a CA that is registered in the trust store of devices with that TEE. In this way, the TEE can check the intermediate and root CA and verify that it trusts this TAM to perform operations on the TEE.

13. IANA Considerations

The error code listed in the next section will be registered.

13.1. Error Code List

This section lists error codes that could be reported by a TA or TEE in a device in responding to a TAM request, and a separate list that OTrP Agent may return when the TEE fails to respond.

13.1.1. TEE Signed Error Code List

ERR_DEV_STATE_MISMATCH - A TEE will return this error code if the DSI hash value from TAM doesn't match the has value of the device's current DSI.

ERR_SD_ALREADY_EXISTS - This error will occur if an SD to be created already exists in the TEE.

ERR_SD_NOT_EMPTY - This is reported if a target SD isn't empty.

ERR_SDNAME_ALREADY_USED A TEE will return this error code if the new SD name already exists in the TEE.

ERR_REQUEST_INVALID - This error will occur if the TEE meets any of the following conditions with a request message: (1) The request from a TAM has an invalid message structure; mandatory information is absent in the message. undefined member or structure is included. (2) TEE fails to verify signature of the message or fails to decrypt its contents.

ERR_SPCERT_INVALID - If a new SP certificate for the SD to be updated is not valid, then the TEE will return this error code.

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

ERR_TA_INVALID - This error will occur when a TEE meets any of following conditions while checking validity of TA: (1) The TA binary has a format that the TEE can't recognize. (2) The TEE fails to decrypt the encoding of the TA binary and personalization data. (3) If an SP isn't registered with the SP SD where the TA will be installed.

ERR_TA_NOT_FOUND - This error will occur when the target TA doesn't exist in the SD.

ERR_TEE_FAIL - If the TEE fails to process a request because of an internal error, it will return this error code.

ERR_TEE_RESOURCE_FULL - This error is reported when a device resource isn't available anymore such as storage space is full.

ERR_TFW_NOT_TRUSTED - A TEE is responsible for determining that the underlying device firmware is trustworthy. If the TEE determines the TFW is not trustworthy, then this error will occur.

ERR_TAM_NOT_TRUSTED - Before processing a request, a TEE needs to make sure whether the sender TAM is trustworthy by checking the validity of the TAM certificate, etc. If the TEE finds that the TAM is not trustworthy, then it will return this error code.

ERR_UNSUPPORTED_CRYPTO_ALG - This error will occur if a TEE receives a request message encoded with cryptographic algorithms that the TEE doesn't support.

ERR_UNSUPPORTED_MSG_VERSION - This error will occur if a TEE receives a message version that the TEE can't deal with.

13.1.2. OTrP Agent Error Code List

ERR_AGENT_TEE_UNKNOWN - This error will occur if the receiver TEE is not supposed to receive the request. That will be determined by checking the TEE name or device id in the request message.

ERR_AGENT_TEE_BUSY - The device TEE is busy. The request can be generally sent again to retry.

ERR_AGENT_TEE_FAIL - The TEE fails to respond to a TAM request. The OTrP Agent will construct an error message in responding to the TAM's request.

14. Security Consideration

14.1. Cryptographic Strength

The strength of the cryptographic algorithms, using the measure of 'bits of security' defined in NIST SP800-57 allowed for OTrP is:

- o At a minimum, 112 bits of security. The limiting factor for this is the RSA-2048 algorithm, which is indicated as providing 112 bits of symmetric key strength in SP800-57. It is important that RSA is supported in order to enhance the interoperability of the protocol.

- o The option exists to choose algorithms providing 128 bits of security. This requires using TEE devices that support ECC P256.

The available algorithms and key sizes specified in this document are based on industry standards. Over time the recommended or allowed cryptographic algorithms may change. It is important that the OTrP allows for crypto-agility. In this specification, TAM and TEE can negotiate an agreed upon algorithm where both include their supported algorithm in OTrP message.

14.2. Message Security

OTrP messages between the TAM and TEE are protected by message security using JWS and JWE. The 'Basic protocol profile' section of this document describes the algorithms used for this. All OTrP TEE devices and OTrP TAMs must meet the requirements of the basic profile. In the future additional 'profiles' can be added.

PKI is used to ensure that the TEE will only communicate with a trusted TAM, and to ensure that the TAM will only communicate with a trusted TEE.

14.3. TEE Attestation

It is important that the TAM can trust that it is talking to a trusted TEE. This is achieved through attestation. The TEE has a private key and certificate built into it at manufacture, which is used to sign data supplied by the TAM. This allows the TAM to verify that the TEE is trusted.

It is also important that the TFW (trusted firmware) can be checked. The TFW has a private key and certificate built into it at manufacture, which allows the TEE to check that that the TFW is trusted.

The GetDeviceState message therefore allows the TAM to check that it trusts the TEE, and the TEE at this point will check whether it trusts the TFW.

14.4. TA Protection

A TA will be delivered in an encrypted form. This encryption is an additional layer within the message encryption described in the Section 11 of this document. The TA binary is encrypted for each target device with the device's TEE SP AIK public key. A TAM can either do this encryption itself or provide the TEE SP AIK public key to an SP such that the SP encrypts the encrypted TA for distribution to the TEE.

The encryption algorithm can use a random AES 256 key "taek" with a 16 byte random IV, and the "taek" is encrypted by the "TEE SP AIK public key". The following encrypted TA data structure is expected by a TEE:

```
"encrypted_ta_bin": {
  "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
  "iv": "<hex of 16 random bytes>",
  "alg": "AESCBC",
  "cipherdata": "<BASE64 encoded encrypted TA binary data>"
}
```

14.5. TA Personalization Data

An SP or TAM can supply personalization data for a TA to initialize for a device. Such data is passed through an InstallTA command from a TAM. The personalization data itself is (or can be) opaque to the TAM. The data can be from the SP without being revealed to the TAM. The data is sent in an encrypted manner in a request to a device such that only the device can decrypt. A device's TEE SP AIK public key for an SP is used to encrypt the data. Here JWE enveloping is used to carry all encryption key parameters along with encrypted data.

```
"encrypted_ta_data": { // "TA personalization data"
  "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
  "iv": "<hex of 16 random bytes>",
  "alg": "AESCBC",
  "cipherdata": "<BASE64 encoded encrypted TA personalization
                data>"
}
```

14.6. TA Trust Check at TEE

A TA binary is signed by a TA signer certificate. This TA signing certificate/private key belongs to the SP, and may be self-signed (i.e., it need not participate in a trust hierarchy). It is the responsibility of the TAM to only allow verified TAs from trusted SPs into the system. Delivery of that TA to the TEE is then the responsibility of the TEE, using the security mechanisms provided by the OTrP.

We allow a way for an (untrusted) application to check the trustworthiness of a TA. OTrP Agent has a function to allow an application to query the information about a TA.

An application in the Rich O/S may perform verification of the TA by verifying the signature of the TA. The GetTAInformation function is available to return the TEE supplied TA signer and TAM signer information to the application. An application can do additional trust checks on the certificate returned for this TA. It might trust the TAM, or require additional SP signer trust chaining.

14.7. One TA Multiple SP Case

A TA for multiple SPs must have a different identifier per SP. A TA will be installed in a different SD for each respective SP.

14.8. OTrP Agent Trust Model

An OTrP Agent could be malware in the vulnerable Rich OS. A Client Application will connect its TAM provider for required TA installation. It gets command messages from the TAM, and passes the message to the OTrP Agent.

The OTrP is a conduit for enabling the TAM to communicate with the device's TEE to manage SDs and TAs. All TAM messages are signed and sensitive data is encrypted such that the OTrP Agent cannot modify or capture sensitive data.

14.9. OCSP Stapling Data for TAM Signed Messages

The GetDeviceStateRequest message from a TAM to a TEE shall include OCSP stapling data for the TAM's signer certificate and for intermediate CA certificates up to the root certificate so that the TEE can verify the signer certificate's revocation status.

A certificate revocation status check on a TA signer certificate is OPTIONAL by a TEE. A TAM is responsible for vetting a TA and the SP before it distributes them to devices. A TEE will trust a TA signer certificate's validation status done by a TAM when it trusts the TAM.

14.10. Data Protection at TAM and TEE

The TEE implementation provides protection of data on the device. It is the responsibility of the TAM to protect data on its servers.

14.11. Privacy Consideration

Devices are issued with a unique TEE certificate to attest the device's validity. This uniqueness also creates a privacy and tracking risk that must be mitigated.

The TEE will only release the TEE certificate to a trusted TAM (it must verify the TAM certificate before proceeding). OTrP is designed such that only a TAM can obtain the TEE device certificate and firmware certificate - the GetDeviceState message requires signature checks to validate the TAM is trusted, and OTrP delivers the device's certificate(s) encrypted such that only that TAM can decrypt the response. A Client Application will never see the device certificate.

An SP-specific TEE SP AIK (TEE SP Anonymous Key) is generated by the protocol for Client Applications. This provides a way for the Client Application to validate some data that the TEE may send without requiring the TEE device certificate to be released to the client device rich O/S, and to optionally allow an SP to encrypt a TA for a target device without the SP needing to be supplied with the TEE device certificate.

14.12. Threat Mitigation

A rogue application may perform excessive TA loading. An OTrP Agent implementation should protect against excessive calls.

Rogue applications might request excessive SD creation. The TAM is responsible to ensure this is properly guarded against.

Rogue OTrP Agent could replay or send TAM messages out of sequence: e.g., a TAM sends update1 and update2. The OTrP Agent replays update2 and update1 again, creating an unexpected result that a client wants. "dsihash" is used to mitigate this. The TEE MUST store DSI state and check that the DSI state matches before it does another update.

Concurrent calls from a TAM to a TEE MUST be handled properly by a TEE. If multiple concurrent TAM operations take place, these could fail due to the "dsihash" being modified by another concurrent operation. The TEE is responsible for resolve any locking such that one application cannot lock other applications from using the TEE, except for a short term duration of the TAM operation taking place. For example, an OTrP operation that starts but never completes (e.g. loss of connectivity) must not prevent subsequent OTrP messages from being executed.

14.13. Compromised CA

A root CA for TAM certificates might get compromised. Some TEE trust anchor update mechanism is expected from device OEM. A compromised intermediate CA is covered by OCSP stapling and OCSP validation check

in the protocol. A TEE should validate certificate revocation about a TAM certificate chain.

If the root CA of some TEE device certificates is compromised, these devices might be rejected by a TAM, which is a decision of the TAM implementation and policy choice. Any intermediate CA for TEE device certificates SHOULD be validated by TAM with a Certificate Revocation List (CRL) or Online Certificate Status Protocol (OCSP) method.

14.14. Compromised TAM

The TEE SHOULD use validation of the supplied TAM certificates and OCSP stapled data to validate that the TAM is trustworthy.

Since PKI is used, the integrity of the clock within the TEE determines the ability of the TEE to reject an expired TAM certificate, or revoked TAM certificate. Since OCSP stapling includes signature generation time, certificate validity dates are compared to the current time.

14.15. Certificate Renewal

TFW and TEE device certificates are expected to be long lived, longer than the lifetime of a device. A TAM certificate usually has a moderate lifetime of 2 to 5 years. A TAM should get renewed or rekeyed certificates. The root CA certificates for a TAM, which are embedded into the trust anchor store in a device, should have long lifetimes that don't require device trust anchor update. On the other hand, it is imperative that OEMs or device providers plan for support of trust anchor update in their shipped devices.

15. Acknowledgements

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Appendix A. Sample Messages

A.1. Sample Security Domain Management Messages

A.1.1. Sample GetDeviceState

A.1.1.1. Sample GetDeviceStateRequest

The TAM builds a "GetDeviceStateTBSRequest" message.

```
{
  "GetDeviceStateTBSRequest": {
    "ver": "1.0",
    "rid": "8C6F9DBB-FC39-435c-BC89-4D3614DA2F0B",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "ocspdat": "c2FtcGx1IG9jc3BkYXQgQjY0IGVuY29kZWQgQVNOMQ==",
    "icaocspdat": "c2FtcGx1IGl jYW9jc3BkYXQgQjY0IGVuY29kZWQgQVNOMQ==",
    "supportedsigalgs": "RS256"
  }
}
```

The TAM signs "GetDeviceStateTBSRequest", creating "GetDeviceStateRequest"

```
{
  "GetDeviceStateRequest": {
    "payload": "
ewoJlkdldERldml jZVN0YXRlVEJlUmVxdWVzdCI6IHsKCQkidmVyIjogIjEuMCIsCgkJ
InJpZCI6IHs4QzZGOURCQilGQzM5LTQzNWmtQkM4OS00RDM2MTREQTJGMEJ9LAoJCSJ0
aWQiOiAiAiezRGNDU0QTdGTLAwMkQtNDElNy04ODRFLUIwREQxQTA2QTThBRX0iLAoJCSJv
Y3NwZGF0IjogImMyRnR jR3hsSUc5amMzQmtZWFFnUWpZMElHVnVZMjlrWldRZlFWTk9N
UT09IiwKCQkiaWNhb2NzcGRhdCI6ICJ jMkZ0Y0d4bElhbGpZVzlkYzNCa1lYUWdRalkw
SUDWdVkyOWtaVlFnUVZOT01RPT0iLAoJCSJzZXBwb3J0ZWRzaWdhbGdzIjogIlJTMjU2
IgoJfQp9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "x5c": [ "ZXhhbXBsZSBBU04xIHNPZ25lcjBjZXJ0aWZpY2F0ZQ==",
               "ZXhhbXBsZSBBU04xIENBIGNlcnRpZml jYXRl" ]
    },
    "signature": "c2FtcGx1IHNPZ25hdHVyZQ"
  }
}
```

A.1.1.1.2. Sample GetDeviceStateResponse

The TAM sends "GetDeviceStateRequest" to the OTrP Agent

The OTrP Agent obtains "dsi" from each TEE. (In this example there is a single TEE.)

The TEE obtains signed "fwdata" from firmware.

The TEE builds "dsi" - summarizing device state of the TEE.

```

{
  "dsi": {
    "tfwdata": {
      "tbs": "ezRGNDU0QTdGLTAwMkQtNDElNy04ODRFLUIwREQxQTA2QThBRX0=",
      "cert": "ZXhhbXBsZSBGVyBjZXJ0aWZpY2F0ZQ==",
      "sigalg": "RS256",
      "sig": "c2FtcGx1IEZXIHNPZ25hdHVyZQ=="
    },
    "tee": {
      "name": "Primary TEE",
      "ver": "1.0",
      "cert": "c2FtcGx1IFRFRSBjZXJ0aWZpY2F0ZQ==",
      "cacert": [
        "c2FtcGx1IENBIGNlcnRpZmljYXRlIDE=",
        "c2FtcGx1IENBIGNlcnRpZmljYXRlIDI="
      ],
      "sdlist": {
        "cnt": "1",
        "sd": [
          {
            "name": "default.acmebank.com",
            "spid": "acmebank.com",
            "talist": [
              {
                "taid": "acmebank.secure.banking",
                "taname": "Acme secure banking app"
              },
              {
                "taid": "acmebank.loyalty.rewards",
                "taname": "Acme loyalty rewards app"
              }
            ]
          }
        ]
      },
      "teeaiklist": [
        {
          "spaik": "c2FtcGx1IEFTTjEgZW5jb2RlZCBQS0NTMSBwdWJsaWNrZXk=",
          "spaiktype": "RSA",
          "spid": "acmebank.com"
        }
      ]
    }
  }
}

```

The TEE encrypts "dsi", and embeds it into a "GetDeviceTEEStateTBSResponse" message.

```

{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{8C6F9DBB-FC39-435c-BC89-4D3614DA2F0B}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "signerreq": "false",
    "edsi": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0K",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMg
            a2V5LCB1c2luZyBSU0ExXzUgcGFkZGluZw"
        }
      ],
      "iv": "ySGmfZ69YlcEilNr5_SGbA",
      "ciphertext":
        "c2FtcGxlIGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZW
        NpcGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGxlIGF1dGhlbnRpdY2F0aW9uIHRhZw"
    }
  }
}

```

The TEE signs "GetDeviceTEESStateTBSResponse" and returns it to the OTrP Agent. The OTrP Agent encodes "GetDeviceTEESStateResponse" into an array to form "GetDeviceStateResponse".

```

{
  "GetDeviceStateResponse": [
    {
      "GetDeviceTEEStateResponse": {
        "payload":
          "ewogICJHZXREZXZpY2VURUVTdGF0ZVRUCU1Jlc3Bvb3N1IjogewogICAgInZlciI6
          ICiXlJjAiLAogICAgInN0YXRlcyI6ICJwYXNzIiwKICAgICJyaWQiOiAiAiezhDNkY5
          REJCLUZDMzktNDMlYy1CQzg5LTREMzYxNERBMkYwQn0iLAogICAgInRpZCI6ICJ7
          NEY0NTRBN0YtMDAyRC00MTU3LTg4NEUtQjBERDFBMDZBOEFFfSIsCgkic2lnbmVy
          cmVxIjoiZmFsc2UiLAogICAgImVkc2kiOiB7CiAgICAgICJwcm90ZWN0ZWQioiAi
          ZXlKbGJtTWlPaUpCTVRJNFewSkRMVWhUTWpVMkluMESiLAogICAgICAicmVjaXBp
          ZW50cyI6IFsKICAgICAgICB7CiAgICAgICAgICAiaGVhZGVyIjogewogICAgICAg
          ICAgImFsZyI6ICJSU0ExXzUiCiAgICAgICAgfSwKICAgICAgICAiZW5jcnldGVk
          X2tleSI6CiAgICAgICAgIogogICAgICAgIFFVlRNVEk0SUNoRFJvc3BJR3RsZVN3
          ZlpXNWpjbmx3ZEdWa01lZHBkR2dnVkdZOTklGS1RRU0J3ZFdkc2FXTWcKICAgICAg
          ICBhMlY1TENCMWMybHVaeUJTVTBFeFh6VWdjR0ZrWkdsdVp3IogogICAgICAgIH0K
          ICAgICAgXSwwKICAgICAgImI2IjogInlTR2lmWjY5WWxjRWlsTnI1X1NHYkeiLAog
          ICAgICAiY2lwaGVydGV4dCI6CiAgICAgICIKICAgICAgYzJGdGNHeGxJRlJ6YVNC
          allYUmhJRlZlWTNKNWNIUmxaQ0IzYVhSb0lFRkZVekV5T0NCclpYa2dabkp2YlNC
          eVpXCI6ICAgICAgIE5wY0dsbGJuUnpMbVZlWTNKNWNIUmxaRjlyWlhrIiwKICAgICAg
          InRhZyI6ICJjMkZ0Y0d4bElHRjFkR2hsYm5ScFkyRjBhVzllSUhSaFp3IogogICAg
          fQogIH0KfQ",
        "protected": "eyJhbGciOiJSUzI1NiJ9",
        "signature": "c2FtcGx1IHNPZ25hdHVyZQ"
      }
    ]
  }
}

```

The TEE returns "GetDeviceStateResponse" back to the OTrP Agent, which returns message back to the TAM.

A.1.2. Sample CreateSD

A.1.2.1. Sample CreateSDRequest

```

{
  "CreateSDTBSRequest": {
    "ver": "1.0",
    "rid": "req-01",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": "false",
    "dsihash": "Iu-c0-fGrpMmzbbtiWI1U8u7wMJE7IK8wkJpsVuf2js",
    "content": {
      "spid": "bank.com",
      "sdname": "sd.bank.com",
      "spcert": "MIIDFjCCAn-
gAwIBAgIJAIk0Tat0tquDMA0GCSqGSIb3DQEBBQUAMGwxCzAJBgNVBAYTAkTAMQ4wD
AYDVQQIDAVTZW91bDESMBAGA1UEBwwJR3Vyby1kb25nMRAwDgYDVQQKDAdTb2xhY21l
hMRAwDgYDVQQLDAdTb2xhY21hMRUwEwYDVQQDDAxTb2xhLWNpYS5jb20wHhcNMTUwN
zAyMDglMTU3WhcNMjAwNjMwMDglMTU3WjBsMQswCQYDVQQGEwJLUjEOMAwGA1UECAw
FU2VvdWwxejAQBgNVBAcMCUdlcm8tZG9uZzZlEQMA4GA1UECgwHU29sYWNpYTEQMA4GA
1UECwwHU29sYWNpYTEVMBMGAlUEAwMU29sYS1jaWEuY29tMIGfMA0GCSqGSIb3DQE
BAQUAAAGNADCBiQKBgQDYWLRFF2OFMEciwSYsyhaLY4kslaWcXA0hCWJRaFzt5mU-
lpSJ4jeu92inBbsXcI8PfRbaItsgWlTD1Wg4gQH4MX_YtaBoOepE--
3JoZZyPyCWS3AaLYWrDmqFXdbza01i8GxB7zz0gWw55bZ9jyzcl5gQzWSqMRpx_dca
d2SP2wIDAQABO4G_MIG8MIGGBgNVHSMefzB9oXCkbjBsMQswCQYDVQQGEwJLUjEOMA
wGA1UECAwFU2VvdWwxejAQBgNVBAcMCUdlcm8tZG9uZzZlEQMA4GA1UECgwHU29sYWNp
YTEQMA4GA1UECwwHU29sYWNpYTEVMBMGAlUEAwMU29sYS1jaWEuY29tgGkAiTRNq3
S2q4MwCQYDVDR0TBAIwADAQBgNVHQ8BAf8EBAMCBsAwFgYDVDR0LAQH_BAwwCgYIKwYB
BQUHAWMwDQYJKoZIhvcNAQEFBQADgYEAfMhRwEQ-
LDa9O7P1N0mcLORpo6fW3QuJfuXbRQRQGoXddXMKazI4VjbGaXhey7Bzvk6TZYDa-
GRiZby1J47UPaDQR3UiDzVvXwCOU6S5yUhNJSw_BeMViYj4lssX28iPpNwLUCVm1QV
THILI6afLCRWXXclcl1L5KGY290OwIdQ",
      "tamid": "TAM_x.acme.com",
      "did": "zAHkb0-Sqh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}

```

Below is a sample message after the content is encrypted and encoded

```

{
  "CreateSDRequest": {
    "payload": "
eyJDcmVhdGVTRFRFCU1JlcXVlc3QiOnsidmVyIjojMS4wIiwicmlkIjoicmVxLTAxIiwidG
lkIjojdHJhbi0wMSIsInRlZSI6IlNlY3VyYVFRFRSIsIm5leHRkc2kiOiJmYWxzZSIsImRz
aWhhc2giOiIyMmVmOWNkM2U3YzZhZTkzMjZjZGI2ZWQ4OTYyMzU1M2NiYmJjMGM5NDRLYz
gyYmNmMjQyNjliMTViOWZkYTNiIiwuY29udGVudCI6eyJwcm90ZWNOZWQiOiJlLUtBbkdw
dVktS0FuVHJpZ0p4Qk1USTRRMEpETFVoVElqVTI0b0NkZlEiLCJyZWNPcGllbnRzIjpbey
JoZWFKZXIiOnsiYXNpIjojUlNBMV81In0sImVuY3J5cHRlZF9rZXkiOiJTuZE2NTl4Q2FJ
cldUeUlsVTZPLUVsZzU4UUhvTlpCekxVRGptVG9vanBaWE54TVpBakRMcWtaSTdEUzhOVG
FIWHcxczFvZjgydVhsM0d6NlVWMkRoZDJ3R2l6Y2VEDGtXclRwZDg4QVYwaWpEYTNXa3lk

```

dEpSVmlPOGdkSlEtV29NSUVJRUXzVGthblZCb25wQkF4ZHE0ckVMbl9TZl1iaFg4Zm9ub2
gxUVUifV0sIm12IjoiQXhZOEERDdERhR2xzYkdsamIzUm9aUSIsImNpcGhlcnRleHQiOiI1
bmVWZXdm55UXprR3hZeWw5QlFrZTJVNjVaOHp4NDdlb3NzM3FETy0xY2FfNEpFY3NLcj
ZhNjF5QzBUb0doYnJOQWJXbVRSemMwsXB5bTF0ZjdGemp4UlhbATZBYnVSM2gzSUPRS1Bj
UUVvRUlkZ2tWX0NaZTM2eTBkVDBpRFBMc1g0QzFkb0dmMEDvaWViRC1yVUglVUteY3BsTW
91tjZvUnFyd0dnNUhxLTJXM3B4MULzY0h4SktRZml1dkYxMTJ4ajBmZFNZX0N2WFE1NTJr
TVRDUW1ZbzRPaGF2R0ZvaG9TZVNaGZSVG1LYWp3OThkTzdhdREdrUEpRU1BtYVHVH1lEMW
JXd01nMXFRV3RPd19EZ1IyZDNzTzVUN0pQMDJDUfprVXBiQ3dZYVcybW9HN1c2Z1c2U3V5
Q2lpd2pQWmZSQmIzSktTVTFtd1kxYXZvdW02OWctaDB6by12TGZvbHRRWFV2LVdPTXZTY0
JzR25NRzZYnMzbXlTWnJlWTNRR09wVVRzdjFCQ0JqSTJpdjkw2U2aXFCcVpxQVBxbzdi
ajYwVlJGQzZPT1NLZEXGQTIyU3pqRHOldmtntXNEaHkwSzlDeVhYN1Z6MkNLTXJvQjNiUE
xZFZ9abtZuVWlktFN5cVJ5cXJxTmVnN1lmQng3aV93X0dzRW9rX1VYZd6RGtneHp6RjZj
XzZ6S0s3UFktVnVmYUo0Z2dHZmlpOHEwMm9RZ1VEZTB2Vm1FWDc0c2VQX2RxakVpZVVOYm
xBZE9sS2dBWlFGdEs4dy1xVUMzSzVGTjRoUG9yDeC2b3lPVUpOQTVFZV2Qy1jR2tMcTNQ
UG1GRmQyaUtOTELCTEJzVWl6c1h3RERvZVA5SmktWGt5ZEQtREN1SHdpCno0OEDNNWVLSj
Q5WVdqRUTfQko2T01NNUNmZH4cDNmVG1uUTdfTXcwZ3FZVDRiOUJJSnBfWjA3TTctNUpE
emg0czhyU3dsQzFXU3V2RmhRWlJCcXJtX2RaUlRiB0VaZldXc1VCSWVNWWdxNG1zb0JqTj
NXSzhnRWYwZGI5a3Z6UG9LYmpJRy10UUE2R2l1X3pHaFVfLXFBV1lLemVKMDZ6djRIWlBO
dHktQXRyTGF0WGhtUTdOQlVrX0hvbjdOUWxhUlglZHVNVmN4bGs1ZHVrWfZNMDgxa09wYV
kzbdliQVffYVhTM0FNAffTTTVsT3dnTDZJazFPYVpaTGFMUE3eJlITnLESmFEWTVhakZK
TWFdV1lfoG94YlNoQUktNXA2MmNuT0xzV0dNWNKTLBGVTZpcWlMR19oc3JfNlNKMURhbd
VtQ0YycnBJLUIitMlhuckxZR01ZS0NEZ2V2dGFnbilDVUV6RURwR3ozQ2VLcWdQU0Vqd3BK
NOM3NXduYtlCSmtTUkpOdNla3hoWELrcnNEazRHVVpMSDdQYzFYZHdRTXhxdWpZnmXJSV
EycjMlNWEtVkotWHdPcFpfY3RPdW96LTA4WHdYQ3RkTEliSFFVTG40RjLMRTtanU0dUxS
bjNSc043WWZ1S3dCVmVEZDJ6R3NBY0s5SV1Da3hOaDk3dDluYW1iMDZqSXVoWXXF5QkhwRU
9nTkhicilrMDY1bW9OVk5lVVUyMm5OdVNKS0ZxVnIxT0dKNGVfNXkzYkNwTmxTeEFPV1Bn
RnJzU0Flc2JJOWw4eVJtVTAwenJYdGc4OWt5SjlCcXN2eXA1RE8wX2FtS1JyMXB1MVJVWF
lFZzB2ampKS1FSdDVZbXRUNFJzaWpzdGRDWDG3UUxJaUdSY0hDdlJzUzZSdDJESmNYR1ht
UGQyc0ZmNUZyNnJnMkFzX3BmUHN3cnF1WlAxbVFLc3RPMFVktXpqMTlyb2N1NHVxVX1HUD
lWWU54cHVnWVdNSjRYbldRelJtWGNTUEJ4VETnenFPS2s3UnRzWWVMNX14LVM4NjV0cHVz
dTA0bXpzYUJRZ21od1ZFVXBRdWNrcG1YWkNLNLH1JUXktaHNFQUlJSmVxdFB3dVAYsXF0X2
I5dlk0bzExeXdzExhzdmp2RnKN0VVZU1MaGE2R2dSanBSbnU5RWIzRn1JZ0U5M0VVNEEW
T0lUMWlOSGNRYWc0ewtOc3dPdKxQbjZIZ21zQ05ESlgwekc2RlFDMTZRdjBSQ25SVTdfV2
VvblhSTUZWUzZRZ1JiSk45R1NMckN5bklJSWxUCDBxNHBaS05zm0tqQ2tMuzJrb3Bhd2Y0
WF9BU1lmTko3a0s5eW5BR0dCcKtnUWJNRWVxUEFmMDBKMLYtVXpuU1JMzmQ4SGs3Y2JEdk
5RQlhHQW9BR0ViaGRwVUC0RXFwMlVyQko3dEtyUUVSR1h4RTVsOFNHY2czQ1RmN2Zoazdx
VEFBVjVsWEFNOUtoUDF1clZRZklfUlBleHfNTG9WQVVKV2syQkF6WF9uSEhkVvVhaSVBIOG
hLeDctdEFRV0dTWUd0R2FmanZJZzI2c082TzloQWZVd3BpSV90MzF6SkZORDU0OTZURHBz
QmNnd2dMLU1UcVhCRUJ2NEhvQld5SG1DVjVFMUwiLCJ0YWciOiJkbXlEeWZJVlNjU1Ren
ExOEgybFRlEEMxbl9HZEtrdnZNMDJUCdHsYzQwIn19fQ",
"protected": "e-KAnGFsZ-KAnTrigJxSUZi1NuKAnX0", //RSAwithSHA256
"header": {
 "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
 "signer": "
 MIIC3zCCAkigAwIBAgIJAJf2fFkE1BYOMA0GCSqGSIB3DQEBBQUAMF0xZAJBgNVBA
 YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxpZm9ybmlhMSEw
 HwYDVQQKBHJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
 cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcml5p

```

    YTETMBEGA1UEBwwKQ2FsaWZvcms5pYTEhMB8GA1UECgwYSW50ZXJuZXQvZ2lkZ2l0cyBQdHkgTHRkMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC8ZtxMlbYickpgSVG-meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA6b_ZI3c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGpMHQGA1UdIwRtMtGuhXqRcMFoxCzAJBgNVBAYTAlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEwHwYDVQQKBHJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGSCCQCX9nxZBNQWDjAJBgNVHRMEAjaAMA4GA1UdDwEB_wQEAWIGwDAWBgnVHVSUBaf8EDDAKBggrBgEFBQcDAzANBgkqhkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8GSZlMdyIZV8fwdEmD90IvtMHgtzK-9wo6Aibj_rVlpxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYAUbFyfrdT5GjjqLlnqh3a_Y3QPscuCjg"
  },
  "signature": "nuQUscTEBLEarZuwd7q1lPIYEJ2eJfur05sT5Y-N03zFRcvljvrqMhtx_pw0Y9YWjmpoWfpfelhwGEko9SgeeBnznmkZbp7kjs6MmX4CKz90Ape3-VI7yL9Yp0WNdRh3425eYfuapCy3lcXFlN5JBAUnU_OzUg3RWxcU_yGnFsw"
}
}

```

A.1.2.2. Sample CreateSDResponse

```
{
  "CreateSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-01",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM",
      "sdname": "sd.bank.com",
      "teespaik": "AQABjY9KiW3hkMmSAAN6CLXot525U85WNlWKAQz5TOdfe_CM8h-
X6_EHXlgOXoyRXaBiKMqWb0YZLCABTWlytdXy2kWa525imRho8Vqn6HDGsJDZPDru9
GnZR8pZX5ge_dWXB_uljMvDttc5iAWEJ8ZgcpLGtBTGLZnQoQbjtnl1IE",
    }
  }
}
```

Below is the response message after the content is encrypted and encoded.

```
{
  "CreateSDResponse": {
    "payload": "eyJJdcmVhdGVTRFRFCU1JlczBvbnNlIjpb7InZlcieiI6IjEuMCIsInN0YXR1cyI6InBhc3MiLCJyaWQiOiJyZXEtMDEiLCJ0aWQiOiJ0c0FmLTAxIiwiaWY29udGVudCI6eyJwcm90ZWNOZWQioiJlLUTtBbkdwVktS0FuVHJpZ0p0qk1USTRRMEpETFVoVElqbTl0b0NkZlEiLCJyZWNPcGllbnRzIjpbeyJoZWZkZXIIOnsiYXNjaWoiUlNBMV81In0sImVuY3J5cHRlZF9r
```



```

ZXkiOiJOX0I4R3pldUlfN2hwd0wwTFpHSTkxVWVBbmXJRkJfcndmZUlyZERrWnFGakls
Vvhjdli0XzhhOGhyeFI4SXR3aEtFZnVfRWVLRDBQb0dqQ2pCSHcxG1ULUN6eWhsbW5v
Slk3LXl1WnZzRkRpc2VNTkd0eGE0OGZJYUs2VWx5NUZMYXBCZVc5TlI5bmktOU9GQV9j
afVuWWl3b2Q4ZTJFa0Vpd0JEZlEzMk0ifV0sImI2IjoiQXhZOERDdERhR2xzYkdsamIz
Um9aUSIsImNpcGhlcnRleHQiOiJsalh6Wk5JTmRlWjFaMXJHVElktjBiVUp1RDRVV2xT
QVptLWd6YnJINFVDYy1jMEFQenMtMwDWSFk4NTRUR3VMYkdyRmVHcDFqM2Fsb1lacWZp
ZnE4aEt3Ty16RF1BN2tmVFhBZHp6czM4em9xeG4zbHoyM2w1RU1GUWWhrOHBRWTRYTHRW
M3ZBQWlnYnlrQ1Q3VS1CWDdWcjbacVNhYWZTQVZ4OFBLQ1RIU3hHN3hHVko0NkxxRzJS
RE54WXQ4RC1SQ3lZUilzRTM0MUFKZldEc2FLaGRRbzJXcjNVN1hTOWFqaXJtWjdqTlJ4
cVRodHJBRWl1Y1ctOEJMdVFHWEZlYUhlMTZrenJKUGl4d0VXbzJ4cmw4cmkwc3ZRCmpl
Z2M3MET2Z0I0NUVaNHZiNXR0YlUya25hN185QU1Wcm4wLUJaQ1Bnb280Mw1FblhuNVJn
TXY2c2V2Y1JPQ2xHMnpWSjFoRkVLYjk2akeiLCJ0YWciOiIzOTZISTk4Uk1NQnR0eDlo
ZUtsODROaVZld0lJSzI0UET2ZlRGYzFrbeJzIn19fQ",
"protected": "e-KANGFsZ-KANTrigJxSUzIlNuKAnX0",
"header": {
  "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
  "signer": "
    MIIC3zCCAkigAwIBAgIJAJf2fFkE1BYOMA0GCSqGSIb3DQEBBQUAMF0xCzAJ
    BgNVBAYTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
    Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGQwHhcN
    MTUwNzAyMDkwMTE4WhcNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzET
    MBEGA1UECAwKQ2FsaWZvcml5pYtETMBEGA1UEBwwKQ2FsaWZvcml5pYtEhMB8G
    A1UECgwYSW50ZXJuZXQgV2lkZ2l0cyBQdHkgTHRkMIGfMA0GCSqGSIb3DQEB
    AQUAA4GNADCBiQKBgQC8ZtxMlbYickpgSVG-
    meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
    AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA
    6b_ZI3c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
    ivhfJ4a6T20EtMM5qwIDAQAB04GsMIGpMHQGA1UdIwRtMGUhxQRCmF0xCzAJ
    BgNVBAYTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
    Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGSCCQCX
    9nxZBNQWDjAJBgNVHRMEAjAAMA4GA1UdDwEB_wQEAWIGwDAWBgNVHSUBAf8E
    DDAKBggrBgEFBQcDAzANBgkqhkiG9w0BAQUFAA0BgQAGkz9QpoxghZUWT4iv
    em4cIckfxzTBBiPHCjrrjB2X8Ktn8GSZlMdyIZV8fwdEmD90IvtMHgtzK-
    9wo6Aibj_rVIpxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fv
    rJvnYAUBFyfrdT5GjqLlnqh3a_Y3QPscuCjg"
  },
  "signature": "jnJtaB0vFFwrE-qKOR3Pu9pf2gNoIls67GgPCTq0U-
qrz97svKpuh32WgCP2MwCoQPEswsEX-nxhIx_siTe4zIP0lnBYn-
R7b25rQaF8708uAOOnBN5Yl2Jk3laIbs-
hGE32aRZDhrVoyEdSvIFrT6AQqD20bIAZGqTR-zA-900"
}
}

```

A.1.3. Sample UpdateSD

A.1.3.1. Sample UpdateSDRequest

```

{
  "UpdateSDTBSRequest": {
    "ver": "1.0",
    "rid": "1222DA7D-8993-41A4-AC02-8A2807B31A3A",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "tee": "Primary TEE ABC",
    "nextdsi": "false",
    "dsi": "IsOvwpzDk8Onw4bCrskTJsONwrbDrcKJYjVTw4vCu8OAw4JEw6zCgsK8w4JCacKxW8Kf
w5o7",
    "content": { // NEEDS to BE ENCRYPTED
      "tamid": "id1.TAMxyz.com",
      "spid": "com.acmebank.spid1",
      "sdname": "com.acmebank.sdname1",
      "changes": {
        "newsdname": "com.acmebank.sdname2",
        "newsid": "com.acquirer.spid1",
        "spcert":
          "MIIDFjCCAn-
          gAwIBAgIJAik0Tat0tquDMA0GCSqGSIb3DQEBAQUAMGwxCzAJBgNVBAYTAkTAMQ4
          wDAYDVQQIDAVTZW91bDESMBAGAlUEBwwJR3Vyby1kb25nMRAwDgYDVQQKDAdTb2x
          hY2lhMRAwDgYDVQQQLDAdTb2xhY2lhMRUwEwYDVQQDDAxTb2xhLWNpYS5jb20wHhc
          NMTUwNzAyMDg1MTU3WhcNMjAwNjMwMDg1MTU3WjBzMQswCQYDVQQGEWJLUjEOMAw
          GA1UECAwFU2VvdWwxEjAQBGNVBACMCUd1cm8tZG9uZzEQMA4GA1UECgwHU29sYWN
          pYTEQMA4GA1UECwwHU29sYWNpYTEVMBMGAlUEAwMU29sYS1jaWEuY29tMIGfMA0
          GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQDYWLrFf2OFMEciwSYsyhaLY4kslaWcXA0
          hCWJRaFzt5mU-
          lpSJ4jeu92inBbsXci8PfrBaItsgWlTD1Wg4gQH4MX_YtaBoOepE--
          3JoZZyPyCWS3AaLYWrDmqFXdbzaOli8GxB7zz0gWw55bZ9jyzcl5gQzWSqMRpx_d
          cad2SP2wIDAQABO4G_MIG8MIGGBgNVHSMefzB9oXCkbjBzMQswCQYDVQQGEWJLUj
          EOMAwGA1UECAwFU2VvdWwxEjAQBGNVBACMCUd1cm8tZG9uZzEQMA4GA1UECgwHU2
          9sYWNpYTEQMA4GA1UECwwHU29sYWNpYTEVMBMGAlUEAwMU29sYS1jaWEuY29tgg
          kAiTRNq3S2q4MwCQYDVROTBAlwADA0BgNVHQ8BAf8EBAMCBsAwFgYDVROlAQH_BA
          wwCgYIKwYBBQUHAWMwDQYJKoZIhvcNAQEFBQADgYEAfMhRwEQ-
          LDa907P1N0mcLORpo6fW3QuJfuXbRQRQGoXddXMKazI4VjbGaXhey7Bzvk6TZYDa
          -
          GRiZbylJ47UPaDQR3UiDzVvXwCOU6S5yUhNJsw_BeMViYj4lssX28iPpNwLUCVm1
          QVTHILI6afLCRWXXclclL5KGY2900wIdQ",
        "renewteespaik": "0"
      }
    }
  }
}

```

A.1.3.2. Sample UpdateSDResponse

```
{
  "UpdateSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "1222DA7D-8993-41A4-AC02-8A2807B31A3A",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "content": {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
      "teespaik":
        "AQABjY9KiWH3hkMmSAAN6CLXot525U85WNlWKAQz5TOdfe_CM8h-
        X6_EHX1gOXoyRXaBiKMqWb0YZLCABTwlytdXy2kWa525imRho8Vqn6HDGsJDZPDru9
        GnZR8pZX5ge_dWXB_uljMvDttc5iAWEJ8ZgcpLGtBTGLZnQoQbjtnllIE",
      "teespaiktype": "RSA"
    }
  }
}
```

A.1.4. Sample DeleteSD

A.1.4.1. Sample DeleteSDRequest

The TAM builds message - including data to be encrypted.

```
{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "tee": "Primary TEE",
    "nextdsi": "false",
    "dsihash": "AAECAwQFBgcICQoLDA0ODwABAgMEBQYHCAkKCwwNDg8=",
    "content": ENCRYPTED {
      "tamid": "TAM1.com",
      "sdname": "default.acmebank.com",
      "deleteta": "1"
    }
  }
}
```

The TAM encrypts the "content".

```

{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "tee": "Primary TEE",
    "nextdsi": "false",
    "dsihash": "AAECAwQFBgcICQoLDA0ODwABAgMEBQYHCAkKCwwNDg8=",
    "content": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMga2V5LCBlc2luZyBSU0ExXzUgcGFkZGluZw"
        }
      ],
      "iv": "rW05DVmQX9ogelMLBIogIA",
      "ciphertext":
        "c2FtcGx1IGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZWNPcGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGx1IGF1dGhlbnRpY2F0aW9uIHRhZw"
    }
  }
}

```

The TAM signs the "DeleteSDTBSRequest" to form a "DeleteSDRequest"

```

{
  "DeleteSDRequest": {
    "payload": "
ewoJIKRlbgV0ZVNEVEJtUmVxdWVzdCI6IHsKCQkidmVyIjogIjEuMCIsCgkJInJp
ZCI6ICJ7NzEyNTUxRjUtREZCMY00M2YwLTlBNjMtNjYzNDQwQjKxRDQ5fSIsCgkJ
InRpZCI6ICJ7NEY0NTRBN0YtMDAyRC00MTU3LTg4NEUtQjBERDFBMDZBOEFFfSIs
CgkJInRlZSI6ICJQcm1tYXJ5IFRFRSIsCgkJIm5leHRkc2kiOiAiZmFsc2UiLAoJ
CSJkc2loYXNoIjogIkFBRUNBdlFGQmdjSUNRb0xEQTBPRHdBQkFnTUVCUVlIQ0Fr
SON3d05EZzg9IiwKCQkiY29udGVudCI6IHsKCQkKJInByb3RlY3RlZCI6ICJleUps
YmlNaU9pSkJNVEk0UTBKRExVaFRNaUySW4wIiwKCQkKJInJlY2lwaWVudHMiOiBb
ewoJCQkKJImh1YWRlcii6IHsKCQkKJCQkiYWxnIjogIlJTQTFFfNSIKCQkKJCX0sCgkJ
CQkiZW5jcnlwdGVkX2tleSI6ICJRVVZUTVRJNElDaERSVXNwSud0bGVtd2daVzVq
Y25sd2RHVmtJSGRwZEbnZlZGtK5JRkpUUVNCd2RXSnNhV0lnYTJWNWUxQjFjMmx1
WnlCUlUwRXhYelVnY0dGalpHbHVadyIKCQkKJfV0sCgkJCSJpdii6ICJyV081RFZt
UVg5b2dlbE1MQklvZ0lBIiwKCQkKJImNpcGhlcnRleHQiOiAiYzJGdGNHeGxJRlJ6
YVNCa1lYUmhJRlZlWTNKNWNIUmxaQ0IzYVhSb0lFRkZVekV5T0NCclpYa2dabkp2
YlNCeVpXTnBjR2xsYm5SekxtVnVZM0o1Y0hSbFpGOXJaWGsilaAoJCQkidGFniJog
ImMyRnRjR3hsSudGMWRHaGxiblJwWTJGMGFXXOXVJSFJoWnciCgkJfQoJfQp9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "x5c": [ "ZXhhbXBsZSBBU04xIHNPZ25lcjBjZXJ0aWZpY2F0ZQ==",
        "ZXhhbXBsZSBBU04xIENBIGNlcnRpZmljYXRl" ]
    },
    "signature": "c2FtcGx1IHNPZ25hdHVyZQ"
  }
}

```

A.1.4.2. Sample DeleteSDResponse

The TEE creates a "DeleteSDTBSResponse" to respond to the "DeleteSDRequest" message from the TAM, including data to be encrypted.

```

{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "content": ENCRYPTED {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
    }
  }
}

```

The TEE encrypts the "content" for the TAM.

```

{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "content": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0K",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMg
            a2V5LCB1c2luZyBSU0ExXzUgcGFkZGluZW"
        }
      ],
      "iv": "ySGmfZ69YlcEilNr5_SGbA",
      "ciphertext":
        "c2FtcGxlIGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZW
        NpcGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGxlIGFldGhlbnRpY2F0aW9uIHRhZW"
    }
  }
}

```

The TEE signs "DeleteSDTBSResponse" to form a "DeleteSDResponse"

```

{
  "DeleteSDResponse": {
    "payload": "
ewoJlKrlbGV0ZVNEVEJlUmVzcG9uc2UiOiB7CgkJInZlciI6IClXlJlAilAoJCSJz
dGF0dXMiOiAicGFzcyIsCgkJInJpZCI6ICJ7NzEyNTUxRjUtREZCMY00M2YwLTlB
NjMtNjYzNDQwQjkxRDQ5fSIsCgkJInRpZCI6ICJ7NEY0NTRBN0YtMDAyRC00MTU3
LTg4NEUtQjBERDFBMDZBOEFFfSIsCgkJImNvbnRlbnQiOiB7CgkJCSJwcm90ZWNO
ZWQiOiAiZXlKbGJtTWlPaUpCTVRJNFewSkRMVWhUTWpVMkluMEsiLAoJCQkicmVj
aXBpZW50cyI6IFt7CgkJCQkiaGVhZGVyIjogewoJCQkJCSJhbGciOiAiUlNBMV81
IgoJCQkJfSwKCQkJCSJlbnNyeXB0ZWRfa2V5IjogIlFVVlRNVEk0SUNoRFJvc3BJ
R3RsZVN3ZlpxNWpjbmx3ZEdWa0lIZHBkR2dnVkJOTklGS1RRU0J3ZFdkc2FXTWdh
MlY1TENCMWMybHVaeUJTVTBFeFh6VWdjR0ZrWkdsdVp3IgoJCQl9XSswKCQkJIml2
IjogInlTR2lmWjY5WWxjRWlsTnIlX1NHYkEiLAoJCQkiY2lwaGVydGV4dCI6ICJj
MkZ0Y0d4bElHUUnphU0JrWVhSaElHVnVZM0o1Y0hSbFpDQjNhWFJvSUVGRlV6RXlP
Q0JyWlhrZlpuSnZiU0J5WldOcGNHbGxib1J6TG1WdVksSjVjSFJsWkY5clpYayIs
CgkJCSJ0YWciOiAiYzJGdGNHeGxJR0YxZEdobGJuUnBZMkYwYVc5dUliUmhadyIK
CQl9Cgl9Cn0",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "signature": "c2FtcGxlIHNPZ25hdHVyZQ"
  }
}

```

The TEE returns "DeleteSDResponse" back to the OTrP Agent, which returns the message back to the TAM.

A.2. Sample TA Management Messages

A.2.1. Sample InstallTA

A.2.1.1. Sample InstallTAResponse

```

{
  "InstallTATBSRequest": {
    "ver": "1.0",
    "rid": "24BEB059-0AED-42A6-A381-817DFB7A1207",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "tee": "Primary TEE ABC",
    "nextdsi": "true",
    "dsihash":
    "
    IsOvwpzDk8Onw4bCrskTJsONwrbDrcKJYjVTw4vCu80Aw4JEw6zCgsK8w4JCacKxW8Kf
    w5o7",
    "content": {
      "tamid": "idl.TAMxyz.com",
      "spid": "com.acmebank.spid1",
      "sdname": "com.acmebank.sdname1",
      "taid": "com.acmebank.taid.banking"
    },
    "encrypted_ta": {
      "key":
      "mLBjodce4j36y64nC/nEs694P3XrLAOokjisXIGfs0H7lOEmT5FtaNDYEMcg9RnE
      ftlJGHO7N0lgcNcjoXBmeuY9VI8xzrsZM9gzH6VBKtVONSx0aw5IAFkNcyPZwDdZ
      MLwhvrzPJ9Fg+bZtrCoJz18PUz+5aNI/dj8+NM85LCXXcBlZF74btJer1Mw6ffzT
      /grPieQTeJlnEm9F3tyRsvCTInsnPJ3dEXv7sJXMrhRKAeZsqKzGX4eiZ3rEY+FQ
      6nXULC8cAj5XTKpQ/EkZ/iGgS0zcXR7KUJv3wFEmtBtPD/+ze08NILLmxM8olQFj
      //Lq0gGtq8vPC8r0oOfmbQ==",
      "iv": "4F5472504973426F726E496E32303135",
      "alg": "AESCBC",
      "ciphertadata":
      ".....0x/5KGCXWfglVrjm7zPVZqtYZ2EovBow+7EmfOJl1tbk.....=",
      "cipherpdata": "0x/5KGCXWfglVrjm7zPVZqtYZ2EovBow+7EmfOJl1tbk="
    }
  }
}

```

A.2.1.2. Sample InstallTAResponse

A sample to-be-signed response of InstallTA looks as follows.

```

{
  "InstallTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "24BEB059-0AED-42A6-A381-817DFB7A1207",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "content": {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
      "dsi": {
        "tfwdata": {

```



```

    "tbs": "ezRGNDU0QTdGLTAwMkQtNDE1Ny04ODRFLUIwREQxQTA2QThBRX0="
    "cert": "ZXhhbXBsZSBGVyBjZXJ0aWZpY2F0ZQ==",
    "sigalg": "U1MyNTY=",
    "sig": "c2FtcGx1IEZXIHNPZ25hdHVyZQ=="
  },
  "tee": {
    "name": "Primary TEE",
    "ver": "1.0",
    "cert": "c2FtcGx1IFRFRSBjZXJ0aWZpY2F0ZQ==",
    "cacert": [
      "c2FtcGx1IENBIGNlcnRpZmljYXRlIDE=",
      "c2FtcGx1IENBIGNlcnRpZmljYXRlIDI="
    ],
    "sdlist": {
      "cnt": "1",
      "sd": [
        {
          "name": "com.acmebank.sdname1",
          "spid": "com.acmebank.spid1",
          "talist": [
            {
              "taid": "com.acmebank.taid.banking",
              "taname": "Acme secure banking app"
            },
            {
              "taid": "acom.acmebank.taid.loyalty.rewards",
              "taname": "Acme loyalty rewards app"
            }
          ]
        }
      ]
    }
  },
  "teeaiklist": [
    {
      "spaik":
        "c2FtcGx1IEFTTjEgZW5jb2RlZCBQS0NTMSBwdWJsaWNrZXk=",
      "spaiktype": "RSA",
      "spid": "acmebank.com"
    }
  ]
}

```

A.2.2. Sample UpdateTA

A.2.2.1. Sample UpdateTAResponse

```

{
  "UpdateTATBSRequest": {
    "ver": "1.0",
    "rid": "req-2",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": " false",
    "dsihash": "gwjul_9MZks3pqUSN1-eLlaVivGXNAxk0AIKW79dn4U",
    "content": {
      "tamid": "TAM1.acme.com",
      "spid": "bank.com",
      "sdname": "sd.bank.com",
      "taid": "sd.bank.com.ta"
    },
    "encrypted_ta": {
      "key":
        "
        XzmAn_RDV3IozMwNWhiB6fmZlIs1YUvMKlQAv_UDoZ1fvGGsRGo9bT0A440aYMgLt
        GilKypoJjCgiJdaHgamaJgRSc4Je2otpnEEagsahvDNoarMCC5nGQdkRxW7Vo2NKG
        L892HGeHkJVshYmlcUlFQ-BhiJ4NAykFwlqC_oc",
      "iv": "AxY8DCtDaGlsbGljb3RoZQ",
      "alg": "AESCBC",
      "ciphernewtadata":
        "KHqOxGn7ib1F_14PG4_UX9DBjOcWkiaZzhVE-U-
        67NsKryHGokeWr2sprWfdU2KWaaNncHoYGwEtBCH7XyNbOFh28nzwUmstep4nHWbAl
        XZYTnKENCABPpuw_G3I3HADo"
    }
  }
}

{
  "UpdateTAResponse": {
    "payload":
      "
      eyJVCGRhdGVUQVRCU1JlcXVlc3QiOmsidmVyIjojMS4wIiwicmlkIjoicmVxLTiiLCJ0
      aWQiOiJ0cmFuLTAxIiwidGVlIjojU2VjdXJpVEVFIiwibmV4dGRzaSI6ImZhbHN1Iiw
      iZHNpaGFzaCI6Imd3anVsXzlnNWmtz3BxVVNOMSl1TDFhVml3R1h0QXhrMEFJS1c3O
      WRuNFUiLCJjb250ZW50Ijp7InByb3RlY3RlZCI6ImV5SmxibUlpT2lKQk1USTRRME
      pETFVoVE1qVTJJbjAiLCJyZWNPcGlbnRzIjpbeyJoZWZkZXIiOmsiYWxnIjojU1N
      BMV81In0sImVuY3J5cHRlZGF9rZXkiOiJYem1Bbl9SRFZrM0lvek13TldoaUI2Zml
      abElzMVlVdk1LbFFBdl9VRG9aMWZ2R0dzUkdvOWJUMEE0NDBhWUlnTHRHaWxLeXB
      vSmpDZ2lqZGFIZ2FtYUlnU1NjNEplMm90cG5FRWFnc2FodkROb2FyTUNDNW5HUW
      RrUnhXN1ZvMk5LZ0xBODkySEdlSGtKVnNoWW0xY1VsRlEtQmhpSjROQXlrRndsc
      UNfb2MifV0sIm12IjojQXhZOERDdERhR2xzYkdsamIzUm9aUSIsImNpcGhlcnRl
      eHQiOiJiYTcwVXRZVetWQmtXRFJuMi0w
      "
    }
  }
}

```

```

SF9IdkZtazl5SGtoVV91bk1OLWc1T3BqLWF1NGFUb21xWklMYzVzYtDENnZZSjF6eW04
QWlJOEJIVXFqc2l5Z0tOcClHdURJUjFzRXc0a2NhMVQ5ZENuU0RydHhSUfhesVdrZmt3
azZlRlNQWiIsInRhZyI6Im9UN01UTE41eWtBTfBoTDR0aUh6T1pPTGVFeU9xZ0NWaEM5
MxpkclMU0UifSwiZW5jcnlwdGVkX3RhIjp7ImtleSI6Ilh6bUFuX1JEVmszSW96TXdO
V2hpQjZmbVpsSXMxWV2TUtsUUF2X1VEbloxZnZHR3NSR285YlQwQTQ0MGFZTWdMdEdp
bEt5cG9KakNnaWpkYUhnYWlhSmdSU2M0SmUyb3RwbkVfYWdzYWw2RE5vYXJNQ0M1bkdR
ZGtSeFc3Vm8yTktnTEE4OTJIR2Vla0pWc2hZbTFjVWxGUS1CaGlKNE5BeWtGd2xxQ19v
YyIsIm12IjoIQXhZOEERddERhR2xzYkdsamIzUm9aUSIsImFsZyI6IkFFU0NCQyIsImNp
cGhlcm5ld3RhZGF0YSI6IktIcU94R243aWlXr18xNFBHNF9VWDlEQmpPY1draUFaaFZF
LVUtNjdOc0tyeUhHb2tlV3Iyc3BSV2ZkVTJLV2FhTm5jSG9ZR3dFdGJDSDDYeU5iT0Zo
MjhuendVbXN0ZXh0bkhXYkFsfWFpZVE5rRU5jQUJQcHV3X0czSTNIQURvIn19fQ",
"protected": " eyJhbGciOiJSUzI1NiJ9",
"header": {
  "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
  "signer": "
MIIC3zCCAkigAwIBAgIJAjF2fFkE1BYOMA0GCSqGSIb3DQEBAQUAMF0xCzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcm5p
YTETMBEGA1UEBwwKQ2FsaWZvcm5pYTEhMB8GA1UECgwYSW50ZXJuZXQgV2lkZ2l0cy
BQdHkgTHRkMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYmCI6bgp094h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGPMHQA1UdIwRtMGUhxqRcMF0xCzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGSCCQX9nxZBNQWDjAJBgNVHR
MEAjAAMA4GA1UdDwEB_wQEAwIGwDAWBgNVHSUBAf8EDDAKBggrBgEFBQcDAZANBgkq
hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
SZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVIpXGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
UBFyfrdT5GjqLlnqH3a_Y3QPscuCjg"
},
"signature": "inB1K6G3EAhF-
FbID83UI25R5Ao8MI4qfrbrmf0UQhjM3O7_g3l6XxN_JkHrGQaZr-
myOkGPVM8BzbUZW5GqxNZwFXwMeaoCjDKc4Apv4WZkd1qKJxkg1k5jaUCfJz1Jmw_XtX
6MHhrLh9ov03S9Ptut1VAQ0FVUB3qFivjSnNU"
}
}

```

A.2.2.2. Sample UpdateTAResponse

```
{
  "UpdateTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-2",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}
```

```

{
  "UpdateTAResponse": {
    "payload": "
eyJVcGRhdGVUQVRCU1Jlc3BvbmlIjp7InZlciI6IjEuMCIsInN0YXR1cyI6InBhc3Mi
LCJyaWQiOiJyZXEtMiIsInRpZCI6InRyYW4tMDEiLCJjb250ZW50Ijp7InByb3RlY3Rl
ZCI6ImV5SmxibUlpT2lkQk1USTRRMEpETFVoVElqVTJJbjAiLCJyZWNPcGllbnRzIjpb
eyJoZWFKZlZlIiOnsiYWxnIjoilUlNBMV81In0sImVuY3J5cHRlZF9rZXkiOiJFaGUxLUJB
UUDJLTNEMFNHdXFGY01MZDJtd0gxQmluRndYQWx1M1FxFVFXZlRRVm55SUowNFc2MnBK
YWVSREFkeTU0R0FSVjBrVzQ0RGw0MkdUUlhhqBE1EZ3BYdXdlLWloc1JVV0tNNldcZ2N3
VXVGQTRUR3gwU01lNTZCd192dnBNAfdMXh2c2FHdFBAQmwxTnZjbXNlbzBhY3FobXlu
bzBDTmF5SVAtX1UifV0sIm12IjoilQXhZOERDdERhR2xzYkdsamIzUm9aUSIsImNpcGhl
cnRleHQiOiJwc2o2dGtyaGJXM0lmVELMeE9GMU5HdFUtTFmeVBidV9KWk9jbklzcWIw
eTNPOHN6OTItaWpWR1ZyRW5WbGlsY1FYeWFNZTNyX1JGdEkwV3B4UmRodyIsInRhZyI6
Ik0zb2dNNk11MVJYMUMybEZvaG5rTkN5b25qNjd2TDNqd2RrZXhFdUlpaTgifXl9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
      "signer": "
MIIC3zCCAkigAwIBAgIJAJf2ffkE1BYOMA0GCSqGSIB3DQEBBQUAMF0xCzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcmlldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcm5p
YTETMBEGA1UEBwwKQ2FsaWZvcm5pYTEhMB8GA1UECgwYSW50ZXJuZXQgV2lkZ2l0cy
BQdHkgTHRkMIGfMA0GCSqGSIB3DQEBAAUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgpO94h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQAB04GSMIGpMHQGA1UdIwRtMGUhxQRCmF0xCzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcmlldCBXaWRnaXRzIFB0eSBMdGSCCQX9nxZBNQWdjAJBgNVHR
MEAjAAMA4GA1UdDwEB_wQEAwIGwDAWBgNVHSUBAf8EDDAKBgggBgEFBQcDAZANBgkq
hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
SZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVipxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
UBFyfrdT5GjqLlnqh3a_Y3QPscuCjg"
    },
    "signature": "
TwaJmt_BBLIMcNrDsJqr8lI7O7lEQxXZNhlUOtFkOMMqf37wOPKtp_99LoS82CVmdpCo
PLaws8zzh-SNIQ42-
9GYO8_9BaEGCiCwy18YgWP9fWNfNv2gR2f12DK4uknkYu1EMBW4YfP81n_pGpb4Gm-
nMk14grVZygaPej3ZZk"
  }
}

```

A.2.3. Sample DeleteTA

A.2.3.1. Sample DeleteTAResponse

```
{
  "DeleteTATBSRequest": {
    "ver": "1.0",
    "rid": "req-2",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": "false",
    "dsihash": "gwjul_9MZks3pqUSN1-eLlaViwGXNAxk0AIKW79dn4U",
    "content": {
      "tamid": "TAM1.acme.com",
      "sdname": "sd.bank.com",
      "taid": "sd.bank.com.ta"
    }
  }
}
```

```

{
  "DeleteTARrequest": {
    "payload":
      "
      eyJEZWXldGVUQVRCU1JlcXVlc3QiOmsidmVyIjojMS4wIiwicmlkIjoicmVxLTIIlCJ0
      aWQiOiJ0cmFuLTaxIiwidGVlIjojU2VjdXJpVEVFIiwibmV4dGRzaSI6ImZhbHNlIiw
      iZHNpaGFzaCI6Imd3anVsXzlnNWmtzM3BxVVNOMS1lTDFhVml3R1hOQXhrMEFJS1c3OWRu
      NFUiLCJjb250ZW50Ijp7InByb3RlY3RlZCI6eyJlbnMiOiJBMTI4Q0JDLUhtMTJ2In0s
      InJlY2lwaWVudHMiOlt7ImhlyYWRLciI6eyJhbGciOiJSU0ExXzUifSwiZW5jcmlwdGVk
      X2tleSI6ImtyaGs0d2dpY0RlX3d0VXQyTW4tSUJsdUtvX0JkeXpNY2plcVlBenBPyRS
      TG9MZzQ0QkFLN2tRVWE1YTg0TEVJRGEzaHNTWDIxdlNzFJLczN4MTJsOUh5VFdfLUNS
      WmZtcUx2bEhlLV9MSVdvc1ZyRTZVMlJqUnRndl1VOWliUkVLCzkzRDRHWM4xVHFuZG9n
      d0tXRf9jdGlnWG1sbzZZVXpCWDZlRldZMCJ9XSwiaXYiOiJBefk4REN0RGFhbHNiR2xq
      YjNSblpRIiwiY2lwaGVydGV4dCI6IkhkNzBVdFlUS1ZCaldeUm4yLTBIX1BGa19yQnpQ
      dGJHdzSNkltMXotdklNeFBSY0Nxa1puZmwyTjRjUTZPSTZCShZJUUFoM2Jic0l0dHlR
      bXhDTE5Nbms8weJBrYm9TdkIyVXlxWEspeGVZIIiwidGFniJoidEtUbFRLdlR2LTrtVVLG
      YldYWnZMMVlhQnRGNloxVlNxoTMzVmI2UEpmcyJ9fx0",
    "protected" : "eyJhbGciOiJSUzI1NiJ9",
    "header" : {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
      "signer": "
      MIIC3zCCAkigAwIBAgIJAjF2fFkE1BYOMA0GCSqGSIb3DQEBAQUAMF0xCzAJBgNVBA
      YTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
      HwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
      cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcmlu
      YTEtMBEGA1UEBwwKQ2FsaWZvcmluYTEtMBEGA1UECgwYSW50ZXJuZXQvZ2lkZ2l0cy
      BQdHkgTHRkMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
      meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
      AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgpO94h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
      c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
      ivhfJ4a6T20EtMM5qwIDAQABO4GsMIGpMHQGA1UdIwRtMGUhxqRcMF0xCzAJBgNVBA
      YTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
      HwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGSCCQCX9nxZBNQWdjAJBgNVHR
      MEAjaAAMA4GA1UdDwEB_wQEAwIGwDAWBgNVHSUBaf8EDDAKBggrBgEFBQcDANBgkq
      hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
      SZlMdyIZV8fwdEmD90IvtMHgtzK-
      9wo6Aibj_rVipxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
      UBfyfrdT5GjqLlnqH3a_Y3QPscuCjg"
    },
    "signature" :
      "
      BZS0_Ab6pqvGNXe5lqT4Sc3jakyWQeiK9KlVSnimWwnjCCyMtyB9bwwvlbILZba3IjFe
      _3F9bIQpSytGS0f2TQrPTK7pSjwDw-3kh7HkHcPPJd-
      PpMMfQvRx7AIV8vBqO9MijIC62iN0V2se5z2v8VFjGSORGgq225w7FvrnWE"
    }
  }
}

```

A.2.3.2. Sample DeleteTAResponse

```
{
  "DeleteTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-2",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}
```



```
{
  "DeleteTAResponse": {
    "payload": "
ew0KCSJEZwXldGVUQVRCU1Jlc3Bvb3N1Ijogew0KCQkidmVyIjogIjEuMCIsDQoJCSJz
dGF0dXMiOiAicGFzc3VzYyIsDQoJCSJyaWQiOiAicmVxLTl1LA0KCQkidG1kIjogInRyYW4t
MDEiLA0KCQkiY29udGVudCI6IHsNCgkKJCSJwcm90ZWN0ZWQoOnsiZw5jiIjoIjQTEyOENC
QyliUzIiNiJ9LA0KCQkKJInJlY2lwaWVudHMiOlsNCgkKJCQl7DQoJCQkKJCSJoZWFKZXXIi
OnsiYWxiIjoIjU1NBMV81In0sDQoJCQkKJCSJlbnNyeXB0ZWRFa2V5IjoiTXdtU1ZHaWU2
eHpfQmxTaFlmTFRKRHhKT3oyNWwhvYy1HZ2NEM2o5OWFyM2E4X2lYY182ZE44bFRtBldD
X19wZEFhaEMyWk5SakdIcTBCZ2JDYTRKalk0eXRkMVbVWDB6M1psbXl1YnRXM29leEpY
el9PMZglWGM4S3hySndjbElyZGx2WUY2OVZmeERLQkVzUHJCdzlVenVla1VmSU4xWlFU
bWZ0QmVaSlJnIg0KCQkKJCX0NCgkKJCVC0sDQoJCQkiaXYiOiJBeFk4REN0RGFhbnNiR2xq
YjNSblpRIiwNCgkKJCSJjaXB0ZXJ0ZXh0IjoiamhQTlV5ZkFtel9rVV9GbEM2LUtCME0l
WDBHNE5MbHc0LWt0bERYajZTWlUteUp6eUFUbCl0Y0ZBWWmWlXJMVEF4cf93N1d1WER0
Y3N3S3zJSSzRjcWciLA0KCQkKJInRhZyI6IlBBeGo5N25oT29qVTNIREhxSl14MGZMNWpt
b0xkTlJkTHRtAMiZUTdrYXciDQoJCX0NCgl9DQp9" ,
    "protected": "eyJhbGciOiJSUzI1NiJ9" ,
    "header": {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d" ,
      "signer": "
MIIC3zCCAkigAwIBAgIJAjf2fFkE1BYOMA0GCSqGSIb3DQEBAQUAMF0xChAJ
BgNVBAYTALVTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxp
Zm9ybmlhMSEwHwYDVQKDBHJbnRlc5ldCBXaWRnaXRzIFB0eSBMdGQwHhcN
MTUwNzAyMDkwMTE4W4cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQGEwJVUzET
MBEGA1UECAwKQ2FsaWZvc5pYETETMBEGA1UEBwwKQ2FsaWZvc5pYETehMB8G
A1UECgwYSW50ZXJuZXQgV2lkZ210cyBqdHkgTHRkMIGfMA0GCSqGSIb3DQEB
AQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA
6b_ZI3c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGPMHQGA1UdIwRtMGUhxQRCmF0xChAJ
BgNVBAYTALVTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxp
Zm9ybmlhMSEwHwYDVQKDBHJbnRlc5ldCBXaWRnaXRzIFB0eSBMdGSCCQCX
9nxZBNQWDjAJBgNVHRMEAjaAAMA4GA1UdDwEB_wQEAWIGwDAWBgNVH5SUBAf8E
DDAKBggrBgEFBQcDZANBgkqhkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4iv
em4cIckfxzTBBiPHCjrrjB2X8Ktn8GSZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVIpXGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fV
rJvnYAUBFyfrdT5GjqLlnqH3a_Y3QPscuCjg"
    } ,
    "signature": "
DfoBOetNelKsnAe_m4Z9K5UbihgWNYZsp5jVybiI05sOagDzv6R4do9npaAlAvpNK8HJ
Cx6D6D22J8GDUExlIhSR1aDuDCQm6QzmjdfdxAz5TRYl6zpPCZqgStoN_g1TZxqxEv6V
Ob5fies4g6MHvCH-Il_-KbHq5YpwGxEEDfg"
  }
}
```

A.3. Example OTrP Agent Option

The most popular TEE devices today are Android powered devices. In an Android device, an OTrP Agent can be a bound service with a service registration ID that a Client Application can use. This option allows a Client Application not to depend on any OTrP Agent SDK or provider.

An OTrP Agent is responsible to detect and work with more than one TEE if a device has more than one. In this version, there is only one active TEE such that an OTrP Agent only needs to handle the active TEE.

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The Open Trust Protocol (OTrP)
draft-ietf-teep-opentrustprotocol-03.txt

Abstract

This document specifies the Open Trust Protocol (OTrP), a protocol that follows the Trust Execution Environment Provisioning (TEEP) architecture and provides a message protocol that provisions and manages Trusted Applications into a device with a Trusted Execution Environment (TEE).

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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 TEE implementations. Different application providers or device administrators may choose to use different TAM providers. There calls for an interoperable protocol for managing TAs running in different TEEs of various devices is needed.

The Trusted Execution Environment Provisioning (TEEP) architecture document [TEEPArch] has set to provide a design guidance for such an interoperable protocol. This document specifies an Open Trust Protocol (OTrP) that follows the architecture guidance.

OTrP defines a mutual trust message protocol between a TAM and a TEE and relies on IETF-defined end-to-end security mechanisms, namely JSON Web Encryption (JWE), JSON Web Signature (JWS), and JSON Web Key (JWK). Other message encoding methods may be supported.

This specification defines message payloads exchanged between devices and a TAM. The messages are designed in anticipation of the use of the most common transport methods such as HTTPS.

Each TA binary and configuration data can be from either of two sources:

1. A TAM supplies the signed and encrypted TA binary and any required configuration data
2. A Client Application supplies the TA binary

This specification considers the first case where TA binary and configuration data are encrypted by recipient's public key that TAM

has to be involved. The second case will also be addressed separately.

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].

3. Terminology

3.1. Definitions

The definitions provided below are defined as used in this document. All the terms defined in the TEEP Architecture document [TEEPArch] will be used, which are not repeated in this document.

OTrP Broker: It is the Broker as defined in the TEEP Architecture document [TEEPArch].

3.2. Abbreviations

| | |
|------|-------------------------------|
| CA | Certificate Authority |
| OTrP | Open Trust Protocol |
| REE | Rich Execution Environment |
| SD | Security Domain |
| SP | Service Provider |
| TA | Trusted Application |
| TEE | Trusted Execution Environment |
| TFW | Trusted Firmware |
| TAM | Trusted Application Manager |

4. OTrP Entities and Trust Model

4.1. System Components

The same system components as defined in the TEEP Architecture document [TEEPArch] are used in OTrP, including TAM, CA, TEE, REE, and OTrP Broker (a.k.a Broker).

Secure boot (for the purposes of OTrP) is optional in enabling authenticity checking of TEEs by the TAM. A TAM provider can choose its policy whether it trusts a TEE if the underlying firmware attestation information is not included.

OTrP uses trust anchors to establish trust between TEEs and TAMs and verifies that they communicate in a trusted way when performing lifecycle management transactions.

4.2. Trust Anchors in TEE

This assumes the Trust Anchor specification defined in the TEEP Architecture document [TEEPArch].

Each TEE comes with a trust store that contains a whitelist of root CA certificates that are used to validate a TAM's certificate. A TEE will accept a TAM to create new Security Domains and install new TAs on behalf of a SP only if the TAM's certificate is chained to one of the root CA certificates in the TEE's trust store.

4.3. Trust Anchors in TAM

The Trust Anchor set in a TAM consists of a list of Certificate Authority certificates that signs various device TEE certificates. A TAM decides what TEE and optionally TFW it will trust when TFW signature data is present in an attestation.

4.4. Keys and Certificate Types

OTrP leverages the following list of trust anchors and identities in generating signed and encrypted command messages that are exchanged between a device's TEE and a TAM. With these security artifacts, OTrP Messages are able to deliver end-to-end security without relying on any transport security.

| Key Entity Name | Location | Issuer | Trust Implication | Cardinality |
|---------------------------------|-----------------------|------------------------|--|------------------------------------|
| 1. TFW key pair and certificate | Device secure storage | FW CA | A whitelist of FW root CA trusted by TAMs | 1 per device |
| 2. TEE key pair and certificate | Device TEE | TEE CA under a root CA | A whitelist of TEE root CA trusted by TAMs | 1 per device |
| 3. TAM key pair and certificate | TAM provider | TAM CA under a root CA | A whitelist of TAM root CA embedded in TEE | 1 or multiple can be used by a TAM |
| 4. SP key pair and certificate | SP | SP signer CA | TAM manages SP. TA trust is delegated to TAM. TEE trusts TAM to ensure that a TA is trustworthy. | 1 or multiple can be used by a TAM |

Table 1: Key and Certificate Types

1. TFW key pair and certificate: A key pair and certificate for evidence of trustworthy firmware in a device. This key pair is optional. Some TEE may present its trusted attributes to a TAM using signed attestation with a TFW key. For example, a platform that uses a hardware based TEE can have attestation data signed by a hardware protected TFW key.

Location: Device secure storage

Supported Key Type: RSA and ECC

Issuer: OEM CA

Trust Implication: A whitelist of FW root CA trusted by TAMs

Cardinality: One per device

2. TEE key pair and certificate: It is used for device attestation to a remote TAM and SP.

This key pair is burned into the device at device manufacturer. The key pair and its certificate are valid for the expected lifetime of the device.

Location: Device TEE

Supported Key Type: RSA and ECC

Issuer: A CA that chains to a TEE root CA

Trust Implication: A whitelist of TEE root CA trusted by TAMs

Cardinality: One per device

3. TAM key pair and certificate: A TAM provider acquires a certificate from a CA that a TEE trusts.

Location: TAM provider

Supported Key Type: RSA and ECC.

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: TAM CA that chains to a root CA

Trust Implication: A whitelist of TAM root CA embedded in TEE

Cardinality: One or multiple can be used by a TAM

4. SP key pair and certificate: an SP uses its own key pair and certificate to sign a TA.

Location: SP

Supported Key Type: RSA and ECC

Supported Key Size: RSA 2048-bit, ECC P-256 and P-384. Other sizes should be anticipated in future.

Issuer: an SP signer CA that chains to a root CA

Trust Implication: TAM manages SP. TA trusts an SP by validating trust against a TAM that the SP uses. A TEE trusts TAM to ensure that a TA from the TAM is trustworthy.

Cardinality: One or multiple can be used by an SP

5. Protocol Scope and Entity Relations

This document specifies messages and key properties that can establish mutual trust between a TEE and a TAM. The protocol provides specifications for the following three entities:

1. Key and certificate types required for device firmware, TEEs, TAs, SPs, and TAMs
2. Data message formats that should be exchanged between a TEE in a device and a TAM
3. An OTrP Broker in the REE that can relay messages between a Client Application and TEE

Figure 1: Protocol Scope and Entity Relationship

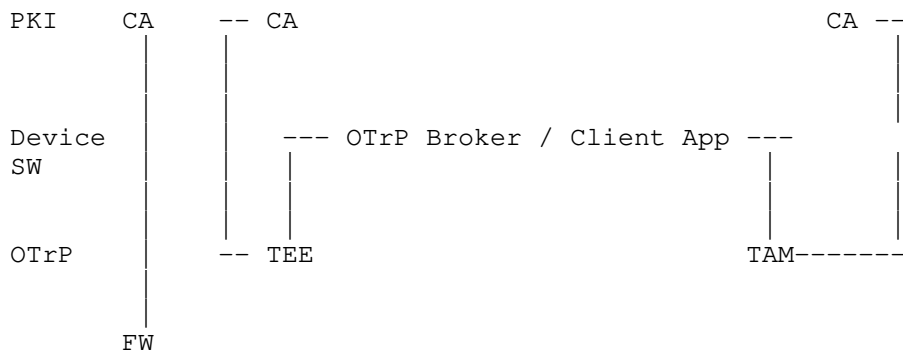
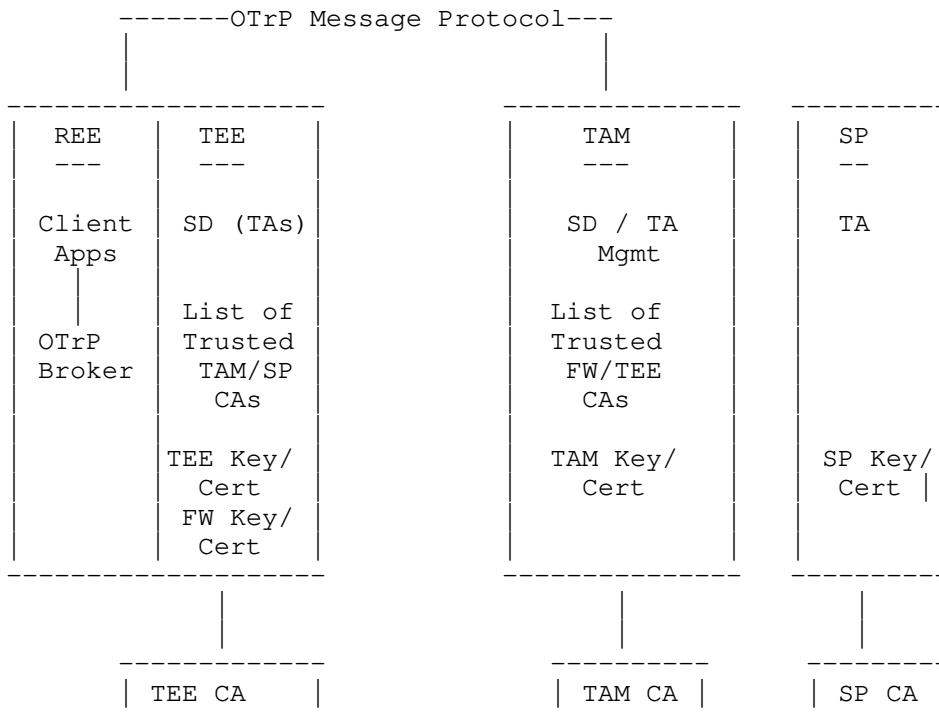


Figure 2: OTrP System Diagram



In the previous diagram, different Certificate Authorities can be used respectively for different types of certificates. OTrP Messages are always signed, where the signer keys is the message creator's private key such as a FW's private key, a TEE's private key, or a TAM's private key.

The main OTrP component consists of a set of standard JSON messages created by a TAM to deliver device SD and TA management commands to a device, and device attestation and response messages created by a TEE that responds to a TAM's OTrP message.

The communication method of OTrP Messages between a TAM and TEE in a device may vary between TAM and TEE providers. A mandatory transport protocol is specified for a compliant TAM and a device TEE.

An OTrP Broker is used to bridge communication between a TAM and a TEE. The OTrP Broker doesn't need to know the actual content of OTrP Messages except for the TEE routing information.

5.1. A Sample Device Setup Flow

Step 1: Prepare Images for Devices

1. [TEE vendor] Deliver TEE Image (CODE Binary) to device OEM
2. [CA] Deliver root CA Whitelist
3. [Soc] Deliver TFW Image

Step 2: Inject Key Pairs and Images to Devices

1. [OEM] Generate Secure Boot Key Pair (May be shared among multiple devices)
2. [OEM] Flash signed TFW Image and signed TEE Image onto devices (signed by Secure Boot Key)

Step 3: Setup attestation key pairs in devices

1. [OEM] Flash TFW Public Key and a bootloader key.
2. [TFW/TEE] Generate a unique attestation key pair and get a certificate for the device.

Step 4: Setup trust anchors in devices

1. [TFW/TEE] Store the key and certificate encrypted with the eFuse key
2. [TEE vendor or OEM] Store trusted CA certificate list into devices

5.2. Derived Keys in The Protocol

The protocol generates one key pair in run time to assist message communication and anonymous verification between a TAM and a TEE.

TEE SP Anonymous Key (AIK): one derived key pair per SP in a device

The purpose of the key pair is to sign data by a TEE without using its TEE device key for anonymous attestation to a Client Application. This key pair is generated in the first SD creation for an SP. It is deleted when all SDs are removed for a SP in a device. The public key of the key pair is given to the caller Client Application and TAM for future TEE returned data validation. The public key of this AIK is also used by a TAM to encrypt TA binary data and personalization data when it sends a TA to a device for installation.

5.3. Security Domain Hierarchy and Ownership

The primary job of a TAM is to help an SP to manage its trusted application components. A TA is typically installed in an SD. An SD is commonly created for an SP.

When an SP delegates its SD and TA management to a TAM, an SD is created on behalf of a TAM in a TEE and the owner of the SD is assigned to the TAM. An SD may be associated with an SP but the TAM has full privilege to manage the SD for the SP.

Each SD for an SP is associated with only one TAM. When an SP changes TAM, a new SP SD must be created to associate with the new TAM. The TEE will maintain a registry of TAM ID and SP SD ID mapping.

From an SD ownership perspective, the SD tree is flat and there is only one level. An SD is associated with its owner. It is up to TEE implementation how it maintains SD binding information for a TAM and different SPs under the same TAM.

It is an important decision in this protocol specification that a TEE doesn't need to know whether a TAM is authorized to manage the SD for an SP. This authorization is implicitly triggered by an SP Client Application, which instructs what TAM it wants to use. An SD is always associated with a TAM in addition to its SP ID. A rogue TAM isn't able to do anything on an unauthorized SP's SD managed by another TAM.

Since a TAM may support multiple SPs, sharing the same SD name for different SPs creates a dependency in deleting an SD. An SD can be deleted only after all TAs associated with this SD is deleted. An SP cannot delete a Security Domain on its own with a TAM if a TAM decides to introduce such sharing. There are cases where multiple virtual SPs belong to the same organization, and a TAM chooses to use the same SD name for those SPs. This is totally up to the TAM implementation and out of scope of this specification.

5.4. SD Owner Identification and TAM Certificate Requirements

There is a need of cryptographically binding proof about the owner of an SD in a device. When an SD is created on behalf of a TAM, a future request from the TAM must present itself as a way that the TEE can verify it is the true owner. The certificate itself cannot reliably be used as the owner because TAM may change its certificate.

To this end, each TAM will be associated with a trusted identifier defined as an attribute in the TAM certificate. This field is kept

the same when the TAM renew its certificates. A TAM CA is responsible to vet the requested TAM attribute value.

This identifier value must not collide among different TAM providers, and one TAM shouldn't be able to claim the identifier used by another TAM provider.

The certificate extension name to carry the identifier can initially use SubjectAltName:registeredID. A dedicated new extension name may be registered later.

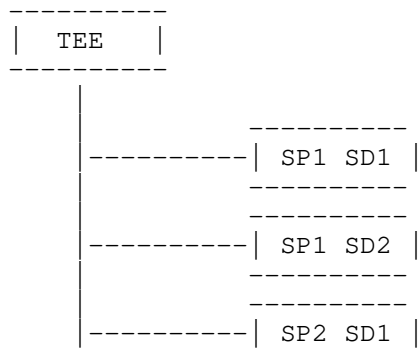
One common choice of the identifier value is the TAM's service URL. A CA can verify the domain ownership of the URL with the TAM in the certificate enrollment process.

A TEE can assign this certificate attribute value as the TAM owner ID for the SDs that are created for the TAM.

An alternative way to represent an SD ownership by a TAM is to have a unique secret key upon SD creation such that only the creator TAM is able to produce a Proof-of-Possession (POP) data with the secret.

5.5. Service Provider Container

A sample Security Domain hierarchy for the TEE is shown below.



OTrP segregates SDs and TAs such that a TAM can only manage or retrieve data for SDs and TAs that it previously created for the SPs it represents.

6. OTrP Broker

A TEE and TAs that run inside the TEE don't generally have capability to communicate to the outside of the hosting device, for example, the TEE specified by Global Platform groups [GPTEE]. This calls for a software module in the REE world to handle the network communication. Each Client Application in REE may carry this communication functionality but it must also interact with the TEE for the message exchange. The TEE interaction will vary according to different TEEs. In order for a Client Application to transparently support different TEEs, it is imperative to have a common interface for a Client Application to invoke for exchanging messages with TEEs.

A shared OTrP Broker comes to meet this need. An OTrP Broker is a Rich Application or SDK that facilitates communication between a TAM and TEE. It also provides interfaces for TAM SDK or Client Applications to query and trigger TA installation that the application needs to use.

This interface for Client Applications may be commonly an Android service call for an Android powered device. A Client Application interacts with a TAM, and turns around to pass messages received from TAM to OTrP Broker.

In all cases, a Client Application needs to be able to identify an OTrP Broker that it can use.

6.1. Role of OTrP Broker

An OTrP Broker abstracts the message exchanges with the TEE in a device. The input data is originated from a TAM that a Client Application connects. A Client Application may also directly call OTrP Broker for some TA query functions.

OTrP Broker may internally process a request from TAM. At least, it needs to know where to route a message, e.g. TEE instance. It doesn't need to process or verify message content.

OTrP Broker returns TEE / TFW generated response messages to the caller. OTrP Broker isn't expected to handle any network connection with an application or TAM.

OTrP Broker only needs to return an OTrP Broker error message if the TEE is not reachable for some reason. Other errors are represented as response messages returned from the TEE which will then be passed to the TAM.

6.2. OTrP Broker and Global Platform TEE Client API

A Client Application may use Global Platform (GP) TEE API for TA communication. OTrP may use the GP TEE Client API but it is internal to OTrP implementation that converts given messages from TAM. More details can be found at [GPTEECLAPI].

6.3. OTrP Broker Implementation Consideration

A Provider should consider methods of distribution, scope and concurrency on device and runtime options when implementing an OTrP Broker. Several non-exhaustive options are discussed below. Providers are encouraged to take advantage of the latest communication and platform capabilities to offer the best user experience.

6.3.1. OTrP Broker Distribution

OTrP Broker installation is commonly carried out at OEM time. A user can dynamically download and install an OTrPBroker on-demand.

It is important to ensure a legitimate OTrP Broker is installed and used. If an OTrP Broker is compromised it may send rogue messages to TAM and TEE and introduce additional risks.

6.3.2. Number of OTrP Broker

We anticipate only one shared OTrP Broker instance in a device. The device's TEE vendor will most probably supply one OTrP Broker. Potentially we expect some open source.

With one shared OTrP Broker, the OTrP Broker provider is responsible to allow multiple TAMs and TEE providers to achieve interoperability. With a standard OTrP Broker interface, TAM can implement its own SDK for its SP Client Applications to work with this OTrP Broker.

Multiple independent OTrP Broker providers can be used as long as they have standard interface to a Client Application or TAM SDK. Only one OTrP Broker is expected in a device.

TAM providers are generally expected to provide SDK for SP applications to interact with an OTrP Broker for the TAM and TEE interaction.

6.4. OTrP Broker Interfaces for Client Applications

A Client Application shall be responsible for relaying messages between the OTrP Broker and the TAM.

If a failure occurs during calling OTrP Broker, an error message described in "Common Errors" section (see Section 7.6) will be returned.

6.4.1. ProcessOTrPMessage call

Description

A Client Application will use this method of the OTrP Broker in a device to pass OTrP messages from a TAM. The method is responsible for interacting with the TEE and for forwarding the input message to the TEE. It also returns TEE generated response message back to the Client Application.

Inputs:

TAMInMsg - OTrP message generated in a TAM that is passed to this method from a Client Application.

Outputs:

A TEE-generated OTrP response message (which may be a successful response or be a response message containing an error raised within the TEE) for the client application to forward to the TAM. In the event of the OTrP Broker not being able to communicate with the TEE, a OTrPBrokerException shall be thrown.

6.4.2. GetTAInformation call

Description

A Client Application may quickly query local TEE about a previously installed TA without requiring TAM each time if it has had the TA's identifier and previously saved TEE SP AIK public key for TA information integrity verification.

Inputs:

```
{
  "TAQuery": {
    "spid": "<SP identifier value of the TA>",
    "taid": "<The identifier value of the TA>"
  }
}
```

Outputs:

The OTrP Broker is expected to return TA signer and TAM signer certificate along with other metadata information about the TA associated with the given identifier. It follows the underlying TEE trust model for authoring the local TA query from a Client Application.

The output is a JSON message that is generated by the TEE. It contains the following information:

- * tamid
- * SP ID
- * TA signer certificate
- * TAM certificate

The message is signed with TEE SP AIK private key.

The Client Application is expected to consume the response as follows.

The Client Application gets signed TA metadata, in particular, the TA signer certificate. It is able to verify that the result is from device by checking signer against TEE SP AIK public key it gets in some earlier interaction with TAM.

If this is a new Client Application in the device that hasn't had TEE SP AIK public key for the response verification, the application can contact the TAM first to do GetDeviceState, and TAM will return TEE SP AIK public key to the app for this operation to proceed.

Output Message:

```

{
  "TAInformationTBS": {
    "taid": "<TA Identifier from the input>",
    "tamid": "<TAM ID for the Security Domain where this TA
              resides>",
    "spid": "<The service provider identifier of this TA>",
    "signercert": "<The BASE64 encoded certificate data of the
                  TA binary application's signer certificate>",
    "signercacerts": [ < The full list of CA certificate chain
                        including the root CA>
    ],
    "cacert": "<The BASE64 encoded CA certificate data of the TA
              binary application's signer certificate>"
  ],
  "tamcert": "<The BASE64 encoded certificate data of the TAM
              that manages this TA.>",
  "tamcacerts": [ < The full list of CA certificate chain
                  including the root CA>
  ],
  "cacert": "<The BASE64 encoded CA certificate data of the TAM
            that manages this TA>"
  ]
}
}

{
  "TAInformation": {
    "payload": "<The BASE64URL encoding of the TAInformationTBS
                JSON above>",
    "protected": "<BASE64URL encoded signing algorithm>",
    "header": {
      "signer": { "<JWK definition of the TEE SP AIK public
                  key>" }
    },
    "signature": "<signature contents signed by TEE SP AIK
                  private key BASE64URL encoded>"
  }
}

```

where the definitions of BASE64 and BASE64URL refer to [RFC4648].

A sample JWK public key representation refers to an example in [RFC7517].

6.5. Sample End-to-End Client Application Flow

6.5.1. Case 1: A New Client Application Uses a TA

1. During the Client Application installation time, the Client Application calls TAM to initialize the device preparation step.
 - A. The Client Application knows it wants to use a Trusted Application TA1 but the application doesn't know whether TA1 has been installed or not. It can use GP TEE Client API [GPTEECLAPI] to check the existence of TA1 first. If it detects that TA1 doesn't exist, it will contact TAM to initiate the installation of TA1. Note that TA1 could have been previously installed by other Client Applications from the same service provider in the device.
 - B. The Client Application sends the TAM the TA list that it depends on. The TAM will query a device for the Security Domains and TAs that have been installed, and instructs the device to install any dependent TAs that have not been installed.
 - C. In general, the TAM has the latest TA list and their status in a device because all operations are instructed by TAM. TAM has such visibility because all Security Domain deletion and TA deletion are managed by the TAM; the TAM could have stored the state when a TA is installed, updated and deleted. There is also the possibility that an update command is carried out inside TEE but a response is never received in TAM. There is also possibility that some manual local reset is done in a device that the TAM isn't aware of the changes.
2. The TAM generates message: GetDeviceStateRequest
3. The Client Application passes the JSON message GetDeviceStateRequest to OTrP Broker call ProcessOTrPMessage. The communication between a Client Application and an OTrP Broker is up to the implementation of the OTrP Broker.
4. The OTrP Broker routes the message to the active TEE. Multiple TEE case: it is up to OTrP Broker to figure this out. This specification limits the support to only one active TEE, which is the typical case today.
5. The target active TEE processes the received OTrP message, and returns a JSON message GetDeviceStateResponse.

6. The OTrP Broker passes the GetDeviceStateResponse to the Client Application.
 7. The Client Application sends GetDeviceStateResponse to the TAM.
 8. The TAM processes the GetDeviceStateResponse.
 - A. Extract TEEspaik for the SP, signs TEEspaik with TAM signer key
 - B. Examine SD list and TA list
 9. The TAM continues to carry out other actions based on the need. The next call could be instructing the device to install a dependent TA.
 - A. Assume a dependent TA isn't in the device yet, the TAM may do the following: (1) create an SD in which to install the TA by sending a CreateSDRequest message. The message is sent back to the Client Application, and then the OTrP Broker and TEE to process; (2) install a TA with an InstallTARequest message.
 - B. If a Client Application depends on multiple TAs, the Client Application should expect multiple round trips of the TA installation message exchanges.
 10. At the last TAM and TEE operation, the TAM returns the signed TEE SP AIK public key to the application.
 11. The Client Application stores the TEEspaik for future loaded TA trust check.
 12. If the TAM finds that this is a fresh device that does not have any SD for the SP yet, then the TAM may next create an SD for the SP.
 13. During Client Application installation, the application checks whether required Trusted Applications are already installed, which may have been provided by the TEE. If needed, it will contact its TAM service to determine whether the device is ready or install TA list that this application needs.
- 6.5.2. Case 2: A Previously Installed Client Application Calls a TA
1. The Client Application checks the device readiness: (a) whether it has a TEE; (b) whether it has TA that it depends. It may happen that TAM has removed the TA this application depends on.

2. The Client Application calls the OTrP Broker to query the TA.
3. The OTrP Broker queries the TEE to get TA information. If the given TA doesn't exist, an error is returned.
4. The Client Application parses the TAInformation message.
5. If the TA doesn't exist, the Client Application calls its TAM to install the TA. If the TA exists, the Client Application proceeds to call the TA.

7. OTrP Messages

The main OTrP component is the set of standard JSON messages created by a TAM to deliver device SD and TA management commands to a device, and device attestation and response messages created by TEE to respond to TAM OTrP Messages.

An OTrP Message is designed to provide end-to-end security. It is always signed by its creator. In addition, an OTrP Message is typically encrypted such that only the targeted device TEE or TAM is able to decrypt and view the actual content.

7.1. Message Format

OTrP Messages use the JSON format for JSON's simple readability and moderate data size in comparison with alternative TLV and XML formats. More compact CBOR format may be used as an alternative choice.

JSON Message security has developed JSON Web Signing and JSON Web Encryption standard in the IETF Workgroup JOSE, see JWS [RFC7515] and JWE [RFC7516]. The OTrP Messages in this protocol will leverage the basic JWS and JWE to handle JSON signing and encryption.

7.2. Message Naming Convention

For each TAM command "xyz", OTrP use the following naming convention to represent its raw message content and complete request and response messages:

| Purpose | Message Name | Example |
|-----------------------|----------------|---------------------|
| Request to be signed | xyzTBSRequest | CreateSDTBSRequest |
| Request message | xyzRequest | CreateSDRequest |
| Response to be signed | xyzTBSResponse | CreateSDTBSResponse |
| Response message | xyzResponse | CreateSDResponse |

7.3. Request and Response Message Template

An OTrP Request message uses the following format:

```
{
  "<name>TBSRequest": {
    <request message content>
  }
}
```

A corresponding OTrP Response message will be as follows.

```
{
  "<name>TBSResponse": {
    <response message content>
  }
}
```

7.4. Signed Request and Response Message Structure

A signed request message will generally include only one signature, and uses the flattened JWS JSON Serialization Syntax, see Section 7.2.2 in [RFC7515].

A general JWS object looks like the following.

```
{
  "payload": "<payload contents>",
  "protected": "<integrity-protected header contents>",
  "header": {
    <non-integrity-protected header contents>,
  },
  "signature": "<signature contents>"
}
```

OTrP signed messages only require the signing algorithm as the mandate header in the property "protected". The "non-integrity-protected header contents" is optional.

OTrP signed message will be given an explicit Request or Response property name. In other words, a signed Request or Response uses the following template.

A general JWS object looks like the following.

```
{
  "<name>[Request | Response]": {
    <JWS Message of <name>TBS[Request | Response]
  }
}
```

With the standard JWS message format, a signed OTrP Message looks like the following.

```
{
  "<name>[Request | Response]": {
    "payload": "<payload contents of <name>TBS[Request | Response]>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents>"
  }
}
```

The top element "<name>[Signed][Request|Response]" cannot be fully trusted to match the content because it doesn't participate in the signature generation. However, a recipient can always match it with the value associated with the property "payload". It purely serves to provide a quick reference for reading and method invocation.

Furthermore, most properties in an unsigned OTrP messages are encrypted to provide end-to-end confidentiality. The only OTrP message that isn't encrypted is the initial device query message that asks for the device state information.

Thus a typical OTrP Message consists of an encrypted and then signed JSON message. Some transaction data such as transaction ID and TEE information may need to be exposed to the OTrP Broker for routing purpose. Such information is excluded from JSON encryption. The device's signer certificate itself is encrypted. The overall final message is a standard signed JSON message.

As required by JSW/JWE, those JWE and JWS related elements will be BASE64URL encoded. Other binary data elements specific to the OTrP

specification are BASE64-encoded. This specification indicates elements that should be BASE64 and those elements that are to be BASE64URL encoded.

7.4.1. Identifying Signing and Encryption Keys for JWS/JWE Messaging

JWS and JWE messaging allow various options for identifying the signing and encryption keys, for example, it allows optional elements including "x5c", "x5t" and "kid" in the header to cover various possibilities.

To protect privacy, it is important that the device's certificate is released only to a trusted TAM, and that it is encrypted. The TAM will need to know the device certificate, but untrusted parties must not be able to get the device certificate. All OTrP messaging conversations between a TAM and device begin with `GetDeviceStateRequest` / `GetDeviceStateResponse`. These messages have elements built into them to exchange signing certificates, described in the section Section 9. Any subsequent messages in the conversation that follow on from this implicitly use the same certificates for signing/encryption, and as a result the certificates or references may be omitted in those subsequent messages.

In other words, the signing key identifier in the use of JWS and JWE here may be absent in the subsequent messages after the initial `GetDeviceState` query.

This has an implication on the TEE and TAM implementation: they have to cache the signer certificates for the subsequent message signature validation in the session. It may be easier for a TAM service to cache transaction session information but not so for a TEE in a device. A TAM can get a device's capability by checking the response message from a TEE to decide whether it should include its TAM signer certificate and OCSP data in each subsequent request message. The device's caching capability is reported in `GetDeviceStateResponse` `signerreq` parameter.

7.5. JSON Signing and Encryption Algorithms

The OTrP JSON signing algorithm shall use SHA256 or a stronger hash method with respective key type. JSON Web Algorithm RS256 or ES256 [RFC7518] SHALL be used for RSA with SHA256 and ECDSA with SHA256. If RSA with SHA256 is used, the JSON web algorithm representation is as follows.

```
{"alg": "RS256"}
```

The (BASE64URL encoded) "protected" header property in a signed message looks like the following:

```
"protected": "eyJhbGciOiJSUzI1NiJ9"
```

If ECSDA with P-256 curve and SHA256 are used for signing, the JSON signing algorithm representation is as follows.

```
{"alg": "ES256"}
```

The value for the "protected" field will be the following.

```
eyJhbGciOiJFUzI1NiJ9
```

Thus, a common OTrP signed message with ES256 looks like the following.

```
{
  "payload": "<payload contents>",
  "protected": "eyJhbGciOiJFUzI1NiJ9",
  "signature": "<signature contents>"
}
```

The OTrP JSON message encryption algorithm SHOULD use one of the supported algorithms defined in the later chapter of this document. JSON encryption uses a symmetric key as its "Content Encryption Key (CEK)". This CEK is encrypted or wrapped by a recipient's key. The OTrP recipient typically has an asymmetric key pair. Therefore, the CEK will be encrypted by the recipient's public key.

A compliant implementation shall support the following symmetric encryption algorithm and anticipate future new algorithms.

```
{"enc": "A128CBC-HS256"}
```

This algorithm represents encryption with AES 128 in CBC mode with HMAC SHA 256 for integrity. The value of the property "protected" in a JWE message will be

```
eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

An encrypted JSON message looks like the following.

```
{
  "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
  "recipients": [
    {
      "header": {
        "alg": "<RSA1_5 etc.>"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON plaintext
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

OTrP doesn't use JWE AAD (Additional Authenticated Data) because each message is always signed after the message is encrypted.

7.5.1. Supported JSON Signing Algorithms

The following JSON signature algorithm is mandatory support in the TEE and TAM:

- o RS256

ES256 is optional to support.

7.5.2. Support JSON Encryption Algorithms

The following JSON authenticated encryption algorithm is mandatory support in TEE and TAM.

- o A128CBC-HS256

A256CBC-HS512 is optional to support.

7.5.3. Supported JSON Key Management Algorithms

The following JSON key management algorithm is mandatory support in TEE and TAM.

- o RSA1_5

ECDH-ES+A128KW and ECDH-ES+A256KW are optional to support.

7.6. Common Errors

An OTrP Response message typically needs to report the operation status and error causes if an operation fails. The following JSON message elements should be used across all OTrP Messages.

```
"status": "pass | fail"

"reason": {
  "error-code": "<error code if there is any>",
  "error-message": "<error message>"
}

"ver": "<version string>"
```

7.7. OTrP Message List

The following table lists the OTrP commands and therefore corresponding Request and Response messages defined in this specification. Additional messages may be added in the future when new task messages are needed.

GetDeviceState -

A TAM queries a device's current state with a message GetDeviceStateRequest. A device TEE will report its version, its FW version, and list of all SDs and TAs in the device that is managed by the requesting TAM. TAM may determine whether the device is trustworthy and decide to carry out additional commands according to the response from this query.

CreateSD -

A TAM instructs a device TEE to create an SD for an SP. The recipient TEE will check whether the requesting TAM is trustworthy.

UpdateSD -

A TAM instructs a device TEE to update an existing SD. A typical update need comes from SP certificate change, TAM certificate change and so on. The recipient TEE will verify whether the TAM is trustworthy and owns the SD.

DeleteSD -

A TAM instructs a device TEE to delete an existing SD. A TEE conditionally deletes TAs loaded in the SD according to a request parameter. An SD cannot be deleted until all TAs in this SD are deleted. If this is the last SD for an SP, TEE MAY also delete TEE SP AIK key for this SP.

InstallTA -

A TAM instructs a device to install a TA into an SD for a SP. The TEE in a device will check whether the TAM and TA are trustworthy.

UpdateTA -

A TAM instructs a device to update a TA into an SD for an SP. The change may commonly be bug fix for a previously installed TA.

DeleteTA -

A TAM instructs a device to delete a TA. The TEE in a device will check whether the TAM and TA are trustworthy.

7.8. OTrP Request Message Routing Rules

For each command that a TAM wants to send to a device, the TAM generates a request message. This is typically triggered by a Client Application that uses the TAM. The Client Application initiates contact with the TAM and receives TAM OTrP Request messages according to the TAM's implementation. The Client Application forwards the OTrP message to an OTrP Broker in the device, which in turn sends the message to the active TEE in the device.

The current version of this specification assumes that each device has only one active TEE, and the OTrP Broker is responsible to connect to the active TEE. This is the case today with devices in the market.

When the TEE responds to a request, the OTrP Broker gets the OTrP response messages back to the Client Application that sent the request. In case the target TEE fails to respond to the request, the OTrP Broker will be responsible to generate an error message to reply the Client Application. The Client Application forwards any data it received to its TAM.

7.8.1. SP Anonymous Attestation Key (SP AIK)

When the first new Security Domain is created in a TEE for an SP, a new key pair is generated and associated with this SP. This key pair is used for future device attestation to the service provider instead of using the device's TEE key pair.

8. Transport Protocol Support

The OTrP message exchange between a TEE device and TAM generally takes place between a Client Application in REE and TAM. A device that is capable to run a TEE and PKI based cryptographic attestation

isn't generally resource constraint to carry out standard HTTPS connections. A compliant device and TAM SHOULD support HTTPS.

9. Detailed Messages Specification

For each message in the following sections all JSON elements are mandatory if not explicitly indicated as optional.

9.1. GetDeviceState

This is the first command that a TAM will send to a device. This command is triggered when an SP's Client Application contacts its TAM to check whether the underlying device is ready for TA operations.

This command queries a device's current TEE state. A device TEE will report its version, its FW version, and list of all SDs and TAs in the device that is managed by the requesting TAM. TAM may determine whether the device is trustworthy and decide to carry out additional commands according to the response from this query.

The request message of this command is signed by the TAM. The response message from the TEE is encrypted. A random message encryption key (MK) is generated by TEE, and this encrypted key is encrypted by the TAM's public key such that only the TAM that sent the request is able to decrypt and view the response message.

9.1.1. GetDeviceStateRequest message

```
{
  "GetDeviceStateTBSRequest": {
    "ver": "1.0",
    "rid": "<Unique request ID>",
    "tid": "<transaction ID>",
    "ocspdats": [<a list of OCSP stapling data>],
    "supportedSigalgs": [<array of supported signing algorithms>]
  }
}
```

The request message consists of the following data elements:

ver - version of the message format

rid - a unique request ID generated by the TAM

tid - a unique transaction ID to trace request and response. This can be from a prior transaction's tid field, and can be used in subsequent message exchanges in this TAM session. The combination of rid and tid MUST be made unique.

ocspdat - 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 such that a recipient TEE can validate the TAM certificate chain revocation status without making its own external OCSP service call. A TEE MAY cache the CA OCSP data such that the array may contain only the OCSP stapling data for the TAM certificate in subsequent exchanges. This is a mandatory field.

supportedsigalgs - an optional property to list the signing algorithms that the TAM is able to support. A recipient TEE MUST choose an algorithm in this list to sign its response message if this property is present in a request. If it is absent, the TEE may use any compliant signing algorithm that is listed as mandatory support in this specification.

The final request message is JSON signed message of the above raw JSON data with TAM's certificate.

```
{
  "GetDeviceStateRequest": {
    "payload": "<BASE64URL encoding of the GetDeviceStateTBSRequest
              JSON above>",
    "protected": "<BASE64URL encoded signing algorithm>",
    "header": {
      "x5c": "<BASE64 encoded TAM certificate chain up to the
            root CA certificate>"
    },
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

The signing algorithm SHOULD use SHA256 with respective key type. The mandatory algorithm support is the RSA signing algorithm. The signer header "x5c" is used to include the TAM signer certificate up to the root CA certificate.

9.1.2. Request processing requirements at a TEE

Upon receiving a request message GetDeviceStateRequest at a TEE, the TEE MUST validate a request:

1. Validate JSON message signing. If it doesn't pass, an error message is returned.
2. Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor.

- * Cache the CA OCSP stapling data and certificate revocation check status for other subsequent requests.
- * A TEE can use its own clock time for the OCSP stapling data validation.

3. Optionally collect Firmware signed data

- * This is a capability in ARM architecture that allows a TEE to query Firmware to get FW signed data. It isn't required for all TEE implementations. When TFW signed data is absent, it is up to a TAM's policy how it will trust a TEE.

4. Collect SD information for the SD owned by this TAM

9.1.3. Firmware Signed Data

Firmware isn't expected to process or produce JSON data. It is expected to just sign some raw bytes of data.

The data to be signed by TFW key needs be some unique random data each time. The (UTF-8 encoded) "tid" value from the `GetDeviceStateTBSRequest` shall be signed by the firmware. TAM isn't expected to parse TFW data except the signature validation and signer trust path validation.

It is possible that a TEE can get some valid TFW signed data from another device. The TEE is responsible to validate TFW integrity to ensure that the underlying device firmware is trustworthy. In some cases, a TEE isn't able to get a TFW signed data, in which case the TEE trust validation is up to a TAM to decide. A TAM may opt to trust a TEE basing on the TEE signer and additional information about a TEE out-of-band.

When TFW signed data is available, a TAM validates the TEE and trusts that a trusted TEE has carried out appropriate trust check about a TFW.

```
TfwData: {  
  "tbs": "<TFW to be signed data, BASE64 encoded>",  
  "cert": "<BASE64 encoded TFW certificate>",  
  "sigalg": "Signing method",  
  "sig": "<TFW signed data, BASE64 encoded>"  
}
```

It is expected that a FW uses standard signature methods for maximal interoperability with TAM providers. The mandatory support list of signing algorithm is RSA with SHA256.

The JSON object above is constructed by a TEE with data returned from the FW. It isn't a standard JSON signed object. The signer information and data to be signed must be specially processed by a TAM according to the definition given here. The data to be signed is the raw data.

9.1.3.1. Supported Firmware Signature Methods

TAM providers shall support the following signature methods. A firmware provider can choose one of the methods in signature generation.

- o RSA with SHA256
- o ECDSA with SHA 256

The value of "sigalg" in the TfwData JSON message SHOULD use one of the following:

- o RS256
- o ES256

9.1.4. Post Conditions

Upon successful request validation, the TEE information is collected. There is no change in the TEE in the device.

The response message shall be encrypted where the encryption key shall be a symmetric key that is wrapped by TAM's public key. The JSON Content Encryption Key (CEK) is used for this purpose.

9.1.5. GetDeviceStateResponse Message

The message has the following structure.

```
{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass | fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "signerreq": true | false // about whether TAM needs to send
                        signer data again in subsequent messages,
    "edsi": "<Encrypted JSON DSI information>"
  }
}
```

where

signerreq - true if the TAM should send its signer certificate and OSCP data again in the subsequent messages. The value may be "false" if the TEE caches the TAM's signer certificate and OSCP status.

rid - the request ID from the request message

tid - the tid from the request message

edsi - the main data element whose value is JSON encrypted message over the following Device State Information (DSI).

The Device State Information (DSI) message consists of the following.

```

{
  "dsi": {
    "tfwdata": {
      "tbs": "<TFW to be signed data is the tid>",
      "cert": "<BASE64 encoded TFW certificate>",
      "sigalg": "Signing method",
      "sig": "<TFW signed data, BASE64 encoded>"
    },
    "tee": {
      "name": "<TEE name>",
      "ver": "<TEE version>",
      "cert": "<BASE64 encoded TEE cert>",
      "cacert": "<JSON array value of CA certificates up to
                  the root CA>",
      "sdlist": {
        "cnt": "<Number of SD owned by this TAM>",
        "sd": [
          {
            "name": "<SD name>",
            "spid": "<SP owner ID of this SD>",
            "talist": [
              {
                "taid": "<TA application identifier>",
                "taname": "<TA application friendly
                           name>" // optional
              }
            ]
          }
        ]
      },
      "teeaiklist": [
        {
          "spaik": "<SP AIK public key, BASE64 encoded>",
          "spaiktype": "<RSA | ECC>",
          "spid": "<sp id>"
        }
      ]
    }
  }
}

```

The encrypted JSON message looks like the following.

```
{
  "protected": "<BASE64URL encoding of encryption algorithm header
                JSON data>",
  "recipients": [
    {
      "header": {
        "alg": "RSA1_5"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON object of dsi
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

Assume we encrypt plaintext with AES 128 in CBC mode with HMAC SHA 256 for integrity, the encryption algorithm header is:

```
{"enc": "A128CBC-HS256"}
```

The value of the property "protected" in the above JWE message will be

```
eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0
```

In other words, the above message looks like the following:

```
{
  "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
  "recipients": [
    {
      "header": {
        "alg": "RSA1_5"
      },
      "encrypted_key": "<encrypted value of CEK>"
    }
  ],
  "iv": "<BASE64URL encoded IV data>",
  "ciphertext": "<Encrypted data over the JSON object of dsi
                (BASE64URL)>",
  "tag": "<JWE authentication tag (BASE64URL)>"
}
```

The full response message looks like the following:

```

{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass | fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "signerreq": "true | false",
    "edsi": {
      "protected": "<BASE64URL encoding of encryption algorithm
                    header JSON data>",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key": "<encrypted value of CEK>"
        }
      ],
      "iv": "<BASE64URL encoded IV data>",
      "ciphertext": "<Encrypted data over the JSON object of dsi
                    (BASE64URL)>",
      "tag": "<JWE authentication tag (BASE64URL)>"
    }
  }
}

```

The CEK will be encrypted by the TAM public key in the device. The TEE signed message has the following structure.

```

{
  "GetDeviceTEESStateResponse": {
    "payload": "<BASE64URL encoding of the JSON message
               GetDeviceTEESStateTBSResponse>",
    "protected": "<BASE64URL encoding of signing algorithm>",
    "signature": "<BASE64URL encoding of the signature value>"
  }
}

```

The signing algorithm shall use SHA256 with respective key type, see Section 7.5.1.

The final GetDeviceStateResponse response message consists of an array of TEE responses.


```
{
  "GetDeviceStateResponse": [ // JSON array
    {"GetDeviceTEEStateResponse": ...},
    ...
    {"GetDeviceTEEStateResponse": ...}
  ]
}
```

9.1.6. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible error conditions is the following.

ERR_REQUEST_INVALID The TEE meets the following conditions with a request message: (1) The request from a TAM has an invalid message structure; mandatory information is absent in the message; or an undefined member or structure is included. (2) TEE fails to verify the signature of the message or fails to decrypt its contents.

ERR_UNSUPPORTED_MSG_VERSION The TEE receives a version of message that the TEE can't deal with.

ERR_UNSUPPORTED_CRYPTO_ALG The TEE receives a request message encoded with a cryptographic algorithm that the TEE doesn't support.

ERR_TFW_NOT_TRUSTED The TEE considers the underlying device firmware be not trustworthy.

ERR_TAM_NOT_TRUSTED The TEE needs to make sure whether the TAM is trustworthy by checking the validity of the TAM certificate and OCSP stapling data and so on. If the TEE finds the TAM is not reliable, it returns this error code.

ERR_TEE_FAIL If the TEE fails to process a request because of its internal error but is able to sign an error response message, it will return this error code.

The response message will look like the following if the TEE signing can work to sign the error response message.

```
{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "fail",
    "rid": "<the request ID from the request message>",
    "tid": "<the transaction ID from the request message>",
    "reason": {"error-code": "<error code>"}
    "supportedsigalgs": [<an array of signature algorithms that
                        the TEE supports>]
  }
}
```

where

supportedsigalgs - an optional property to list the JWS signing algorithms that the active TEE supports. When a TAM sends a signed message that the TEE isn't able to validate, it can include signature algorithms that it is able to consume in this status report. A TAM can generate a new request message to retry the management task with a TEE-supported signing algorithm.

If the TEE isn't able to sign an error message due to an internal device error, a general error message should be returned by the OTrP Broker.

9.1.7. TAM Processing Requirements

Upon receiving a GetDeviceStateResponse message at a TAM, the TAM MUST validate the following.

- o Parse to get list of GetDeviceTEESStateResponse JSON objects
- o Parse the JSON "payload" property and decrypt the JSON element "edsi". The decrypted message contains the TEE signer certificate.
- o Validate the GetDeviceTEESStateResponse JSON signature. The signer certificate is extracted from the decrypted message in the last step.
- o Extract TEE information and check it against its TEE acceptance policy.
- o Extract the TFW signed element, and check the signer and data integration against its TFW policy.
- o Check the SD list and TA list and prepare for a subsequent command such as "CreateSD" if it needs to have a new SD for an SP.

9.2. Security Domain Management

9.2.1. CreateSD

This command is typically preceded with a `GetDeviceState` command that has acquired the device information of the target device by the TAM. The TAM sends such a command to instruct a TEE to create a new Security Domain for an SP.

A TAM sends an OTrP `CreateSDRequest` Request message to a device TEE to create a Security Domain for an SP. Such a request is signed by the TAM where the TAM signer may or may not be the same as the SP's TA signer certificate. The resulting SD is associated with two identifiers for future management:

- o TAM as the owner. The owner identifier is a registered unique TAM ID that is stored in the TAM certificate.
- o SP identified by its TA signer certificate as the authorization. A TAM can add more than one SP certificate to an SD.

A Trusted Application that is signed by a matching SP signer certificate for an SD is eligible to be installed into that SD. The TA installation into an SD by a subsequent `InstallTARrequest` message may be instructed from a TAM.

9.2.1.1. CreateSDRequest Message

The request message for CreateSD has the following JSON format.

```
{
  "CreateSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON data will be
                        // encrypted
      "spid": "<SP ID value>",
      "sdname": "<SD name for the domain to be created>",
      "spcert": "<BASE64 encoded SP certificate>",
      "tamid": "<An identifiable attribute of the TAM
               certificate>",
      "did": "<SHA256 hash of the TEE cert>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse.

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is expected in the response from the TEE to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD creation. The encryption key is TAMmk that is encrypted by the target TEE's public key. The entire message is signed by the TAM private key TAMpriv. A separate TAMmk isn't used in the latest specification because JSON encryption will use a content encryption key for exactly the same purpose.

spid - A unique id assigned by the TAM for its SP. It should be unique within a TAM namespace.

sdname - a name unique to the SP. TAM should ensure it is unique for each SP.

spcert - The SP's TA signer certificate is included in the request. This certificate will be stored by the device TEE which uses it to check against TA installation. Only if a TA is signed by a matching spcert associated with an SD will the TA be installed into the SD.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate. TEE will be responsible to assign this ID to the SD. The TAM certificate attribute for this attribute tamid MUST be vetted by the TAM signer issuing CA. With this trusted identifier, the SD query at TEE can be fast upon TAM signer verification.

did - The SHA256 hash of the binary-encoded device TEE certificate. The encryption key CEK will be encrypted the recipient TEE's public key. This hash value in the "did" property allows the recipient TEE to check whether it is the expected target to receive such a request. If this isn't given, an OTrP message for device 2 could be sent to device 1. It is optional for the TEE to check because the successful decryption of the request message with this device's TEE private key already proves it is the target. This explicit hash value makes the protocol not dependent on message encryption method in future.

A CreateSDTBSRequest message is signed to generate a final CreateSDRequest message as follows.

```
{
  "CreateSDRequest": {
    "payload": "<CreateSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

The TAM signer certificate is included in the "header" property.

9.2.1.2. Request Processing Requirements at a TEE

Upon receiving a CreateSDRequest request message at a TEE, the TEE MUST do the following:

1. Validate the JSON request message as follows
 - * Validate JSON message signing.
 - * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor.
 - * Compare dsihash with its current state to make sure nothing has changed since this request was sent.
 - * Decrypt to get the plaintext of the content: (a) spid, (b) sd name, (c) did.
 - * Check that an SPID is supplied.
 - * spcert check: check it is a valid certificate (signature and format verification only).
 - * Check "did" is the SHA256 hash of its TEEcert BER raw binary data.
 - * Check whether the requested SD already exists for the SP.
 - * Check that the tamid in the request matches the TAM certificate's TAM ID attribute.
2. If the request was valid, create action
 - * Create an SD for the SP with the given name.
 - * Assign the tamid from the TAMCert to this SD.
 - * Assign the SPID and SPCert to this SD.
 - * Check whether a TEE SP AIK key pair already exists for the given SP ID.
 - * Create TEE SP AIK key pair if it doesn't exist for the given SP ID.
 - * Generate new DSI data if the request asks for updated DSI.
3. Construct a CreateSDResponse message

- * Create raw content
 - + Operation status
 - + "did" or full signer certificate information,
 - + TEE SP AIK public key if DSI isn't going to be included
 - + Updated DSI data if requested
 - * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver the response message. (a) The OTrP Broker returns this to the Client Application; (b) The Client App passes this back to the TAM.
 5. TAM processing. (a) The TAM processes the response message; (b) the TAM can look up signer certificate from the device ID "did".

If a request is illegitimate or signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.1.3. CreateSDResponse Message

The response message for a CreateSDRequest contains the following content.

```
{
  "CreateSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id received from the request>",
      "sdname": "<SD name for the domain created>",
      "teespaik": "<TEE SP AIK public key, BASE64 encoded>",
      "dsi": "<Updated TEE state, including all SDs owned by
        this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - The SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

teespaik - The newly generated SP AIK public key for the given SP. This is an optional value if the device has had another domain for the SP that has triggered TEE SP AIK key pair for this specific SP.

There is a possible extreme error case where the TEE isn't reachable or the TEE final response generation itself fails. In this case, the TAM might still receive a response from the OTrP Broker if the OTrP Broker is able to detect such error from TEE. In this case, a general error response message should be returned by the OTrP Broker, assuming OTrP Broker even doesn't know any content and information about the request message.

In other words, the TAM should expect to receive a TEE successfully signed JSON message, a general "status" message, or none when a client experiences a network error.

```
{
  "CreateSDResponse": {
    "payload": "<CreateSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by the TEE device private
                  key (BASE64URL)>"
  }
}
```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.2.1.4. Error Conditions

An error might occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_ALREADY_EXIST

ERR_SD_NOT_FOUND

ERR_SPCERT_INVALID

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.2.2. UpdateSD

This TAM initiated command can update an SP's SD that it manages for any of the following needs: (a) Update an SP signer certificate; (b) Add an SP signer certificate when an SP uses multiple to sign TA binaries; (c) Update an SP ID.

The TAM presents the proof of the SD ownership to the TEE, and includes related information in its signed message. The entire request is also encrypted for end-to-end confidentiality.

9.2.2.1. UpdateSDRequest Message

The UpdateSD request message has the following JSON format.

```
{
  "UpdateSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON will be encrypted
      "tamid": "<tamid associated with this SD>",
      "spid": "<SP ID>",
      "sdname": "<SD name for the domain to be updated>",
      "changes": {
        "newsdname": "<Change the SD name to this new name>",
          // Optional
        "newspid": "<Change SP ID of the domain to this new value>",
          // Optional
        "spcert": ["<BASE64 encoded new SP signer cert to be added>"],
          // Optional
        "deloldspcert": ["<The SHA256 hex value of an old SP cert
          assigned into this SD that should be deleted >"],
          // Optional
        "renewteespaik": true | false
      }
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value as the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is expected to be returned in the response from the TEE to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It

helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - the identifier of the SP whose SD will be updated. This value is still needed because the SD name is considered unique only within an SP.

sdname - the name of the target SD to be updated.

changes - its content consists of changes are to be updated in the given SD.

newsdname - the new name of the target SD to be assigned if this value is present.

newspid - the new SP ID of the target SD to be assigned if this value is present.

spcert - a new TA signer certificate of this SP to be added to the SD if this is present.

deloldspcert - an SP certificate assigned into the SD is to be deleted if this is present. The value is the SHA256 fingerprint of the old SP certificate.

renewteespaik - the value should be true or false. If it is present and the value is true, the TEE MUST regenerate TEE SP AIK for this SD's owner SP. The newly generated TEE SP AIK for the SP must be returned in the response message of this request. If there is more than one SD for the SP, a new SPID for one of the domains will always trigger a new teespaik generation as if a new SP were introduced to the TEE.

The UpdateSDTBSRequest message is signed to generate the final UpdateSDRequest message.

```
{
  "UpdateSDRequest": {
    "payload": "<UpdateSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

TAM signer certificate is included in the "header" property.

9.2.2.2. Request Processing Requirements at a TEE

Upon receiving a request message UpdateSDRequest at a TEE, the TEE must validate a request:

1. Validate the JSON request message

- * Validate JSON message signing
- * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor. The TAM certificate status check is generally not needed anymore in this request. The prior request should have validated the TAM certificate's revocation status.
- * Compare dsihash with the TEE cached last response DSI data to this TAM.
- * Decrypt to get the plaintext of the content.
- * Check that the target SD name is supplied.
- * Check whether the requested SD exists.
- * Check that the TAM owns this TAM by verifying tamid in the SD matches TAM certificate's TAM ID attribute.
- * Now the TEE is ready to carry out update listed in the "content" message.

2. If the request is valid, update action

- * If "newsdname" is given, replace the SD name for the SD to the new value

- * If "newspid" is given, replace the SP ID assigned to this SD with the given new value
 - * If "spcert" is given, add this new SP certificate to the SD.
 - * If "deloldspcert" is present in the content, check previously assigned SP certificates to this SD, and delete the one that matches the given certificate hash value.
 - * If "renewteespaik" is given and has a value of 'true', generate a new TEE SP AIK key pair, and replace the old one with this.
 - * Generate new DSI data if the request asks for updated DSI
 - * Now the TEE is ready to construct the response message
3. Construct UpdateSDResponse message
- * Create raw content
 - + Operation status
 - + "did" or full signer certificate information,
 - + TEE SP AIK public key if DSI isn't going to be included
 - + Updated DSI data if requested
 - * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver response message. (a) The OTrP Broker returns this to the app; (b) The app passes this back to the TAM.
5. TAM processing. (a) The TAM processes the response message; (b) The TAM can look up the signer certificate from the device ID "did".

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.2.3. UpdateSDResponse Message

The response message for a UpdateSDRequest contains the following content.

```
{
  "UpdateSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "cert": "<TEE certificate>", // optional
      "teespaik": "<TEE SP AIK public key, BASE64 encoded>",
      "teespaiktype": "<TEE SP AIK key type: RSA or ECC>",
      "dsi": "<Updated TEE state, including all SD owned by
        this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - The request should have known the signer certificate of this device from a prior request. This hash value of the device TEE certificate serves as a quick identifier only. A full device certificate isn't necessary.

teespaik - the newly generated SP AIK public key for the given SP if the TEE SP AIK for the SP is asked to be renewed in the request. This is an optional value if "dsi" is included in the response, which will contain all up-to-date TEE SP AIK key pairs.

Similar to the template for the creation of the encrypted and signed CreateSDResponse, the final UpdateSDResponse looks like the following.

```
{
  "UpdateSDResponse": {
    "payload": "<UpdateSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device private
                  key (BASE64URL)>"
  }
}
```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.2.2.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_SDNAME_ALREADY_USED

ERR_SPCERT_INVALID

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.2.3. DeleteSD

A TAM sends a DeleteSDRequest message to a TEE to delete a specified SD that it owns. An SD can be deleted only if there is no TA associated with this SD in the device. The request message can

contain a flag to instruct the TEE to delete all related TAs in an SD and then delete the SD.

The target TEE will operate with the following logic.

1. Look up the given SD specified in the request message
2. Check that the TAM owns the SD
3. Check that the device state hasn't changed since the last operation
4. Check whether there are TAs in this SD
5. If TA exists in an SD, check whether the request instructs whether the TA should be deleted. If the request instructs the TEE to delete TAs, delete all TAs in this SD. If the request doesn't instruct the TEE to delete TAs, return an error "ERR_SD_NOT_EMPTY".
6. Delete the SD
7. If this is the last SD of this SP, delete the TEE SP AIK key.

9.2.3.1. DeleteSDRequest Message

The request message for DeleteSD has the following JSON format.

```
{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>", // this may be from prior message
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED { // this piece of JSON will be encrypted
      "tamid": "<tamid associated with this SD>",
      "sdname": "<SD name for the domain to be updated>",
      "deleteta": true | false
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous response
GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

sdname - the name of the target SD to be updated.

deleteta - the value should be boolean 'true' or 'false'. If it is present and the value is 'true', the TEE should delete all TAs associated with the SD in the device.

According to the OTrP message template, the full request DeleteSDRequest is a signed message over the DeleteSDTBSRequest as follows.

```
{
  "DeleteSDRequest": {
    "payload": "<DeleteSDTBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

TAM signer certificate is included in the "header" property.

9.2.3.2. Request Processing Requirements at a TEE

Upon receiving a request message DeleteSDRequest at a TEE, the TEE must validate a request:

1. Validate the JSON request message
 - * Validate JSON message signing
 - * Validate that the request TAM certificate is chained to a trusted CA that the TEE embeds as its trust anchor. The TAM certificate status check is generally not needed anymore in this request. The prior request should have validated the TAM certificate's revocation status.
 - * Compare dsihash with the TEE cached last response DSI data to this TAM
 - * Decrypt to get the plaintext of the content
 - * Check that the target SD name is supplied
 - * Check whether the requested SD exists
 - * Check that the TAM owns this TAM by verifying that the tamid in the SD matches the TAM certificate's TAM ID attribute
 - * Now the TEE is ready to carry out the update listed in the "content" message
2. If the request is valid, deletion action
 - * Check TA existence in this SD
 - * If "deleteta" is "true", delete all TAs in this SD. If the value of "deleteta" is false and some TA exists, return an error "ERR_SD_NOT_EMPTY"
 - * Delete the SD
 - * Delete the TEE SP AIK key pair if this SD is the last one for the SP
 - * Now the TEE is ready to construct the response message
3. Construct a DeleteSDResponse message
 - * Create response content

- + Operation status
 - + "did" or full signer certificate information,
 - + Updated DSI data if requested
- * The response message is encrypted with the same JWE CEK of the request without recreating a new content encryption key.
 - * The encrypted message is signed with TEEpriv. The signer information ("did" or TEEcert) is encrypted.
4. Deliver response message. (a) The OTrP Broker returns this to the app; (b) The app passes this back to the TAM
 5. TAM processing. (a) The TAM processes the response message; (b) The TAM can look up signer certificate from the device ID "did".

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.2.3.3. DeleteSDResponse Message

The response message for a DeleteSDRequest contains the following content.

```
{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
        this TAM>"
    }
  }
}
```

In the response message, the following fields MUST be supplied.

did - The request should have known the signer certificate of this device from a prior request. This hash value of the device TEE certificate serves as a quick identifier only. A full device certificate isn't necessary.

The final DeleteSDResponse looks like the following.

```
{
  "DeleteSDResponse": {
    "payload": "<DeleteSDTBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
      private key (BASE64URL)>"
  }
}
```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.2.3.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors is as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_EMPTY

ERR_SD_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3. Trusted Application Management

This protocol doesn't introduce a TA container concept. All TA authorization and management will be up to the TEE implementation.

The following three TA management commands are supported.

- o InstallTA - provision a TA by TAM
- o UpdateTA - update a TA by TAM
- o DeleteTA - remove TA registration information with an SD, remove the TA binary and all TA-related data in a TEE

9.3.1. InstallTA

TA binary data and related personalization data if there is any can be from two sources:

1. A TAM supplies the signed and encrypted TA binary
2. A Client Application supplies the TA binary

This specification primarily considers the first case where a TAM supplies a TA binary. This is to ensure that a TEE can properly validate whether a TA is trustworthy. Further, TA personalization data will be encrypted by the TEE device's SP public key for end-to-end protection. A Client Application bundled TA case will be addressed separately later.

A TAM sends the following information in a InstallTAREquest message to a target TEE:

- o The target SD information: SP ID and SD name
- o Encrypted TA binary data. TA data is encrypted with the TEE SP AIK.
- o TA metadata. It is optional to include the SP signer certificate for the SD to add if the SP has changed signer since the SD was created.

The TEE processes the command given by the TAM to install a TA into an SP's SD. It does the following:

- o Validation
 - * The TEE validates the TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD with the SD name
 - * Checks that the TAM owns the SD

- * Checks that the DSI hash matches which shows that the device state hasn't changed
- o If the request is valid, continue to do the TA validation
 - * Decrypt to get the TA binary data and any personalization data with the "TEE SP AIK private key"
 - * Check that SP ID is the one that is registered with the SP SD
 - * Check that the TA signer is either a newly given SP certificate or the one that is already trusted by the SD from the previous TA installation. The TA signing method is specific to a TEE. This specification doesn't define how a TA should be signed; a TAM should support TEE specific TA signing when it supports that TEE.
 - * If a TA signer is given in the request, add this signer into the SD.
- o If the above validation passed, continue to do TA installation
 - * The TEE re-encrypts the TA binary and its personalization data with its own method.
 - * The TEE enrolls and stores the TA in a secure storage.
- o Construct a response message. This involves signing encrypted status information for the requesting TAM.

9.3.1.1. InstallTAResponse Message

The request message for InstallTA has the following JSON format.

```
{
  "InstallTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "spid": "<SPID value>",
      "sdname": "<SD name for the domain to install the TA>",
      "spcert": "<BASE64 encoded SP certificate >", // optional
      "taid": "<TA identifier>"
    },
    "encrypted_ta": {
      "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
      "iv": "<hex of 16 random bytes>",
      "alg": "<encryption algorithm. AESCBC by default.>",
      "ciphertadata": "<BASE64 encoded encrypted TA binary data>",
      "cipherpdata": "<BASE64 encoded encrypted TA personalization
        data>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - An SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - SP identifier of the TA owner SP

sdname - the name of the target SD where the TA is to be installed

spcert - an optional field to specify the SP certificate that signed the TA. This is sent if the SP has a new certificate that hasn't been previously registered with the target SD where the TA should be installed.

taid - the identifier of the TA application to be installed

encrypted_ta - the message portion contains encrypted TA binary data and personalization data. The TA data encryption key is placed in "key", which is encrypted by the recipient's public key, using JWE enveloped structure. The TA data encryption uses symmetric key based encryption such as AESCBC.

According to the OTrP message template, the full request InstallTAResponse is a signed message over the InstallTATBSRequest as follows.

```
{
  "InstallTAResponse": {
    "payload": "<InstallTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

9.3.1.2. InstallTAResponse Message

The response message for a InstallTAResponse contains the following content.


```

{
  "InstallTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
              this TAM>"
    }
  }
}

```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message InstallTAResponse looks like the following.

```

{
  "InstallTAResponse": {
    "payload": "<InstallTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                  private key (BASE64URL)>"
  }
}

```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.3.1.3. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_INVALID

ERR_TA_ALREADY_INSTALLED

ERR_TEE_FAIL

ERR_TEE_RESOURCE_FULL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3.2. UpdateTA

This TAM-initiated command can update a TA and its data in an SP's SD that it manages for the following purposes.

1. Update TA binary
2. Update TA's personalization data

The TAM presents the proof of the SD ownership to a TEE, and includes related information in its signed message. The entire request is also encrypted for end-to-end confidentiality.

The TEE processes the command from the TAM to update the TA of an SP SD. It does the following:

- o Validation
 - * The TEE validates the TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD with the SD name
 - * Checks that the TAM owns the SD
 - * Checks DSI hash matches that the device state hasn't changed
- o TA validation

- * Both TA binary and personalization data are optional, but at least one of them shall be present in the message
- * Decrypt to get the TA binary and any personalization data with the "TEE SP AIK private key"
- * Check that SP ID is the one that is registered with the SP SD
- * Check that the TA signer is either a newly given SP certificate or the one in SD.
- * If a TA signer is given in the request, add this signer into the SD.
- o If the above validation passes, continue to do TA update
 - * The TEE re-encrypts the TA binary and its personalization data with its own method
 - * The TEE replaces the existing TA binary and its personalization data with the new binary and data.
- o Construct a response message. This involves signing a encrypted status information for the requesting TAM.

9.3.2.1. UpdateTAResponse Message

The request message for UpdateTA has the following JSON format.

```
{
  "UpdateTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "spid": "<SPID value>",
      "sdname": "<SD name for the domain to be created>",
      "spcert": "<BASE64 encoded SP certificate >", // optional
      "taid": "<TA identifier>"
    },
    "encrypted_ta": {
      "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEEspaik public key>",
      "iv": "<hex of 16 random bytes>",
      "alg": "<encryption algorithm. AESCBC by default.>",
      "ciphernewtadata": "<Change existing TA binary to this new TA
        binary data(BASE64 encoded and encrypted)>",
      "ciphernewpdata": "<Change the existing data to this new TA
        personalization data(BASE64 encoded and encrypted)>"
      // optional
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It

helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

spid - SP identifier of the TA owner SP

spcert - an optional field to specify the SP certificate that signed the TA. This is sent if the SP has a new certificate that hasn't been previously registered with the target SD where the TA is to be installed.

sdname - the name of the target SD where the TA should be updated

taid - an identifier for the TA application to be updated

encrypted_ta - the message portion contains newly encrypted TA binary data and personalization data.

According to the OTrP message template, the full request UpdateTARequest is a signed message over the UpdateTATBSRequest as follows.

```
{
  "UpdateTARequest": {
    "payload": "<UpdateTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM private key>"
  }
}
```

9.3.2.2. UpdateTAResponse Message

The response message for a UpdateTARequest contains the following content.

```

{
  "UpdateTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
             this TAM>"
    }
  }
}

```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message UpdateTAResponse looks like the following.

```

{
  "UpdateTAResponse": {
    "payload": "<UpdateTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                 private key (BASE64URL)>"
  }
}

```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.3.2.3. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_INVALID

ERR_TA_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

9.3.3. DeleteTA

This operation defines OTrP messages that allow a TAM to instruct a TEE to delete a TA for an SP in a given SD. A TEE will delete a TA from an SD and also TA data in the TEE. A Client Application cannot directly access TEE or OTrP Broker to delete a TA.

9.3.3.1. DeleteTATBSRequest Message

The request message for DeleteTA has the following JSON format.

```
{
  "DeleteTATBSRequest": {
    "ver": "1.0",
    "rid": "<unique request ID>",
    "tid": "<transaction ID>",
    "tee": "<TEE routing name from the DSI for the SD's target>",
    "nextdsi": true | false,
    "dsihash": "<hash of DSI returned in the prior query>",
    "content": ENCRYPTED {
      "tamid": "<TAM ID previously assigned to the SD>",
      "sdname": "<SD name of the TA>",
      "taid": "<the identifier of the TA to be deleted from the
        specified SD>"
    }
  }
}
```

In the message,

rid - A unique value to identify this request

tid - A unique value to identify this transaction. It can have the same value for the tid in the preceding GetDeviceStateRequest.

tee - The TEE ID returned from the previous GetDeviceStateResponse

nextdsi - Indicates whether the up-to-date Device State Information (DSI) is to be returned in the response to this request.

dsihash - The BASE64-encoded SHA256 hash value of the DSI data returned in the prior TAM operation with this target TEE. This value is always included such that a receiving TEE can check whether the device state has changed since its last query. It helps enforce SD update order in the right sequence without accidentally overwriting an update that was done simultaneously.

content - The "content" is a JSON encrypted message that includes actual input for the SD update. The standard JSON content encryption key (CEK) is used, and the CEK is encrypted by the target TEE's public key.

tamid - SD owner claim by TAM - an SD owned by a TAM will be associated with a trusted identifier defined as an attribute in the signer TAM certificate.

sdname - the name of the target SD where the TA is installed

taid - an identifier for the TA application to be deleted

According to the OTrP message template, the full request DeleteTAResponse is a signed message over the DeleteTATBSRequest as follows.

```
{
  "DeleteTAResponse": {
    "payload": "<DeleteTATBSRequest JSON above>",
    "protected": "<integrity-protected header contents>",
    "header": "<non-integrity-protected header contents>",
    "signature": "<signature contents signed by TAM
                  private key>"
  }
}
```


9.3.3.2. Request Processing Requirements at a TEE

A TEE processes a command from a TAM to delete a TA of an SP SD. It does the following:

1. Validate the JSON request message
 - * The TEE validates TAM message authenticity
 - * Decrypt to get request content
 - * Look up the SD and the TA with the given SD name and TA ID
 - * Checks that the TAM owns the SD, and TA is installed in the SD
 - * Checks that the DSI hash matches and the the device state hasn't changed
2. Deletion action
 - * If all the above validation points pass, the TEE deletes the TA from the SD
 - * The TEE SHOULD also delete all personalization data for the TA
3. Construct DeleteTAResponse message.

If a request is illegitimate or the signature doesn't pass, a "status" property in the response will indicate the error code and cause.

9.3.3.3. DeleteTAResponse Message

The response message for a DeleteTARequest contains the following content.

```

{
  "DeleteTATBSResponse": {
    "ver": "1.0",
    "status": "<operation result>",
    "rid": "<the request ID received>",
    "tid": "<the transaction ID received>",
    "content": ENCRYPTED {
      "reason": "<failure reason detail>", // optional
      "did": "<the device id hash>",
      "dsi": "<Updated TEE state, including all SD owned by
             this TAM>"
    }
  }
}

```

In the response message, the following fields MUST be supplied.

did - the SHA256 hash of the device TEE certificate. This shows the device ID explicitly to the receiving TAM.

The final message DeleteTAResponse looks like the following.

```

{
  "DeleteTAResponse": {
    "payload": "<DeleteTATBSResponse JSON above>",
    "protected": {
      "<BASE64URL of signing algorithm>"
    },
    "signature": "<signature contents signed by TEE device
                 private key (BASE64URL)>"
  }
}

```

When the TEE fails to respond, the OTrP Broker will not provide a subsequent response to the TAM. The TAM should treat this as if the device has gone offline where a response is never delivered back.

9.3.3.4. Error Conditions

An error may occur if a request isn't valid or the TEE runs into some error. The list of possible errors are as follows. Refer to the Error Code List (Section 13.1) for detailed causes and actions.

ERR_REQUEST_INVALID

ERR_UNSUPPORTED_MSG_VERSION

ERR_UNSUPPORTED_CRYPTO_ALG

ERR_DEV_STATE_MISMATCH

ERR_SD_NOT_FOUND

ERR_TA_NOT_FOUND

ERR_TEE_FAIL

ERR_TAM_NOT_AUTHORIZED

ERR_TAM_NOT_TRUSTED

10. Response Messages a TAM May Expect

A TAM expects some feedback from a remote device when a request message is delivered to a device. The following three types of responses SHOULD be supplied.

Type 1: Expect a valid TEE-generated response message

A valid TEE signed response may contain errors detected by a TEE, e.g. a TAM is trusted but some TAM-supplied data is missing, for example, SP ID doesn't exist. TEE MUST be able to sign and encrypt.

If a TEE isn't able to sign a response, the TEE returns an error to the OTrP Broker without giving any other internal information. The OTrP Broker will be generating the response.

Type 2: The OTrP Broker generated error message when TEE fails. OTrP Broker errors will be defined in this document.

A Type 2 message has the following format.

```
{
  "OTrPBrokerError": {
    "ver": "1.0",
    "rid": "",
    "tid": "",
    "errcode": "ERR_AGENT_TEE_UNKNOWN | ERR_AGENT_TEE_BUSY"
  }
}
```

Type 3: OTrP Broker itself isn't reachable or fails. A Client Application is responsible to handle error and respond the TAM in its own way. This is out of scope for this specification.

11. Basic Protocol Profile

This section describes a baseline for interoperability among the protocol entities, mainly, the TAM and TEE.

A TEE MUST support RSA algorithms. It is optional to support ECC algorithms. A TAM SHOULD use a RSA certificate for TAM message signing. It may use an ECC certificate if it detects that the TEE supports ECC according to the field "supportedsigalgs" in a TEE response.

A TAM MUST support both RSA 2048-bit algorithm and ECC P-256 algorithms. With this, a TEE and TFW certificate can be either RSA or ECC type.

JSON signing algorithms

- o RSA PKCS#1 with SHA256 signing : "RS256"
- o ECDSA with SHA256 signing : "ES256"

JSON asymmetric encryption algorithms (describes key-exchange or key-agreement algorithm for sharing symmetric key with TEE):

- o RSA PKCS#1 : "RSA1_5"
- o ECDH using TEE ECC P-256 key and ephemeral ECC key generated by TAM : "ECDH-ES+A128W"

JSON symmetric encryption algorithms (describes symmetric algorithm for encrypting body of data, using symmetric key transferred to TEE using asymmetric encryption):

- o Authenticated encryption AES 128 CBC with SHA256 :
{"enc": "A128CBC-HS256"}

12. Attestation Implementation Consideration

It is important to know that the state of a device is appropriate before trusting that a device is what it says it is. The attestation scheme for OTrP must also be able to cope with different TEEs, including those that are OTrP compliant and those that use another mechanism. In the initial version, only one active TEE is assumed.

It is out of scope how the TAM and the device implement the trust hierarchy verification. However, it is helpful to understand what each system provider should do in order to properly implement an OTrP trust hierarchy.

In this section, we provide some implementation reference consideration.

12.1. OTrP Trusted Firmware

12.1.1. Attestation signer

It is proposed that attestation for OTrP is based on the TFW layer, and that further attestation is not performed within the TEE itself during Security Domain operations. The rationale is that the device boot process will be defined to start with a secure bootloader protected with a harden key in eFUSE. The process releases attestation signing capabilities into the TFW once a trust boot has been established. In this way the release of the attestation signer can be considered the first "platform configuration metric", using Trust Computing Group (TCG) terminology.

12.1.2. TFW Initial Requirements

- R1 The TFW must be possible for verification during boot
- R2 The TFW must allow a public / private key pair to be generated during device manufacture
- R3 The public key and certificate must be possible to store securely
- R4 The private key must be possible to store encrypted at rest
- R5 The private key must only be visible to the TFW when it is decrypted
- R6 The TFW must be able to read a list of root and intermediate certificates that it can use to check certificate chains with. The list must be stored such that it cannot be tampered with
- R7 Need to allow a TEE to access its unique TEE specific private key

12.2. TEE Loading

During boot, the TFW is required to start all of the root TEEs. Before loading them, the TFW must first determine whether the code sign signature of the TEE is valid. If TEE integrity is confirmed, the TEE may be started. The TFW must then be able to receive the identity certificate from the TEE (if that TEE is OTrP compliant). The identity certificate and keys will need to be baked into the TEE image, and therefore also covered by the code signer hash during the manufacturing process. The private key for the identity certificate must be securely protected. The private key for a TEE identity must

never be released no matter how the public key and certificate are released to the TFW.

Once the TFW has successfully booted a TEE and retrieved the identity certificate, the TFW will commit this to the platform configuration register (PCR) set, for later use during attestation. At minimum, the following data must be committed to the PCR for each TEE:

1. Public key and certificate for the TEE
2. TEE identifier that can be used later by a TAM to identify this TEE

12.3. Attestation Hierarchy

The attestation hierarchy and seed required for TAM protocol operation must be built into the device at manufacture. Additional TEEs can be added post-manufacture using the scheme proposed, but it is outside of the current scope of this document to detail that.

It should be noted that the attestation scheme described is based on signatures. The only decryption that may take place is through the use of a bootloader key.

12.3.1. Attestation Hierarchy Establishment: Manufacture

During manufacture the following steps are required:

1. A device-specific TFW key pair and certificate are burnt into the device. This key pair will be used for signing operations performed by the TFW.
2. TEE images are loaded and include a TEE instance-specific key pair and certificate. The key pair and certificate are included in the image and covered by the code signing hash.
3. The process for TEE images is repeated for any subordinate TEEs, which are additional TEEs after the root TEE that some devices have.

12.3.2. Attestation Hierarchy Establishment: Device Boot

During device boot the following steps are required:

1. The boot module releases the TFW private key by decrypting it with the bootloader key.

2. The TFW verifies the code-signing signature of the active TEE and places its TEE public key into a signing buffer, along with its identifier for later access. For a non-OTrP TEE, the TFW leaves the TEE public key field blank.
3. The TFW signs the signing buffer with the TFW private key.
4. Each active TEE performs the same operation as the TFW, building up their own signed buffer containing subordinate TEE information.

12.3.3. Attestation Hierarchy Establishment: TAM

Before a TAM can begin operation in the marketplace to support devices of a given TEE, it must obtain a TAM certificate from a CA that is registered in the trust store of devices with that TEE. In this way, the TEE can check the intermediate and root CA and verify that it trusts this TAM to perform operations on the TEE.

13. IANA Considerations

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

This section first requests that IANA assign a media type: application/otrp+json.

Type name: application

Subtype name: otrap+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 Section 12 of [RFC7159] and Section 14 of this document

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

Published specification: [TEEPArch]

Applications that use this media type: OTrP 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

The error code listed in the next section will be registered.

13.1. Error Code List

This section lists error codes that could be reported by a TA or TEE in a device in responding to a TAM request, and a separate list that OTrP Broker may return when the TEE fails to respond.

13.1.1. TEE Signed Error Code List

ERR_DEV_STATE_MISMATCH - A TEE will return this error code if the DSI hash value from TAM doesn't match the has value of the device's current DSI.

ERR_SD_ALREADY_EXISTS - This error will occur if an SD to be created already exists in the TEE.

ERR_SD_NOT_EMPTY - This is reported if a target SD isn't empty.

ERR_SDNAME_ALREADY_USED A TEE will return this error code if the new SD name already exists in the TEE.

ERR_REQUEST_INVALID - This error will occur if the TEE meets any of the following conditions with a request message: (1) The request from a TAM has an invalid message structure; mandatory information is absent in the message. undefined member or structure is included. (2) TEE fails to verify signature of the message or fails to decrypt its contents.

ERR_SPCERT_INVALID - If a new SP certificate for the SD to be updated is not valid, then the TEE will return this error code.

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

ERR_TA_INVALID - This error will occur when a TEE meets any of following conditions while checking validity of TA: (1) The TA binary has a format that the TEE can't recognize. (2) The TEE fails to decrypt the encoding of the TA binary and personalization data. (3) If an SP isn't registered with the SP SD where the TA will be installed.

ERR_TA_NOT_FOUND - This error will occur when the target TA doesn't exist in the SD.

ERR_TEE_FAIL - If the TEE fails to process a request because of an internal error, it will return this error code.

ERR_TEE_RESOURCE_FULL - This error is reported when a device resource isn't available anymore such as storage space is full.

ERR_TFW_NOT_TRUSTED - A TEE is responsible for determining that the underlying device firmware is trustworthy. If the TEE determines the TFW is not trustworthy, then this error will occur.

ERR_TAM_NOT_TRUSTED - Before processing a request, a TEE needs to make sure whether the sender TAM is trustworthy by checking the validity of the TAM certificate, etc. If the TEE finds that the TAM is not trustworthy, then it will return this error code.

ERR_UNSUPPORTED_CRYPTO_ALG - This error will occur if a TEE receives a request message encoded with cryptographic algorithms that the TEE doesn't support.

ERR_UNSUPPORTED_MSG_VERSION - This error will occur if a TEE receives a message version that the TEE can't deal with.

14. Security Consideration

14.1. Cryptographic Strength

The strength of the cryptographic algorithms, using the measure of 'bits of security' defined in NIST SP800-57 allowed for OTrP is:

- o At a minimum, 112 bits of security. The limiting factor for this is the RSA-2048 algorithm, which is indicated as providing 112 bits of symmetric key strength in SP800-57. It is important that

RSA is supported in order to enhance the interoperability of the protocol.

- o The option exists to choose algorithms providing 128 bits of security. This requires using TEE devices that support ECC P256.

The available algorithms and key sizes specified in this document are based on industry standards. Over time the recommended or allowed cryptographic algorithms may change. It is important that the OTrP allows for crypto-agility. In this specification, TAM and TEE can negotiate an agreed upon algorithm where both include their supported algorithm in OTrP message.

14.2. Message Security

OTrP messages between the TAM and TEE are protected by message security using JWS and JWE. The 'Basic protocol profile' section of this document describes the algorithms used for this. All OTrP TEE devices and OTrP TAMs must meet the requirements of the basic profile. In the future additional 'profiles' can be added.

PKI is used to ensure that the TEE will only communicate with a trusted TAM, and to ensure that the TAM will only communicate with a trusted TEE.

14.3. TEE Attestation

It is important that the TAM can trust that it is talking to a trusted TEE. This is achieved through attestation. The TEE has a private key and certificate built into it at manufacture, which is used to sign data supplied by the TAM. This allows the TAM to verify that the TEE is trusted.

It is also important that the TFW (trusted firmware) can be checked. The TFW has a private key and certificate built into it at manufacture, which allows the TEE to check that that the TFW is trusted.

The GetDeviceState message therefore allows the TAM to check that it trusts the TEE, and the TEE at this point will check whether it trusts the TFW.

14.4. TA Protection

A TA will be delivered in an encrypted form. This encryption is an additional layer within the message encryption described in the Section 11 of this document. The TA binary is encrypted for each target device with the device's TEE SP AIK public key. A TAM can

either do this encryption itself or provide the TEE SP AIK public key to an SP such that the SP encrypts the encrypted TA for distribution to the TEE.

The encryption algorithm can use a random AES 256 key "taek" with a 16 byte random IV, and the "taek" is encrypted by the "TEE SP AIK public key". The following encrypted TA data structure is expected by a TEE:

```
"encrypted_ta_bin": {
  "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEESpaik public key>",
  "iv": "<hex of 16 random bytes>",
  "alg": "AESCBC",
  "cipherdata": "<BASE64 encoded encrypted TA binary data>"
}
```

14.5. TA Personalization Data

An SP or TAM can supply personalization data for a TA to initialize for a device. Such data is passed through an InstallTA command from a TAM. The personalization data itself is (or can be) opaque to the TAM. The data can be from the SP without being revealed to the TAM. The data is sent in an encrypted manner in a request to a device such that only the device can decrypt. A device's TEE SP AIK public key for an SP is used to encrypt the data. Here JWE enveloping is used to carry all encryption key parameters along with encrypted data.

```
"encrypted_ta_data": { // "TA personalization data"
  "key": "<JWE enveloped data of a 256-bit symmetric key by
        the recipient's TEESpaik public key>",
  "iv": "<hex of 16 random bytes>",
  "alg": "AESCBC",
  "cipherdata": "<BASE64 encoded encrypted TA personalization
                data>"
}
```

14.6. TA Trust Check at TEE

A TA binary is signed by a TA signer certificate. This TA signing certificate/private key belongs to the SP, and may be self-signed (i.e., it need not participate in a trust hierarchy). It is the responsibility of the TAM to only allow verified TAs from trusted SPs into the system. Delivery of that TA to the TEE is then the responsibility of the TEE, using the security mechanisms provided by the OTrP.

We allow a way for an (untrusted) application to check the trustworthiness of a TA. OTrP Broker has a function to allow a Client Application to query the information about a TA.

An application in the Rich O/S may perform verification of the TA by verifying the signature of the TA. The GetTAInformation function is available to return the TEE supplied TA signer and TAM signer information to the application. An application can do additional trust checks on the certificate returned for this TA. It might trust the TAM, or require additional SP signer trust chaining.

14.7. One TA Multiple SP Case

A TA for multiple SPs must have a different identifier per SP. A TA will be installed in a different SD for each respective SP.

14.8. OTrP Broker Trust Model

An OTrP Broker could be malware in the vulnerable REE. A Client Application will connect its TAM provider for required TA installation. It gets command messages from the TAM, and passes the message to the OTrP Broker.

The OTrP is a conduit for enabling the TAM to communicate with the device's TEE to manage SDs and TAs. All TAM messages are signed and sensitive data is encrypted such that the OTrP Broker cannot modify or capture sensitive data.

14.9. OCSF Stapling Data for TAM Signed Messages

The GetDeviceStateRequest message from a TAM to a TEE shall include OCSF stapling data for the TAM's signer certificate and for intermediate CA certificates up to the root certificate so that the TEE can verify the signer certificate's revocation status.

A certificate revocation status check on a TA signer certificate is OPTIONAL by a TEE. A TAM is responsible for vetting a TA and the SP before it distributes them to devices. A TEE will trust a TA signer certificate's validation status done by a TAM when it trusts the TAM.

14.10. Data Protection at TAM and TEE

The TEE implementation provides protection of data on the device. It is the responsibility of the TAM to protect data on its servers.

14.11. Privacy Consideration

Devices are issued with a unique TEE certificate to attest the device's validity. This uniqueness also creates a privacy and tracking risk that must be mitigated.

The TEE will only release the TEE certificate to a trusted TAM (it must verify the TAM certificate before proceeding). OTrP is designed such that only a TAM can obtain the TEE device certificate and firmware certificate - the GetDeviceState message requires signature checks to validate the TAM is trusted, and OTrP delivers the device's certificate(s) encrypted such that only that TAM can decrypt the response. A Client Application will never see the device certificate.

An SP-specific TEE SP AIK (TEE SP Anonymous Key) is generated by the protocol for Client Applications. This provides a way for the Client Application to validate some data that the TEE may send without requiring the TEE device certificate to be released to the client device rich O/S , and to optionally allow an SP to encrypt a TA for a target device without the SP needing to be supplied with the TEE device certificate.

14.12. Threat Mitigation

A rogue application may perform excessive TA loading. An OTrP Broker implementation should protect against excessive calls.

Rogue applications might request excessive SD creation. The TAM is responsible to ensure this is properly guarded against.

Rogue OTrP Broker could replay or send TAM messages out of sequence: e.g., a TAM sends update1 and update2. The OTrP Broker replays update2 and update1 again, creating an unexpected result that a client wants. "dsihash" is used to mitigate this. The TEE MUST store DSI state and check that the DSI state matches before it does another update.

Concurrent calls from a TAM to a TEE MUST be handled properly by a TEE. If multiple concurrent TAM operations take place, these could fail due to the "dsihash" being modified by another concurrent operation. The TEE is responsible for resolve any locking such that one application cannot lock other applications from using the TEE, except for a short term duration of the TAM operation taking place. For example, an OTrP operation that starts but never completes (e.g. loss of connectivity) must not prevent subsequent OTrP messages from being executed.

14.13. Compromised CA

A root CA for TAM certificates might get compromised. Some TEE trust anchor update mechanism is expected from device OEMs. A compromised intermediate CA is covered by OCSP stapling and OCSP validation check in the protocol. A TEE should validate certificate revocation about a TAM certificate chain.

If the root CA of some TEE device certificates is compromised, these devices might be rejected by a TAM, which is a decision of the TAM implementation and policy choice. Any intermediate CA for TEE device certificates SHOULD be validated by TAM with a Certificate Revocation List (CRL) or Online Certificate Status Protocol (OCSP) method.

14.14. Compromised TAM

The TEE SHOULD use validation of the supplied TAM certificates and OCSP stapled data to validate that the TAM is trustworthy.

Since PKI is used, the integrity of the clock within the TEE determines the ability of the TEE to reject an expired TAM certificate, or revoked TAM certificate. Since OCSP stapling includes signature generation time, certificate validity dates are compared to the current time.

14.15. Certificate Renewal

TFW and TEE device certificates are expected to be long lived, longer than the lifetime of a device. A TAM certificate usually has a moderate lifetime of 2 to 5 years. A TAM should get renewed or rekeyed certificates. The root CA certificates for a TAM, which are embedded into the trust anchor store in a device, should have long lifetimes that don't require device trust anchor update. On the other hand, it is imperative that OEMs or device providers plan for support of trust anchor update in their shipped devices.

15. Acknowledgements

We thank Alin Mutu for his contribution to many discussion that helped to design the trust flow mechanisms, and the creation of the flow diagrams. We also thank the following people (in alphabetical order) for their input and review: Sangsu Baek, Rob Coombs, Dapeng Liu, Dave Thaler, and Pengfei Zhao.

16. References

16.1. Normative References

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Appendix A. Sample Messages

A.1. Sample Security Domain Management Messages

A.1.1. Sample GetDeviceState

A.1.1.1. Sample GetDeviceStateRequest

The TAM builds a "GetDeviceStateTBSRequest" message.

```
{
  "GetDeviceStateTBSRequest": {
    "ver": "1.0",
    "rid": "8C6F9DBB-FC39-435c-BC89-4D3614DA2F0B",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "ocspdat": "c2FtcGx1IG9jc3BkYXQgQjY0IGVuY29kZWQgQVNOMQ==",
    "icaocspdat": "c2FtcGx1IGl1jYW9jc3BkYXQgQjY0IGVuY29kZWQgQVNOMQ==",
    "supportedsigalgs": "RS256"
  }
}
```

The TAM signs "GetDeviceStateTBSRequest", creating "GetDeviceStateRequest"

```
{
  "GetDeviceStateRequest": {
    "payload": "ewoJIKdlldERldmljZVN0YXRlVEJTUmVxdWVzdCI6IHsKCQkidmVyIjogIjEuMCIsCgkJInJpZCI6IHs4QzZGOURCQilGQzM5LTQzNWmtQkM4OS00RDM2MTREQTJGMEJ9LAoJCSJ0aWQiOiAieZRGNDU0QTdGLTAwMkQtNDElNy04ODRFLUIwREQxQTA2QThBRX0iLAoJCSJvY3NwZGF0IjogImMyRnRjR3hsSUc5amMzQmtZWFFnUWpZME1HVnVZMjlrWldRZ1FWTk9NUT09IiwKCQkiaWNhb2NzcGRhdCI6ICJjMkZ0Y0d4bElHbGpZVz1qYzNCa1lYUWdRalkwSUDWdVkyOWtaV1FnUVZOT01RPT0iLAoJCSJzdXBwb3J0ZWRzaWdhbGdzIjogIlJTMjU2IgoJfQp9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "x5c": ["ZXhhbXBsZSBBU04xIHNPZ251ciBjZXJ0aWZpY2F0ZQ==",
        "ZXhhbXBsZSBBU04xIENBIGNlcnRpZmljYXRl"]
    },
    "signature": "c2FtcGx1IHNPZ25hdHVyZQ"
  }
}
```

A.1.1.2. Sample GetDeviceStateResponse

The TAM sends "GetDeviceStateRequest" to the OTrP Broker

The OTrP Broker obtains "dsi" from each TEE. (In this example there is a single TEE.)

The TEE obtains signed "fwdata" from firmware.

The TEE builds "dsi" - summarizing device state of the TEE.

```

{
  "dsi": {
    "tfwdata": {
      "tbs": "ezRGNDU0QTdGLTAwMkQtNDE1Ny04ODRFLUIwREQxQTA2QThBRX0=",
      "cert": "ZXhhbXBsZSBGVyBjZXJ0aWZpY2F0ZQ==",
      "sigalg": "RS256",
      "sig": "c2FtcGx1IEZXIHNPZ25hdHVyZQ=="
    },
    "tee": {
      "name": "Primary TEE",
      "ver": "1.0",
      "cert": "c2FtcGx1IFRFRSBjZXJ0aWZpY2F0ZQ==",
      "cacert": [
        "c2FtcGx1IENBIGNlcnRpZmljYXRlIDE=",
        "c2FtcGx1IENBIGNlcnRpZmljYXRlIDI="
      ],
      "sdlist": {
        "cnt": "1",
        "sd": [
          {
            "name": "default.acmebank.com",
            "spid": "acmebank.com",
            "talist": [
              {
                "taid": "acmebank.secure.banking",
                "taname": "Acme secure banking app"
              },
              {
                "taid": "acmebank.loyalty.rewards",
                "taname": "Acme loyalty rewards app"
              }
            ]
          }
        ]
      },
      "teeaiklist": [
        {
          "spaik": "c2FtcGx1IEFTTjEgZW5jb2RlZCBQS0NTMSBwdWJsaWNrZXk=",
          "spaiktype": "RSA",
          "spid": "acmebank.com"
        }
      ]
    }
  }
}

```

The TEE encrypts "dsi", and embeds it into a "GetDeviceTEEStateTBSResponse" message.

```

{
  "GetDeviceTEESStateTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{8C6F9DBB-FC39-435c-BC89-4D3614DA2F0B}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "signerreq": "false",
    "edsi": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0K",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMga2V5LCB1c2luZyBSU0ExXzUgcGFkZGluZW"
        }
      ],
      "iv": "ySGmfZ69YlcEilNr5_SGbA",
      "ciphertext":
        "c2FtcGx1IGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZW50cGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGx1IGF1dGhlbnRpdY2F0aW9uIHRhZW"
    }
  }
}

```

The TEE signs "GetDeviceTEESStateTBSResponse" and returns it to the OTrP Broker. The OTrP Broker encodes "GetDeviceTEESStateResponse" into an array to form "GetDeviceStateResponse".

```

{
  "GetDeviceStateResponse": [
    {
      "GetDeviceTEEStateResponse": {
        "payload":
          "ewogICJHZXREZXZpY2VURUVTdGF0ZVRVCU1Jlc3Bvb3N1IjogewogICAgInZlciI6
          ICixLjAiLAogICAgInN0YXR1cyI6ICJwYXNzIiwKICAgICJyaWQiOiAiezhDNkY5
          REJCLUZDMzktNDM1Yy1CQzg5LTREMzYxNERBMkYwQn0iLAogICAgInRpZCI6ICJ7
          NEY0NTRBN0YtMDAyRC00MTU3LTg4NEUtQjBERDFBMDZBOEFFfSIsCgkic2lnbmVy
          cmVxIjoizMfsc2UiLAogICAgImVkc2kiOiB7CiAgICAgICJwcm90ZWN0ZWQiOiAi
          ZXlKbGJtTWlPaUpCTVRJNFwSkRMVWhUTWpVMkluMESiLAogICAgICAicmVjaXBp
          ZW50cyI6IFsKICAgICAgICB7CiAgICAgICAgICAiaGVhZGVyIjoigewogICAgICAg
          ICAgImFsZyI6ICJSU0ExXzUiCiAgICAgICAgfSwKICAgICAgICAiZW5jcnldGVk
          X2tleSI6CiAgICAgICAgIogogICAgICAgIFFVVLjRNVEk0SUNoRFJvc3BJR3RsZVN3
          ZlpXNWpjbmx3ZEdWa01lZHBkR2dnVkdZOTk1GS1RRU0J3ZFdkc2FXTWcKICAgICAg
          ICBhMlY1TENCMWMybHVaeUJTVTBFeFh6VWdjR0ZrWkdsdVp3IogogICAgICAgIH0K
          ICAgICAgXSwwKICAgICAgImI2IjoigInlTR2lmWjY5WWxjRWlsTnI1X1NHYkEiLAog
          ICAgICAiY2lwaGVydGV4dCI6CiAgICAgICIKICAgICAgYzJGdGNHeGxJR1J6YVNC
          allYUmhJR1ZlWTNKNWNIUmxaQ0IzYVhSb0lFRkZVekV5T0NCclpYa2dabkp2YlNC
          eVpXCI6ICAgICAgIE5wY0dsbGJuUnpMbVZlWTNKNWNIUmxaRjlyWlhrIiwKICAgICAg
          InRhZyI6ICJjMkZ0Y0d4bElHRjFkR2hsYm5ScFkyRjBhVzllSUhSaFp3IogogICAg
          fQogIH0KfQ",
        "protected": "eyJhbGciOiJSUzI1NiJ9",
        "signature": "c2FtcGx1IHNPZ25hdHVyZQ"
      }
    ]
  }
}

```

The TEE returns "GetDeviceStateResponse" back to the OTrP Broker, which returns message back to the TAM.

A.1.2. Sample CreateSD

A.1.2.1. Sample CreateSDRequest

```

{
  "CreateSDTBSRequest": {
    "ver": "1.0",
    "rid": "req-01",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": "false",
    "dsi": "Iu-c0-fGrpMmzbbttiWI1U8u7wMJE7IK8wkJpsVuf2js",
    "content": {
      "spid": "bank.com",
      "sdname": "sd.bank.com",
      "spcert": "MIIDFjCCAn-
gAwIBAgIJAIk0Tat0tquDMA0GCSqGSIb3DQEBAQUAMGwxCzAJBgNVBAYTAkTAMQ4wD
AYDVQQIDAVTZW91bDESMBAGA1UEBwwJR3Vyby1kb25nMRAwDgYDVQQKDAdTb2xhY21l
hMRAwDgYDVQQLDAdTb2xhY21lMRUwEwYDVQQDDAxTb2xhLWNpYS5jb20wHhcNMTUwN
zAyMDg1MTU3WhcNMjAwNjMwMDg1MTU3WjBzMQswCQYDVQQGEwJLUjEOMAwGA1UECAw
FU2VvdWwxEjAQBgNVBAcMCUd1cm8tZG9uZzEQMA4GA1UECgwHU29sYWNpYTEQMA4GA
1UECwwHU29sYWNpYTEVMBMGGA1UEAwwMU29sYS1jaWEuY29tMIGfMA0GCSqGSIb3DQE
BAQUAAAGNADCBiQKBgQDYWLRff2OFMEciwSYsyhaLY4kslaWcXA0hCWJRaFzt5mU-
lpSJ4jeu92inBbsXcI8PfRbaItsgW1TD1Wg4gQH4MX_YtaBoOepE--
3JoZZyPyCWS3AaLYWrDmqFXdbza01i8GxB7zz0gWw55bZ9jyzcl5gQzWSqMRpx_dca
d2SP2wIDAQABO4G_MIG8MIGGBgNVHSMefzB9oXCkbjBzMQswCQYDVQQGEwJLUjEOMA
wGA1UECAwFU2VvdWwxEjAQBgNVBAcMCUd1cm8tZG9uZzEQMA4GA1UECgwHU29sYWNp
YTEQMA4GA1UECwwHU29sYWNpYTEVMBMGGA1UEAwwMU29sYS1jaWEuY29tggkAiTRNq3
S2q4MwCQYDVDR0TBAlwADAQBgNVHQ8BAf8EBAMCBsAwFgYDVDR0LAQH_BAwwCgYIKwYB
BQUHAWMwDQYJKoZIhvcNAQEFBQADgYEAfMhRwEQ-
LDa907P1N0mcLORpo6fW3QuJfuXbRQRQGoXddXMKazI4VjbGaXhey7Bzvk6TZYDa-
GRiZby1J47UPaDQR3UiDzVvXwCOU6S5yUhNJsW_BeMViYj4lssX28iPpNwLUCVm1QV
THILI6afLCRWXXclcl1L5KGY290OwIdQ",
      "tamid": "TAM_x.acme.com",
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}

```

Below is a sample message after the content is encrypted and encoded

```

{
  "CreateSDRequest": {
    "payload": "
eyJDCmVhdGVTRFRFCU1JlcXVlc3QiOmsidmVyIjojMS4wIiwicmlkIjoicmVxLTAxIiwidG
lkIjojdHJhbi0wMSIsInRlZSI6IlNlY3VyYVFRFRSIsIm5leHRkc2kiOiJmYWxzZSIsImRz
aWhhc2giOiIyMmVmOWNkM2U3YzZhZTkzMjZjZGI2ZWQ4OTYyMzU1M2NiYmJjMGM5NDRLYz
gyYmNjMjQyNjliMTViOWZkYTNiIiwuY29udGVudCI6eyJwcm90ZWNOZWQiOiJlLUtBbkdW
dVktS0FuVHJpZ0p4Qk1USTRRMEpETFVoVE1qVTI0b0NkZlEiLCJyZWNPcGllbnRzIjpbey
JoZWfkZXIiOmsiYWNpIjojU1NBMV81In0sImVuY3J5cHRlZF9rZXkiOiJTuZuE2NTl4Q2FJ
cldUeUlsVTZPLUVsZzU4UUhvT1pCekxVRGptVG9vanBaWE54TVpBakRMcWtaSTdEUzhOVG
FIWHcxczFvZjgydVhsM0d6NlVWMkRoZDZJR2l6Y2VEDGtXclRwZDg4QVYwaWpEYTNXa3lk

```

dEpSVmlPOGdkSlEtV29NSUVJRUXzVGthblZCb25wQkF4ZHE0ckVMbl19TZl1liaFg4Zm9ub2
gxUVUifV0sIm12IjoiQXhZOERDdERhR2xzYkdsamIzUm9aUSIsImNpcGhlcnRleHQiOiI1
bmVWZXdm55UXprR3hZeWw5QlFrZTJVNjVaOHp4NDdlb3NzM3FETy0xY2FfNEpFY3NLcj
ZhNjF5QzBUb0doYnJOQWJXbVRSemMwsXB5bTF0ZjdGemp4UlhbATZBYnVSM2gzSUPRS1Bj
UUVvRUlkZ2tWX0NaZTM2eTBkVDBpRFBMc1g0QzFkb0dmMEDvaWViRC1yVUg1VUteY3BsTW
91tjZvUnFyd0dnNUhxLTJXM3B4MULzY0h4SktRZm11dkYxMTJ4ajBmZFNZX0N2WFE1NTJr
TVRDUW1ZbzRPaGF2R0ZvaG9TZVNaGZSVG1LYWp3OThkTzdhdREdrUEpRU1BtYVHVHw1lEMW
JXd01nMXFRV3RPd19EZ1IyZDNzTzVUN0pQMDJDUfprVXBiQ3dZYVcybW9HN1c2Z1c2U3V5
Q2lpd2pQWmZSqmIzSktTVTFTd1kxYXZvdW02OWctaDB6by12TGZvbHRRWFV2LVdPTXZTY0
JzR25NRzZYznMzbXlTWnJlWTNRR09wVVRzdjFCQ0JqSTJpdjkw2U2aXFCcVpxQVBxbzdi
ajYwVlJGQzZPT1NLZEXGQTIyU3pqRHo1dmtntXNEaHkwSzlDeVhYN1Z6MkNLTXJvQjNiUE
xZFZF9abtZuVWlkTFN5cVJ5cXJxTmVnN1lmQng3aV93X0dzRW9rX1VYZXd6RGtneHp6RjZj
XzZ6S0s3UFktVnVmYUo0Z2dHZmlpOHEwMm9RZ1VEZTB2Vm1FWDC0c2VQXZRxakVpZVVOYm
xBZE9sS2dBWlFGdEs4dy1xVUMzSzVGTjRoUG9yDeC2b3lPVUpOQTVFZV2Qy1jR2tMcTNQ
UG1GRmQyaUtOTELCTEJzVWl6c1h3RERvZVA5SmktWgt5ZEQtREN1SHdpCno0OEEDNNWVLSj
Q5WVdqRUtFQko2T01NNUNmZH4cDNmVG1uUTdfTXcwZ3FZVDRiOUJJSnBfwjA3TTctNUPe
emg0czhyU3dsQzFXU3V2RmhRWlJCcXJtX2RaUlRiB0VaZldXc1VCSWVNWWdxNG1zb0JqTj
NXSzhnRWYwZGI5a3Z6UG9LYmpJRy10UUE2R2l1X3pHaFVfLXFBV1lLemVKMDZ6djRIWlBO
dHktQXRyTGF0WGhtUTdOQlVrX0hvbjdOUWxhU1g1ZHVNVmN4bGs1ZHVrWFZNMDgxa09wYV
kzbdliQVffYvHtM0FNAffTTTVsT3dnTDZJazFPYVpaTGfMLUE3eJlITnLESmFEWTVhakZK
TWFdV1lfoG94Y1NoQUktNXA2MmNuT0xzV0dNWNKTLBGVTZpcWlMR19oc3JfN1NKMURhbd
VtQ0YycnBJLUItMlhuckxZR01ZS0NEZ2V2dGFnbilDVUV6RURwR3ozQ2VLcWdQU0Vqd3BK
NOM3NXduYt1CSmtTUKpOdNla3hoWE1rcnNEazRHVVpMSDdQYzFYZHdRTXhxdWpZnmXJSV
EycjM1NWETVkotWHdPcFpfY3RPdW96LTA4WHdYQ3RkTEliSFFVTG40RjLMRTtanU0dUxS
bjNSc043WWZ1S3dCVmVEZDJ6R3NBY0s5SV1Da3hOaDk3dDluYW1iMDZqSXVOWXF5QkhWRU
9nTkhicilrMDY1bW9OVk5lVVUyMm5OdVNKS0ZxVnIxT0dKNGVfNXkzYkNwTmxTeEFPV1Bn
RnJzU0Flc2JJOWw4eVJtVTAwenJYdGc4OWt5SjlCcXN2eXA1RE8wX2FtS1JyMXB1MVJVWF
lFZzB2ampKS1FSdDVZbXRUNFJzaWpQdGRDWDg3UUxJaUdSY0hDdlJzUzZSdJESmNYR1ht
UGQyc0ZmNUZyNnJnMkFzX3BmUHN3cnF1WlAxbVFLc3RPMFVktXpqMTlyb2N1NHVxVXlHUD
lWWU54cHVnWVdNSjRYb1dRelJtWGNTUEJ4VETnenFPS2s3UnRzWWVMNX14LVM4NjV0cHVz
dTA0bXpzYUJRZ21od1ZFVXBRdWNrcG1YWkNLNLH1JUXktaHNFQUlJSmVxdFB3dVAySXF0X2
I5dlk0bzExeXdzeXhZdmp2RnKNK0VVZU1MaGE2R2dSanBSbnU5RWIzRn1JZ0U5M0VVNEEW
T0lUMWlOSGNRYWc0eWtOc3dPdkxQbjZIZ21zQ05ESlgwekc2RlFDMTZRdjBSQ25SVTdfV2
VvblhSTUZWUzZRZ1JiSk45R1NMckN5bklJSWxUCDBxNHBaS05zM0tqQ2tMUzJrb3Bhd2Y0
WF9BU1lmTko3a0s5eW5BR0dCcKtnUWJNRWVxUEFmMDBKM1YtVXpuU1JMzmQ4SGs3Y2JEdk
5RQlhHQW9BR0ViaGRwVUC0RXFwMlVyQko3dEtyUUVSR1h4RTVsOFNHY2czQ1RmN2Zoazdx
VEFBVjVsWEFnoUtoUDF1clZRZk1fUlBleHfNTG9WQVVKV2syQkF6WF9uSEhkVVhaSVBIOG
hLeDctdEFRV0dTWUd0R2FmanZJZzI2c082TzloQWZVd3BpSV90MzF6SkZORDU0OTZURHBz
QmNnd2dMLU1UcVhCRUJ2NEhvQld5SG1DVjVFMUwiLCJ0YWciOiJkbXlEeWZJVlNjU1Ren
ExOEgybFRiEEMxbl9HZEtrdnZNMDJUChdsYzQwIn19fQ",
"protected": "e-KAnGFsZ-KAnTrigJxSUzI1NuKAnX0", //RSAwithSHA256
"header": {
 "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
 "signer": "
 MIIC3zCCAkigAwIBAgIJAJf2ffkE1BYOMA0GCSqGSIB3DQEBBQUAMF0xZAJBgNVBA
 YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxpZm9ybmlhMSEw
 HwYDVQQKBHJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
 cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEwJVUzETMBEGA1UECAwKQ2FsaWZvcml5p

```

    YTETMBEGA1UEBwwKQ2FsaWZvcn5pYTEhMB8GA1UECgwYSW50ZXJuZXQgV2lkZ2l0cy
    BQdHkgTHRkMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
    meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
    AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgpO94h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
    c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
    ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGpMHQGA1UdIwRtMGuhXqRcMFoxCzAJBgNVBA
    YTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxpZm9ybmlhMSEw
    HwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGSCCQCX9nxZBNQWDjAJBgNVHR
    MEAjaAAMA4GA1UdDwEB_wQEAWIGDAWBGNVHSubAf8EDDAKBggrBgEFBQcDAzANBgkq
    hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
    SZlMdyIZV8fwdEmD90IvtMHgtzK-
    9wo6Aibj_rVIpXGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
    UBFyfrdT5GjqLlnqH3a_Y3QPscuCjg"
  },
  "signature": "nuQUsCTEBLeaRzuwd7q1iPIYEJ2eJfur05sT5Y-
  N03zFRcv1jvrqMHTx_pw0Y9YWjpmoWfpfelhwGEko9SgeeBnznmkZbp7kjs6MmX4CKz
  9OApe3-VI7yL9Yp0WNdRh3425eYfuapCy3lcXFln5JBAUnU_OzUg3RWxcU_yGnFsw"
}
}

```

A.1.2.2. Sample CreateSDResponse

```

{
  "CreateSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-01",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM",
      "sdname": "sd.bank.com",
      "teespaik": "AQABjY9KiwH3hkMmSAAN6CLXot525U85WNlWKAQz5TOdfe_CM8h-
      X6_EHX1gOXoyRXaBiKmqWb0YZLCABTwlytdXy2kWa525imRho8Vqn6HDGsJDZPDru9
      GnZR8pZX5ge_dWXB_uljMvDttc5iAWEJ8ZgcpLGtBTGLZnQoQbjtn1lIE",
    }
  }
}

```

Below is the response message after the content is encrypted and encoded.

```

{
  "CreateSDResponse": {
    "payload": "
    eyJDcmVhdGVTRFRCU1Jlc3BvbmlIjp7InZlciI6IjEuMCIsInN0YXR1cyI6InBhc3Mi
    LCJyaWQiOiJyZXEtMDEiLCJ0aWQiOiJ0cmFuLTAxIiwIY29udGVudCI6eyJwcm90ZWNO
    ZWQiOiJlLUtBbkdwVktS0FuVHJpZ0p4Qk1USTRMEpETFVoVE1qVTI0b0NkZ1EiLCJy
    ZWNpcGllbnRzIjpbeyJoZWZkZXIiOiJ0c3R5bWV8IiwuImVudC5cHRlZF9r

```

```

ZXkiOiJOX0I4R3pldUlfN2hwd0wwTFpHSTkxVWVBbmXJRkJfcndmZU1yZERrWnFGak1s
VVhjdlI0XzhhOGhyeFI4SXR3aEtFZnVfRWVLRDBQb0dqQ2pCSHcxG1ULUN6eWhsbW5v
Slk3LXl1WnZzRkRpc2VNTkd0eGE0OGZJYUs2VWx5NUZMYXBCZVc5T1I5bmktOU9GQV9j
aFVuWW13b2Q4ZTJFa0Vpd0JEZ1EzMk0ifV0sIm12IjoiQXhZOERDdERhR2xzYkdsamIz
Um9aUSIsImNpcGhlcnRleHQiOiJsalh6Wk5JTmR1WjFaMXJHVElktjBiVUp1RDRVV2xT
QVptLWd6YnJINFVDYy1jMEFQenMtMwDWSFk4NTRUR3VMYkdyRmVHcDFqM2Fsb1lacWZp
ZnE4aEt3Ty16RF1BN2tmVFhBZHp6czM4em9xeG4zbHoyM2w1RU1GUWhrOHBRWTRYTHRw
M3ZBQWlnYn1rQ1Q3VS1CWDdWcjbacVNhYWZTQVZ4OFBLQ1RIU3hHN3hHVko0NkxxRzJS
RE54WXQ4RC1SQ3lZUi1zRTM0MUfKZldeC2FLaGRRbzJXc jNVN1hTOWFqaXJtWjdqTlJ4
cVRodHJBRWl1Y1ctOEJMdVFHWEZ1YUhlMTZrenJKUGl4d0VXbzJ4cmw4cmkwc3ZrChPl
Z2M3MET2Z0IONUVaNHZiNXR0YlUya25hN185QU1Wcm4wLUJaQ1Bnb280MWlFblhuNVJn
TXY2c2V2Y1JPQ2xHMnpWSjFoRkVLYjk2akeiLCJ0YWciOiIzOTZISTk4Uk1NQnR0eDlo
ZUtsODROaVZLd0lJSzI0UET2Z1RGYzFrbeJzIn19fQ",
"protected": "e-KAnGFsZ-KAnTrigJxSUzI1NuKAnX0",
"header": {
  "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
  "signer": "
MIIC3zCCAkigAwIBAgIJAJf2ffKe1BYOMA0GCSqGSIb3DQEBBQUAMF0xCzAJ
BgNVBAYTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGQwHhcN
MTUwNzAyMDkwMTE4WWhcNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzET
MBEGA1UECAwKQ2FsaWZvcm5pYtETMBEGA1UEBwwKQ2FsaWZvcm5pYtEhMB8G
A1UECgwYSW50ZXJuZXQgV2lkZ2l0cyBQdHkgTHRkMIGfMA0GCSqGSIb3DQEB
AQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA
6b_ZI3c4cz8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGpMHQGA1UdIwRtMGUhxQRCMF0xCzAJ
BgNVBAYTA1VTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGSCCQCX
9nxZBNQWDjAJBGNVHRMEA jAAMA4GA1UdDwEB_wQEAWIGDAWBgNVH5SUBAf8E
DDAKBggrBgEFBQcDazANBgkqhkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4iv
em4cIckfxzTBBiPHCjrrjB2X8Ktn8GSZ1MdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVipxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fv
rJvnYAUBFyfrdT5GjqLlnqH3a_Y3QPscuCjg"
},
"signature": "jnJtaB0vFFwrE-qKOR3Pu9pf2gNoI1s67GgPCTq0U-
qrz97svKpuh32WgCP2MwCoQPEswsEX-nxhIx_siTe4zIPO1nBYn-
R7b25rQaF8708uAOOnBN5Y12Jk3laIbs-
hGE32aRZDhrVoyEdSvIFrT6AQqD20bIAZGqTR-za-900"
}
}

```

A.1.3. Sample UpdateSD

A.1.3.1. Sample UpdateSDRequest

```

{
  "UpdateSDTBSRequest": {
    "ver": "1.0",
    "rid": "1222DA7D-8993-41A4-AC02-8A2807B31A3A",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "tee": "Primary TEE ABC",
    "nextdsi": "false",
    "dsihash":
    "
    IsOvwpzDk8Onw4bCrsKTJsONwrbDrcKJYjVTw4vCu8OAw4JEw6zCgsK8w4JCacKxW8Kf
    w5o7",
    "content": { // NEEDS to BE ENCRYPTED
      "tamid": "id1.TAMxyz.com",
      "spid": "com.acmebank.spid1",
      "sdname": "com.acmebank.sdname1",
      "changes": {
        "newsdname": "com.acmebank.sdname2",
        "newspid": "com.acquirer.spid1",
        "spcert":
        "MIIDFjCCAn-
        gAwIBAgIJAik0Tat0tquDMA0GCSqGSIB3DQEBBQUAMGwxCzAJBgNVBAYTAkTAMQ4
        wDAYDVQQIDAVTZW91bDESMBAGAlUEBwwJR3Vyby1kb25nMRAwDgYDVQQKDAkTb2x
        hY2lhMRAwDgYDVQQLDAdTb2xhY2lhMRUwEwYDVQQDDAxTb2xhLWNpYS5jb20wHhc
        NMTUwNzAyMDg1MTU3WhcNMjAwNjMwMDg1MTU3WjBsMQswCQYDVQQGEwJLUjEOMAw
        GA1UECAwFU2VvdWwxEjAQBgNVBAcMCUdlcm8tZG9uZzEQMA4GA1UECgwHU29sYWN
        pYTEQMA4GA1UECwwHU29sYWNpYTEVMBMGAlUEAwWUMU29sYS1jaWEuY29tMIGfMA0
        GCSqGSIB3DQEBBQUAA4GNADCBiQKBgQDYWLrFf2OFMEciwSYsyhaLY4kslaWcXA0
        hCWJRaFzt5mU-
        lpSJ4jeu92inBbsXcI8PfRbaItsgW1TD1Wg4gQH4MX_YtaBoOepE--
        3JoZZyPyCWS3AaLYWrDmqFXdbzaO1i8GxB7zz0gWw55bZ9jyzcl5gQzWSqMRpx_d
        cad2SP2wIDAQABo4G_MIG8MIGGBgNVHSMefzB9oXCkbjBsMQswCQYDVQQGEwJLUj
        EOMAwGA1UECAwFU2VvdWwxEjAQBgNVBAcMCUdlcm8tZG9uZzEQMA4GA1UECgwHU2
        9sYWNpYTEQMA4GA1UECwwHU29sYWNpYTEVMBMGAlUEAwWUMU29sYS1jaWEuY29tgg
        kAiTRNq3S2q4MwCQYDVROTBAlwADA0BgNVHQ8BAf8EBAMCBsAwFgYDVRO1AQH_BA
        wwCgYIKwYBBQUHAWMwDQYJKoZIhvcNAQEFBQADgYEAfMhRwEQ-
        LDa9O7P1N0mcLORpo6fW3QuJfuXbRQRQGoXddXMKazI4VjbGaXhey7Bzvk6TZYDa
        -
        GRiZby1J47UPaDQR3UiDzVvXwCOU6S5yUhNJsW_BeMViYj4lssX28iPpNwLUCVm1
        QVTHILI6afLCRWXXclclL5KGY2900wIdQ",
        "renewteespaik": "0"
      }
    }
  }
}

```

A.1.3.2. Sample UpdateSDResponse

```
{
  "UpdateSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "1222DA7D-8993-41A4-AC02-8A2807B31A3A",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "content": {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
      "teespaik":
        "AQABjY9Kiwh3hkMmSAAN6CLXot525U85WNlWKAQz5TOdfe_CM8h-
        X6_EHX1gOXoyRXaBiKMqWb0YZLCABTwlytdXy2kWa525imRho8Vqn6HDGsJDZPDru9
        GnZR8pZX5ge_dWXB_uljMvDttc5iAWEJ8ZgcpLGtBTGLZnQoQbjtn1lIE",
      "teespaiktype": "RSA"
    }
  }
}
```

A.1.4. Sample DeleteSD

A.1.4.1. Sample DeleteSDRequest

The TAM builds message - including data to be encrypted.

```
{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "tee": "Primary TEE",
    "nextdsi": "false",
    "dsihash": "AAECAwQFBgcICQoLDA0ODwABAgMEBQYHCAkKCwwNDg8=",
    "content": ENCRYPTED {
      "tamid": "TAM1.com",
      "sdname": "default.acmebank.com",
      "deleteta": "1"
    }
  }
}
```

The TAM encrypts the "content".

```

{
  "DeleteSDTBSRequest": {
    "ver": "1.0",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "tee": "Primary TEE",
    "nextdsi": "false",
    "dsihash": "AAECAwQFBgcICQoLDA0ODwABAgMEBQYHCAkKCwwNDg8=",
    "content": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMga2V5LCB1c2luZyBSU0ExXzUgcGFkZGluZW"
        }
      ],
      "iv": "rW05DVmQX9ogelMLBIogIA",
      "ciphertext":
        "c2FtcGx1IGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZWNPcGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGx1IGF1dGhlbnRpY2F0aW9uIHRhZW"
    }
  }
}

```

The TAM signs the "DeleteSDTBSRequest" to form a "DeleteSDRequest"

```

{
  "DeleteSDRequest": {
    "payload": "
ewoJIkRlbGV0ZVNEVEJlTUUmVxdWVzdCI6IHsKCQkidmVyIjogIjEuMCIsCgkJInJp
ZCI6ICJ7NzEyNTUxRjUtREZCMY00M2YwLTlBNjMtNjYzNDQwQjkxRDQ5fSIsCgkJ
InRpZCI6ICJ7NEY0NTRBN0YtMDAyRC00MTU3LTg4NEUtQjBERDFBMDZBOEFFfSIs
CgkJInRlZSI6ICJQcmItYXJ5IFRFRSIsCgkJIm5leHRkc2kiOiAiZmFsc2UiLAoJ
CSJkc2loYXNoIjogIkFBRUNBdlFGQmdjSUNRb0xEQTBPRHdBQkFnTUUVUUVlIQ0Fr
S0N3d05EZzg9IiwKCQkiY29udGVudCI6IHsKCQkKJInByb3RlY3RlZCI6ICJleUps
YmlNaU9pSkJNVEk0UTBKRExVaFRNaUySW4wIiwKCQkKJInJlY2lwaWVudHMiOiBb
ewoJCQkKJImh1YWRlciI6IHsKCQkKJCQkiYWxnIjogIlJlJTQTFfNSIKCQkKJCX0sCgkJ
CQkiZW5jcnlwdGVkX2tleSI6ICJRVVZUTVRJNElDaERSVXNwSUd0bGVtd2daVzVq
Y25sd2RHVmtJSGRwZEbnZlZGt5JRkpUUVNCd2RXSnNhV0lnYTJWNuXzQjFjMmx1
WnlCU1UwRXhYelVnY0dGalpHbHVadyIKCQkKJfV0sCgkJCSJpdiiI6ICJyV081RFZt
UVg5b2dlbE1MQklvZ0lBIiwKCQkKJImNpcGhlcnRleHQiOiAiYzJGdGNHeGxJRlJ6
YVNCa1lYUmhJRlZlWTNKNWNIUmxaQ0IzYVhSb0lFRkZVekV5T0NCclpYa2dabkp2
YlNCeVpXTnBjR2xsYm5SekxtVnVZM0o1Y0hSbFpGOXJaWGsilaAoJCQkidGFniJog
ImMyRnRjR3hsSUdGMWRHaGxiblJwWTJGMGFjOjVJSFJoWnciCgkJfQoJfQp9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "x5c": ["ZXhhbXBsZSBBU04xIHNPZ251ciBjZXJ0aWZpY2F0ZQ==",
        "ZXhhbXBsZSBBU04xIENBIGNlcnRpZmljYXRl"]
    },
    "signature": "c2FtcGxlIHNPZ25hdHVyZQ"
  }
}

```

A.1.4.2. Sample DeleteSDResponse

The TEE creates a "DeleteSDTBSResponse" to respond to the "DeleteSDRequest" message from the TAM, including data to be encrypted.

```

{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "content": ENCRYPTED {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
    }
  }
}

```

The TEE encrypts the "content" for the TAM.

```

{
  "DeleteSDTBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "{712551F5-DFB3-43f0-9A63-663440B91D49}",
    "tid": "{4F454A7F-002D-4157-884E-B0DD1A06A8AE}",
    "content": {
      "protected": "eyJlbmMiOiJBMTI4Q0JDLUhTMjU2In0K",
      "recipients": [
        {
          "header": {
            "alg": "RSA1_5"
          },
          "encrypted_key":
            "QUVTMTI4IChDRUspIGtleSwgZW5jcnlwdGVkIHdpdGggVFNNIFJTQSBwdWJsaWMg
            a2V5LCB1c2luZyBSU0ExXzUgcGFkZGluZw"
        }
      ],
      "iv": "ySGmfZ69YlcEilNr5_SGbA",
      "ciphertext":
        "c2FtcGx1IGRzaSBkYXRhIGVuY3J5cHRlZCB3aXRoIEFFUzEyOCBrZXkgZnJvbSB5ZW
        NpcGllbnRzLmVuY3J5cHRlZF9rZXk",
      "tag": "c2FtcGx1IGFldGhlbnRpY2F0aW9uIHRhZw"
    }
  }
}

```

The TEE signs "DeleteSDTBSResponse" to form a "DeleteSDResponse"

```

{
  "DeleteSDResponse": {
    "payload": "
ewoJIkRlbGV0ZVNEVEJtUmVzcG9uc2UiOiB7CgkJInZlciI6ICIxLjAiLAoJCSJz
dGF0dXMiOiAicGFzcyIsCgkJInJpZCI6ICJ7NzEyNTUxRjUtREZCMY00M2YwLTlB
NjMtNjYzNDQwQjkxRDQ5fSIsCgkJInRpZCI6ICJ7NEY0NTRBN0YtMDAyRC00MTU3
LTg4NEUtQjBERDFBMDZBOEFFfSIsCgkJImNvbnRlbnQiOiB7CgkJCSJwcm90ZWNO
ZWQiOiAiZXlKbGJtTWlPaUpCTVRJNFewSkRMVWhUTWpVMkluMEsiLAoJCQkicmVj
aXBpZW50cyI6IFt7CgkJCQkiaGVhZGVyIjogewoJCQkJCSJhbGciOiAiUlNBMV81
IgoJCQkJfSwKCQkJCSJlbnNyeXB0ZWRfa2V5IjogIlFVVlRNVEk0SUNoRFJvc3BJ
R3RsZVN3ZlpxNWpjbmx3ZEdWa0lIZHBkr2dnVkJOTklGS1RRU0J3ZFdKc2FXTWdh
MlY1TENCMMMybHVaeUJTVTBFeFh6VWdjR0ZrWkdsdVp3IgoJCQl9XSwwKCQkJIml2
IjogInlTR2lmWjY5WWxjRWlsTnI1X1NHYkEiLAoJCQkiY2lwaGVydGV4dCI6ICJj
MkZ0Y0d4bElHUUnphU0JrWVhSaElHVnVZM0o1Y0hSbFpDQjNhWFJvSUVGRlV6RXlP
Q0JyWlhrZlpuSnZiU0J5WldOcGNHbGxib1J6TG1WdVksSjVjSFJsWkY5clpYayIs
CgkJCSJ0YWciOiAiYzJGdGNHeGxJR0YxZEdobGJuUnBZMkYwYVc5dUllUmhadyIK
CQl9Cgl9Cn0",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "signature": "c2FtcGxlIHNPZ25hdHVyZQ"
  }
}

```

The TEE returns "DeleteSDResponse" back to the OTrP Broker, which returns the message back to the TAM.

A.2. Sample TA Management Messages

A.2.1. Sample InstallTA

A.2.1.1. Sample InstallTAResponse

```

{
  "InstallTATBSRequest": {
    "ver": "1.0",
    "rid": "24BEB059-0AED-42A6-A381-817DFB7A1207",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "tee": "Primary TEE ABC",
    "nextdsi": "true",
    "dsihash":
    "
    IsOvwppzDk8Onw4bCrsKTJsONwrbDrcKJYjVTw4vCu80Aw4JEw6zCgsK8w4JCacKxW8Kf
    w5o7",
    "content": {
      "tamid": "idl.TAMxyz.com",
      "spid": "com.acmebank.spid1",
      "sdname": "com.acmebank.sdname1",
      "taid": "com.acmebank.taid.banking"
    },
    "encrypted_ta": {
      "key":
      "mLBjodcE4j36y64nC/nEs694P3XrLAOokjisXIGfs0H7lOEmT5FtaNDYEMcg9RnE
      ftlJGHO7N0lgcNcjoXBmeuY9VI8xzrsZM9gzH6VBKtVONSx0aw5IAFkNcyPZwDdZ
      MLwhvrzPJ9Fg+bZtrCoJz18PUz+5aNl/dj8+NM85LCXXcBlZF74btJer1Mw6ffzT
      /grPiEQTeJ1nEm9F3tyRsvctInsnPJ3dEXv7sJXMrhRKAeZsqKzGX4eiZ3rEY+FQ
      6nXULC8cAj5XTKpQ/EkZ/iGgS0zcXR7KUJv3wFEmtBtPD/+ze08NILLmxM8olQFj
      //Lq0gGtq8vPC8r0oOfmbQ==",
      "iv": "4F5472504973426F726E496E32303135",
      "alg": "AESCBC",
      "ciphertadata":
      ".....0x/5KGCXWfg1Vrjm7zPVZqtYZ2EovBow+7EmfOJ1tbk.....=",
      "cipherpdata": "0x/5KGCXWfg1Vrjm7zPVZqtYZ2EovBow+7EmfOJ1tbk="
    }
  }
}

```

A.2.1.2. Sample InstallTAResponse

A sample to-be-signed response of InstallTA looks as follows.

```

{
  "InstallTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "24BEB059-0AED-42A6-A381-817DFB7A1207",
    "tid": "4F454A7F-002D-4157-884E-B0DD1A06A8AE",
    "content": {
      "did": "MTZENTE5Qzc0Qzk0NkUxMzYxNzk0NjY4NTc3OTY4NTI=",
      "dsi": {
        "tfwdata": {

```

```

    "tbs": "ezRGNDU0QTdGLTAwMkQtNDE1Ny04ODRFLUIwREQxQTA2QThBRX0="
    "cert": "ZXhhbXBsZSBGVyBjZXJ0aWZpY2F0ZQ==",
    "sigalg": "U1MyNTY=",
    "sig": "c2FtcGx1IEZXIHNPZ25hdHVyZQ=="
  },
  "tee": {
    "name": "Primary TEE",
    "ver": "1.0",
    "cert": "c2FtcGx1IFRFRSBjZXJ0aWZpY2F0ZQ==",
    "cacert": [
      "c2FtcGx1IENBIGNlcnRpZmljYXRlIDE=",
      "c2FtcGx1IENBIGNlcnRpZmljYXRlIDI="
    ],
    "sdlist": {
      "cnt": "1",
      "sd": [
        {
          "name": "com.acmebank.sdname1",
          "spid": "com.acmebank.spid1",
          "talist": [
            {
              "taid": "com.acmebank.taid.banking",
              "taname": "Acme secure banking app"
            },
            {
              "taid": "acom.acmebank.taid.loyalty.rewards",
              "taname": "Acme loyalty rewards app"
            }
          ]
        }
      ]
    }
  },
  "teeaiklist": [
    {
      "spaik":
        "c2FtcGx1IEFTTjEgZW5jb2RlZCBQS0NTMSBwdWJsaWNrZXk=",
      "spaiktype": "RSA",
      "spid": "acmebank.com"
    }
  ]
}

```


A.2.2. Sample UpdateTA

A.2.2.1. Sample UpdateTAResponse

```

{
  "UpdateTATBSRequest": {
    "ver": "1.0",
    "rid": "req-2",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": " false",
    "dsihash": "gwjul_9MZks3pqUSN1-eLlaViwGXNAxk0AIKW79dn4U",
    "content": {
      "tamid": "TAM1.acme.com",
      "spid": "bank.com",
      "sdname": "sd.bank.com",
      "taid": "sd.bank.com.ta"
    },
    "encrypted_ta": {
      "key":
      "
      XzmAn_RDV3IozMwNWhiB6fmZlIs1YUvMKlQAv_UDoZ1fvGGsRGo9bT0A440aYMgLt
      GilKypoJjCgiJdaHgamaJgRSc4Je2otpnEEagsahvDNoarMCC5nGQdkRxW7Vo2NKG
      L892HGeHkJVshYmlcU1FQ-BhiJ4NAykFwlqC_oc",
      "iv": "AxY8DCtDaGlsbGljb3RoZQ",
      "alg": "AESCBC",
      "ciphernewtadata":
      "KHqOxGn7ib1F_14PG4_UX9DBjOcWkiAZhVE-U-
      67NsKryHGokeWr2spRWfdU2KWaaNncHoYGWetbCH7XyNbOFh28nzwUmstep4nHWbAl
      XZYTnkENcABPpuw_G3I3HADo"
    }
  }
}

{
  "UpdateTAResponse": {
    "payload":
    "
    eyJVCGRhdGVUQVRCU1JlcXVlc3QiOnsidmVyIjoMS4wIiwicmlkIjoicmVxLTiLCJ0
    aWQiOiJ0cmFuLTAxIiwidGVlIjoIU2VjdXJpVEVFfiwibmV4dGRzaSI6ImZhbHN1Iiw
    iZHNpaGFzaCI6Imd3anVsXzlnNWmtzM3BxVVNOMS1lTDFhVml3R1hOQXhrMEFJS1c3O
    WRuNFUiLCJjb250ZW50Ijp7InByb3RlY3RlZCI6ImV5SmxibU1pT2lKQk1USTRRMEp
    ETFVoVE1qVTJJbjAiLCJyZWNPcGlbnRzIjpbeyJoZWZkZXIiOnsiYWxnIjoIU1NB
    MV81In0sImVuY3J5cHRlZGF9rZXkiOiJYem1Bbl9SRFZrM0lvek13TldoaUI2Zmlab
    ElzMVlVdk1LbFFBdl9VRG9aMWZ2R0dzUkdvOWJUMEE0NDBhWU1nTHRHaWxLeXBv
    SmpDZ2lqZGFIZ2FtYU1nU1NjNEplMm90cG5FRWFnc2FodkROb2FyTUNDNW5HUWRr
    UnhXN1ZvMk5LZ0xBODkySEdlSGtKVnNoWW0xY1VsRlEtQmhpSjROQXlrRndscUNfb
    2MifV0sIm12IjoIQXhZOERDERhR2xzYkdsamIzUm9aUSIsImNpcGhlcnRleHQiOiJ
    IYITcwVXRZVetWQmtXRFJuMi0w
  "
  }
}

```

```

SF9IdkZtazl5SGtoVV91bk1OLWc1T3BqLWF1NGFUb21xWklMYzVzYTdENnZSjF6eW04
QWlJOEJIVXFqc2l5Z0tOcC1HdURJUjFzRXc0a2NhMVQ5ZENuU0RydHhSUfhESVdrZmt3
azZlRlNQWiIsInRhZyI6Im9UN01UTE41eWtBTfBoTDR0aUh6T1pPTGVFeU9xZ0NWaEM5
MXpkclldMU0UifSwiZW5jcnlwdGVkX3RhIj7ImtleSI6Ilh6bUFuX1JEVmszSW96TXdO
V2hpQjZmbVpsSXMxWV2TUtsUUF2X1VEbl0xZnZHR3NSR285Y1QwQTQ0MGFZTWdMdEdp
bEt5cG9KakNnaWpkYUhnYW1hSmdSU2M0SmUyb3RwbkVfYWdzYW1h2RE5vYXJNQM1bkdR
ZGtSeFc3Vm8yTktnTEE4OTJIR2Vla0pWc2hZbTFjVWxGUS1CaGlKNE5BeWtGd2xxQ19v
YyIsIm12Ijo1QXhZOEERDdERhR2xzYkdsamIzUm9aUSIsImFsZyI6IkFFU0NCQyIsImNp
cGhlcm5ld3RhZGF0YSI6IktIcU94R243aW1xR18xNFBHNF9VWD1EQmpPY1draUFaaFZF
LVUtNjdOc0tyeUhb2t1V3Iyc3BSV2ZkVTJLV2FhTm5jSG9ZR3dFdGJDSDDYeU5iT0Zo
MjhuendVbXN0ZXh0bkhXYkFsWFpZVE5rRU5jQUJQcHV3X0czSTNIQURvIn19fQ",
"protected": " eyJhbGciOiJSUzI1NiJ9",
"header": {
  "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
  "signer": "
MIIC3zCCAkigAwIBAgIJAJf2fFkE1BYOMA0GCSqGSIb3DQEBAQUAMF0xMzA1BjBBAQ
YTA1VTMRMwEQYDVQIDApDyWxpZm9ybmlhMRMwEQYDVQIDApDyWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcmlldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcm5p
YTEtMBEGA1UEBwwKQ2FsaWZvcm5pYTEhMB8GA1UECgwYSW50ZXJuZXQgV2lkZ2l0cy
BQdHkgTHRkMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfeD4EazdMBp5fmgLRGdCYMcI6bgpO94h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGPMHQA1UdIwRtMGUhxqRcMF0xMzA1BjBBAQ
YTA1VTMRMwEQYDVQIDApDyWxpZm9ybmlhMRMwEQYDVQIDApDyWxpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcmlldCBXaWRnaXRzIFB0eSBMdGSCCQCX9nxZBNQWDjA1BjBBAQ
MEAJAAMA4GA1UdDwEB_wQEAWIGwDAWBgNVHSAf8EDDAKBggrBgEFBQcDAZANBgkq
hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
SZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVIpxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
UBFyfrdT5GjqLlnqH3a_Y3QPscuCjg"
},
"signature": "inB1K6G3EAhF-
FbID83UI25R5Ao8MI4qfrbrmf0UQhjM3O7_g3l6XxN_JkHrGQaZr-
myOkGPVM8BzbUZW5GqxNZwFXwMeaoCjDKc4Apv4WZkd1qKJxkg1k5jaUCfJz1Jmw_XtX
6MHhrLh9ov03S9Ptut1VAQ0FVUB3qFivjSnNU"
}
}

```

A.2.2.2. Sample UpdateTAResponse

```
{
  "UpdateTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-2",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}
```

```

{
  "UpdateTAResponse": {
    "payload": "
eyJVcGRhdGVUQVRCU1Jlc3BvbmlIjp7InZlciI6IjEuMCIsInN0YXR1cyI6InBhc3Mi
LCJyaWQiOiJyZXEtMiIsInRpZCI6InRyYW4tMDEiLCJjb250ZW50Ijp7InByb3RlY3Rl
ZCI6ImV5SmxibUlpT2lKQk1USTRRMEpETFVoVE1qVTJJbjAiLCJyZWNPcGllbnRzIjpb
eyJoZWFKZlZlIiOnsiYWxnIjoilU1NBMV81In0sImVuY3J5cHRlZF9rZXkiOiJFaGUxLUJB
UUDJLTNEMFNHdXFGY01MZDJtd0gxQmluRndYQWx1M1FxFVFXZ1RRVm55SUowNFc2MnBK
YWVSREFkeTU0R0FSVjBrVzQ0RGw0MkdUUlhhbE1EZ3BYdXdlWl0clJVV0tNNldCZ2N3
VXVGQTRUR3gwU0I1NTZCd192dnBNAfdMXh2c2FHdFBAQmwxTnZjbXNlbzBhY3FobXlu
bzBDTmF5SVAtX1Uifv0sIm12IjoilQXhZOERDdERhR2xzYkdsamIzUm9aUSIsImNpcGhl
cnRleHQiOiJwc2o2dGtyaGJXM0lmVElMeE9GMU5HdFUtCTFmeVBidV9KwK9jbklYcWIw
eTNPOHN6OTItaWpWR1ZyRW5WbGlsY1FYeWFnZTNyX1JGdEkwV3B4UmRodyIsInRhZyI6
Ik0zb2dnNk11MVJYMUMybEZvaG5rTkN5b25qNjd2TDNqd2RrZXhFdUlpaTg1fX19",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
      "signer": "
MIIC3zCCAkigAwIBAgIJAJf2ffkE1BYOMA0GCSqGSIB3DQEBBQUAMF0xChAJBgNVBA
YTA1VTMRMwEQYDVQIDApdYXpZm9ybmlhMRMwEQYDVQQHDApYXpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4WWh
cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcml5p
YTETMBEGA1UEBwwKQ2FsaWZvcml5pYTeHMB8GA1UECgwYSW50ZXJuZXQgV2lkZ2l0cy
BQdHkgTHRkMIGfMA0GCSqGSIB3DQEBQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgpO94h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQAB04GsMIGpMHQGA1UdIwRtMGUhxQRCMF0xChAJBgNVBA
YTA1VTMRMwEQYDVQIDApdYXpZm9ybmlhMRMwEQYDVQQHDApYXpZm9ybmlhMSEw
HwYDVQQKDBhJbnRlcml5dCBXaWRnaXRzIFB0eSBMdGSCCQX9nxZBNQWDjAJBgNVHR
MEAjAAMA4GA1UdDwEB_wQEAWIGWDAWBgNVHSUBAf8EDDAKBggrBgEFBQcDAzANBgkq
hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
SZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVipxGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
UBFyfrdT5GjqLlnqh3a_Y3QPscuCjg"
    },
    "signature": "
Twajmt_BBLIMcNrDsJqr8lI7O7lEQxXZNhlUOtFkOMMqf37wOPKtp_99LoS82CVmdpCo
PLaws8zzh-SNIQ42-
9GYO8_9BaEGCiCwy18YgWP9fWNfNv2gR2f12DK4uknkYu1EMBW4YfP81n_pGpb4Gm-
nMk14grVZygaPej3ZZk"
  }
}

```

A.2.3. Sample DeleteTA

A.2.3.1. Sample DeleteTAResponse

```
{
  "DeleteTATBSRequest": {
    "ver": "1.0",
    "rid": "req-2",
    "tid": "tran-01",
    "tee": "SecuriTEE",
    "nextdsi": "false",
    "dsihash": "gwjul_9MZks3pqUSN1-eL1aViwGXNAxk0AIKW79dn4U",
    "content": {
      "tamid": "TAM1.acme.com",
      "sdname": "sd.bank.com",
      "taid": "sd.bank.com.ta"
    }
  }
}
```

```
{
  "DeleteTARrequest": {
    "payload":
      "eyJEZWxldGVUQVRCU1JlcXVlc3QiOnsidmVyIjoimS4wIiwicmlkIjoicmVxLTIiLCJ0aWQiOiJ0cmFuLTAxIiwidGVlIjoieU2VjdXJpVEVFIiwibmV4dGRzaSI6ImZhbnHNlIiwiaWZHNpaGFzaCI6Imd3anVsXzlnNWmtzM3BxVVNOMS1lTDFhVml3R1h0QXhrMEFJS1c3OWRuNFUyLjIjY250ZW50Ijpw7InByb3RlY3RlZCI6eyJlbnMiOiJBMTI4Q0JDLUhTMjU2In0sInJlY2lwaWVudHM0Olt7Imh1YWRLciI6eyJhbGciOiJSU0ExXzUifSwiZW5jcnlwdGVkX2tleSI6ImtyaGs0d2dpY0RlX3d0VXQyTW4tSUJsdUtvX0JkeXpNY2p1cVlBenBPYnRSTG9MZZzQ0QkFLN2tRVWE1YTg0TEVJRGEzaHNTdWlxdldnZFJLczN4MTJsoUh5VFdfLUNSWmZtcUx2bEhlLV9MSVdvc1ZyRTZVMlJqUnRndl1VOWliUkVlLczkzRDRHWm4xVHFuZG9nd0tXRF9jdGlnWG1sbzZzVXpCWDZhr1dZMCJ9XSwiaXYiOiJBefk4RENORGfHbHNiR2xqYjNSblpRIiwiY2lwaGVydGV4dCI6IkhhNzBVdFlUS1ZCaldeUm4yLTBIX1BGal9yQnpQdGJHdzhSNktlMXotdklNeFBSY0Nxa1puZmwyTjRjUTZPSTZCSHZJUUFoM2Jic0l0dHlRbXhDTE5Nb8wejbBrYm9TdkiYVXlxWExpeGVZIiwidGFnIjoieEtUbFRlLdlR2LTRtVVIgYldyWnZMMVlhQnRGNloxVlNxoTMzMVmi2UEpmcyJ9fX0",
    "protected" : "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
      "signer": "
MIIC3zCCAkigAwIBAgIJAJf2fFkE1BYOMA0GCSqGSIB3DQEBBQUAMF0x CzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxpZm9ybmlhMSEw
HwYDVQQKBHJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcNMTUwNzAyMDkwMTE4Wh
cNMjAwNjMwMDkwMTE4WjBaMQswCQYDVQGEWJVUzETMBEGA1UECAwKQ2FsaWZvcmlh
YTETMBEGA1UEBwwKQ2FsaWZvcmlhYTEhMB8GA1UECgwYSW50ZXJuZXQvZ2lkZ2l0cy
BQdHkgTHRkMIGfMA0GCSqGSIB3DQEBQUAA4GNADCBiQKBgQC8ZtxM1bYickpgSVG-
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA6b_ZI3
c4cZ8eu73VMNrrn_z3WTZlExlpT9Xvj-
ivhfJ4a6T20EtMM5qWIDAQABo4GsMIGPMHQGA1UdIwRtMGUhxQRCMF0x CzAJBgNVBA
YTA1VTMRMwEQYDVQIDApDYWxpZm9ybmlhMRMwEQYDVQIDApDYWxpZm9ybmlhMSEw
HwYDVQQKBHJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGSCCQX9nxZBNQWDjAJBgNVHR
MEAjAAMA4GA1UdDwEB_wQEAWIGDAWBGNVHSUBAF8EDDAKBggrBgEFBQcDAzANBgkq
hkiG9w0BAQUFAAOBgQAGkz9QpoxghZUWT4ivem4cIckfxzTBBiPHCjrrjB2X8Ktn8G
SZlMdyIZV8fwdEmD90IvtMHgtzK-
9wo6Aibj_rVIpXGb7trP82uzc2X8VwYnQbuqQyzofQvcwZHLyplvi95pZ5fVrJvnYA
UBFyfrdT5GjjLlnqh3a_Y3QPscuCjg"
    },
    "signature" :
      "
BZS0_Ab6pqvGNXe5lqT4Sc3jakyWQeiK9KlVSnimwWnjCCyMtyB9bwvlbILZba3IJIfe
_3F9bIqP5ytGS0f2TQrPTKC7psjwDw-3kh7HkHcPPJd-
PpMMfQvRx7AIV8vBqO9MiJIC62iN0V2se5z2v8VFjGSORGgq225w7FvrnWE"
    }
  }
}
```

A.2.3.2. Sample DeleteTAResponse

```
{
  "DeleteTATBSResponse": {
    "ver": "1.0",
    "status": "pass",
    "rid": "req-2",
    "tid": "tran-01",
    "content": {
      "did": "zAHkb0-SQh9U_OT8mR5dB-tygcqpUJ9_x07pIiw8WoM"
    }
  }
}
```

```
{
  "DeleteTAResponse": {
    "payload": "
ew0KCSJEZwXldGVUQVRCU1Jlc3BvbmlIjogew0KCQkidmVyIjogIjEuMCIsDQoJCSJz
dGF0dXMlOiAicGFzc3IsDQoJCSJyaWQiOiAicmVxLTlIiLA0KCQkidGlKIjogInRyYW4t
MDEiLA0KCQkiY29udGVudCI6IHsNCgkJCSJwcm90ZWN0ZWQlOnsiZW5jIjoiTTEyOENC
QylIUzI1NiJ9LA0KCQkIInJlY2lwaWVudHMlOlslNCgkJCQl7DQoJCQkJCSJoZWfkZXIi
OnsiYWxnIjoilNBMV81In0sDQoJCQkJCSJlbnNyeXB0ZWRFa2V5IjoITXdtU1ZHaWU2
eHpfQmxTaEFlmTFRKRHhKT3oyNWVhYy1HZ2NEM2o5OWFyM2E4X21YY182ZE44bFRTb1dD
X19wZEFHaEMyWk5SakdIcTBCZ2JDYTRKalk0eXRkMVBVWDB6M1psbXl1YnRXM29leEpY
el9PMzg1WGM4S3hySndjbElyZGx2WUY2OVZmeERLQkVzUHJCdzlVenVla1VmSU4xWlFU
bWZ0QmVaSlJnIg0KCQkJCX0NCgkJCVC0sDQoJCQkiaXYiOiJBeFk4REN0RGFhbnHNiR2xq
YjNSblpRIiwNCgkJCSJjaXB0ZXJ0ZXh0IjoiamhQTlV5ZkFtel9rVV9GbEM2LUtCME0l
WDBHNE5MbHc0LWt0bERYajZTWlUteUp6eUFUbC1oY0ZBWWMWLXJMVVEF4cF93N1dlWER0
Y3N3SsZJSSzRjcWciLA0KCQkIInRhZyI6I1lBBeGo5N25oT29qVTNIREhxSl14MGZMNWpt
b0xkTlJkTHRTAMiZUTdrYXciDQoJCX0NCgl9DQp9",
    "protected": "eyJhbGciOiJSUzI1NiJ9",
    "header": {
      "kid": "e9bc097a-ce51-4036-9562-d2ade882db0d",
      "signer": "
MIIC3zCCAkgAwIBAgIJAJf2fFkE1BYOMA0GCSqGSIb3DQEBAQUAMF0xChAJ
BgNVBAYTAlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcn
MTUwNzAyMDkwMTE4W4hcnMjAwNjMwMDkwMTE4W4jBAMQswCQYDVQQGEWJVUzET
MBEGA1UECAwKQ2FsaWZvcmlpY29udGVudCI6IHsNCgkJCSJwcm90ZWN0ZWQlOnsiZW5j
IjoiTTEyOENCQylIUzI1NiJ9LA0KCQkIInJlY2lwaWVudHMlOlslNCgkJCQl7DQoJCQk
JCSJoZWfkZXIiOnsiYWxnIjoilNBMV81In0sDQoJCQkJCSJlbnNyeXB0ZWRFa2V5IjoITX
dtU1ZHaWU2eHpfQmxTaEFlmTFRKRHhKT3oyNWVhYy1HZ2NEM2o5OWFyM2E4X21YY182ZE
44bFRTb1dDX19wZEFHaEMyWk5SakdIcTBCZ2JDYTRKalk0eXRkMVBVWDB6M1psbXl1Yn
RXM29leEpYel9PMzg1WGM4S3hySndjbElyZGx2WUY2OVZmeERLQkVzUHJCdzlVenVla1Vm
SU4xWlFUbWZ0QmVaSlJnIg0KCQkJCX0NCgkJCVC0sDQoJCQkiaXYiOiJBeFk4REN0RGFh
bnHNiR2xqYjNSblpRIiwNCgkJCSJjaXB0ZXJ0ZXh0IjoiamhQTlV5ZkFtel9rVV9GbEM2
LUtCME0lWDBHNE5MbHc0LWt0bERYajZTWlUteUp6eUFUbC1oY0ZBWWMWLXJMVVEF4cF93
N1dlWER0Y3N3SsZJSSzRjcWciLA0KCQkIInRhZyI6I1lBBeGo5N25oT29qVTNIREhxSl14
MGZMNWptb0xkTlJkTHRTAMiZUTdrYXciDQoJCX0NCgl9DQp9",
meHInI3f_chlMBdL8l7daOEztSs_a6GLqmvSu-
AoDpTsfEd4EazdMBp5fmgLRGdCYMcI6bgp094h5CCnlj8xFKPq7qGixdwGUA
6b_ZI3c4cZ8eu73VMNrrn_z3WTZlExlpT9XVj-
ivhfJ4a6T20EtMM5qwIDAQABo4GsMIGpMHQGA1UdIwRtMGUhxQRCMF0xChAJ
BgNVBAYTAlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRMwEQYDVQQHDApDYWxp
Zm9ybmlhMSEwHwYDVQQKDBhJbnRlcm5ldCBXaWRnaXRzIFB0eSBMdGQwHhcn
MTUwNzAyMDkwMTE4W4hcnMjAwNjMwMDkwMTE4W4jBAMQswCQYDVQQGEWJVUzET
MBEGA1UECAwKQ2FsaWZvcmlpY29udGVudCI6IHsNCgkJCSJwcm90ZWN0ZWQlOnsiZW5j
IjoiTTEyOENCQylIUzI1NiJ9LA0KCQkIInJlY2lwaWVudHMlOlslNCgkJCQl7DQoJCQk
JCSJoZWfkZXIiOnsiYWxnIjoilNBMV81In0sDQoJCQkJCSJlbnNyeXB0ZWRFa2V5IjoITX
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    },
    "signature": "
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CxD6D22J8GDUExlIhSR1aDuDCQm6QzmjdfdxAz5TRYl6zPFCzqgStoN_g1TZxqxEv6V
Ob5fies4g6MHvCH-I1_-KbHq5YpwGxEEfdg"
  }
}
```


A.3. Example OTrP Broker Option

The most popular TEE devices today are Android powered devices. In an Android device, an OTrP Broker can be a bound service with a service registration ID that a Client Application can use. This option allows a Client Application not to depend on any OTrP Broker SDK or provider.

An OTrP Broker is responsible to detect and work with more than one TEE if a device has more than one. In this version, there is only one active TEE such that an OTrP Broker only needs to handle the active TEE.

Appendix B. Contributors

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