Federal Office
for Information Security

Technical Guideline BSI TR-03181 CSP2

Cryptographic Service Provider 2

Part 1: Architecture and Concepts

Version 0.94
Public draft

Table 1: Version history

Document Version	Date	Changes
0.1	2020-09-25	first draft
0.5	2020-12-14	content complete
0.6	2021-01-29	1st internal review
0.7	2021-02-18	1st public beta
0.75	2021-03-23	certificate handling, attestation, reviewer comments
0.8	2021-05-06	2nd public beta
0.81	2021-07-21	Life cycle integration
0.9	2022-02-03	3rd public beta
0.91	2022-06-29	scope, optional modules, reviewer comments
0.93	2022-12-19	reworked resource states
0.94	2023-04-03	public draft as BSI-TR 03181-1 CSP2

Draft Disclaimer

This document is a draft specification for public review. It has no final status and may change at any time and in incompatible ways.

Changes to the presented generic concepts are likely to occur as the work on specific APIs for different CSP platforms and the accompanying life cycle integration progresses. Currently, the following topics are identified for possible modification:

- Responsibilities of administrative roles. The goal is to allow for securely separated application specific configuration and management of associated CSP resources.
- Availability and usability of wrapping keys for secure import of application specific assets.
- Availability and usability of attestation mechanisms and secure storage.

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1 Introduction

Security related products usually not only have to be secure, but are also constrained by development skills, time, and costs as well as certification costs and time. Even worse, such products are usually composed of several components, e.g. hardware, firmware, operating system and application(s), introducing a lot of unavoidable dependencies and complexities. The overall security of such composed products heavily depends on how those components interact with each other. Even a minor weakness in one component may have a severe side effect in another component. To ensure the security of such products, an evaluation of the whole architecture is required. While a composite certification according to Common Critiera [1] is well suited to prove that a product fulfills certain security requirements, it can be a lengthy, non-deterministic, and costly process, depending on the evaluation level and complexity of the product. This usually does not fit very well to short product (development) cycles and competitive prices in a lot of industries.

The Cryptographic Service Provider (CSP) is designed to increase the security of composed products and to reduce time and costs of certifications of products. In a nutshell, the CSP securely encapsulates essential cryptographic functions and protocols at a high level and provides them as services to applications. The Cryptographic Service Provider then requires a thorough security certification. But the certification effort for applications is heavily reduced, as they use the cryptographic functions and protocols via well-defined interfaces that are designed to prevent misuse and ensure that the application has no direct access to sensitive cryptographic data. In particular, the certification of applications using the CSP does not require a composite certification. Applications and CSP can be certified separately and with different assurance levels, utilizing *coordinated* protection profiles.

In particular, the CSP is not another cryptographic library that aims at simplifying application development. In contrast to a cryptographic library that provides implementations of cryptographic primitives and protocols at an abstract level to applications, the CSP consists of active components that are able to interact with the infrastructure (via extensions) to manage keys and credentials on behalf of the respective application that owns the key material. The cryptographic services provided by the CSP are self-contained, such that the application using the CSP is exempted from performing complicated and error-prone management obligations that often affect the security of the application.

The CSP aims at reducing the risk of incorrect use of cryptography by providing:

- Logically separated and self-contained[1] security functions, including:
  - Cryptographic Signatures including optional timestamping and signature enumeration.
  - Protected Sessions for secure communication and content protection (e.g. disk encryption).
  - Identification and authentication protocols based on passwords (PIN/PUK) and keys, e.g. PACE, CA, TA, ...
- Extensive audit functionality for security relevant events.
- Secure access to sensitive cryptographic resources (e.g. keys, passwords and applications) and the option to share resources among multiple applications by enforcing a configurable role and access control model.
- Sensitive management operations that are performed by dedicated administrative applications.
- Redundancy and performance gains by clustering a set of CSPs.
- Convenient interfaces for application developers.

This implies that application developers should restrict themselves to cryptographic services provided by the CSP instead of implementing security functions on their own. To discourage application developers from extending the CSP, the interface does not allow direct access to any sensitive cryptographic material but use references instead. Application developers may still use cryptographic libraries and/or implement

[1] The CSP catches and fulfills most if not all of the obligations for secure usage of the underlying platform specific security functionality.

cryptographic primitives and protocols that are not provided by the CSP on their own. However, in those cases the application developer is also responsible for the security of the implementation.

To summarize the benefits, using the CSP in a composed IT product

- enables development and certification of the application independent of the platform.
- allows for a security certification of applications with lower security assurance, as important cryptographic operations and protocols are encapsulated in the CSP in a way that prevents typical cryptographic misuse
- provides sufficient security functionality to support a variety of security related applications.
- allows for an easy deployment within any application.

Exemplary applications using the CSP include:

- (electronic) ID applications, e.g. passports and other government issued ID cards or company IDs.
- Second Factor Authentication, e.g. u2f (CTAP1) or FIDO2 (CTAP) enabled token.
- (Timestamped) Signature Creation, e.g. for electronic record keeping systems.

Within this Technical Guideline an example application is used to explain the functionality of the CSP:

A *signature application* will be installed on a CSP-enabled Secure Element (e.g. a smart card) to become a signature creation device for an external user. The installation and configuration of the application on the Secure Element will be performed by a Trusted Service Manager (TSM), who uses a TSM Application on the Secure Element to configure the CSP with authentication data (PIN and PUK) for the external user and the signature key pair. Furthermore, the audit functionality of the CSP is used to keep track of authentication failures of the external user as well as signature generation. A logging application is used to produce a timestamped audit trail of those events.

1.1 Structure

The Technical Guideline *Cryptographic Service Provider* consists of several parts.

This **Part 1** of the specification describes the general architecture of the CSP and the fundamental concepts. It contains:

- A generic description of possible architectures of a composed IT product using the CSP, i.e. platform mode and client-server mode.
- A generic description of users, roles, (administrative) applications and management functions.
- Generic requirements for the life cycle of a composed IT product, including application development, provisioning and personalization.
- A description of the available types of resources, e.g. keys and passwords, their configurable attributes, access restrictions and life cycle.
- The supported cryptographic primitives, algorithms, protocols and supporting functionality.

The provided descriptions and concepts in this part try to be as open to different implementations and platforms as feasible, avoiding terminology hinting at specific technologies if possible.

The mapping of those concepts to specific platforms, e.g. Secure Elements or Hardware Security Modules, is subject of (not yet released) subsequent parts.

Part 2 maps the provided generic concepts onto (embedded) Secure Elements running a JavaCard OS. It focuses on:

- The mapping of entities and roles typically needed in the context of (secure) composed IT products in mobile devices and smart cards.
- The usage and inclusion of card management capabilities typically found on those platforms, e.g. GlobalPlatform mechanisms.
- A JavaCard API for the provided CSP functionality, including life cycle management.

All parts may contain optional or conditional concepts and functionality, to partially reflect the limitations of specific platforms as well as specific sets of use cases. For part 1 of this technical guideline all concepts and functionality are considered mandatory with the following exceptions:

- Auditing and Timestamping, including their respective management functionality, are optional.
- Cluster Mode is optional.
- Cypher suites exclusively needed for TLS, S/MIME and SSH are optional.

The above pursues the partitioning of the protection profiles 'CSP', 'CSP Time Stamp Service and Audit' and 'CSP Time Stamp Service, Audit and Clustering', respectively.

1.2 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 [2]. The key word "CONDITIONAL" is to be interpreted as follows:

CONDITIONAL: The usage of an item is dependent on the usage of other items. It is therefore further qualified under which conditions the item is REQUIRED or RECOMMENDED.

When used in tables (profiles), the key words are abbreviated as shown in Table 2.

Table 2: Key Words

Key word		Abbrev.
MUST / SHALL	REQUIRED	m
MUST NOT / SHALL NOT	–	x
SHOULD	RECOMMENDED	r
SHOULD NOT	–	–
MAY	OPTIONAL	o
–	CONDITIONAL	c

2 Architecture

The business logic of the given use case is implemented in one or more applications utilizing the provided cryptographic services of the CSP. Application and CSP may be operated either on the same platform in *Platform Mode* or on different platforms in *Client-Server Mode*. In the latter, CSP acts as the server, and the application is the client. Figure 1 gives an overview of both modes; details on the modes are described in Section *2.1* and Section *2.2*.

Note: The CSP MAY provide both modes simultaneously.

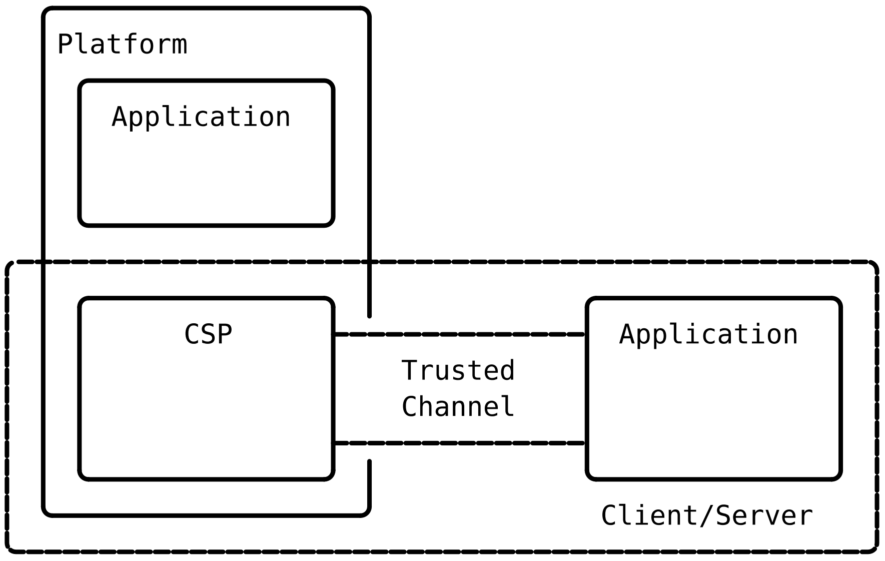


Figure 1: CSP Modes of Operation. Platform and Operational Environment

In the context of this document the term *platform* refers to the hardware and software needed to execute the CSP or application. The platform and its configuration, including additional software, form the *operational environment* of the CSP. Depending on the type of CSP and platform additional requirements for the operational environment exist, as detailed below.

The CSP platform is typically:

- A smartcard or a secure element, comprising the hardware, the operating system and additional software (e.g. the Card Manager and native libraries). In this context the CSP and its platform are often certified as a composite product, i.e. the CSP includes its platform and provides its own operation environment fulfilling all requirements. As such, the CSP itself can become the platform for further applications, see Platform Mode below.
- A Linux Appliance, comprising all hardware components including e.g. a TPM, the Linux Distribution and additional Software Packages that are required for the operation of the CSP. Here, the CSP is typically found to be implemented in software only, using the Appliance, its services and additional software as the operational environment.

2.1 Platform Mode

In Platform Mode, the CSP and the application that uses the CSP share the same (physical) platform.

2.1.1 Operational Environment in Platform Mode

The Operational Environment of the CSP MUST ensure the following:

- Integrity of the implementation of the CSP and of the applications.
- Implicit mutual authentication of application and CSP.

- Integrity protection of the communication between application and CSP.
- Integrity and confidentiality of stored sensitive data.
- Authenticity of installed update code.

The underlying platform MUST provide the Operational Environment.

Note: Depending on the underlying platform, consisting of hard- and software, implementing the Operational Environment may require additional mechanisms implemented in software that are not directly provided by the operating system. If required, those additional mechanisms are not part of the CSP.

2.2 Client-Server Mode

In Client-Server Mode, the CSP and the Application run in different Operational Environments and communicate via a Trusted Channel.

2.2.1 Trusted Channel

The application and the CSP MUST use a Trusted Channel that SHALL provide mutual authentication of CSP and application. The Trusted Channel SHALL protect the integrity and SHOULD protect the confidentiality of the communication. It is RECOMMENDED to use a cryptographically protected Secure Channel (cf. Section 7) as the Trusted Channel. In this case, the application SHALL initiate the establishment of the Secure Channel.

Note: To initiate a secure channel, the application must implement or use cryptographic functions to setup the Secure Channel that are not provided by the remote CSP.

If both the application and the CSP are operated in the same trusted environment, a physically protected Trusted Channel may be used instead of a Secure Channel.

2.2.2 Operational Environment of the CSP in Client-Server Mode

The Operational Environment of the CSP MUST ensure the following:

- Integrity of the CSP implementation.
- Integrity and confidentiality of stored sensitive data.
- Authenticity of installed update code.

The CSP SHALL be executed on a platform that implements a suitable Operational Environment.

Note: Depending on the underlying platform, consisting of hard- and software, implementing the Operational Environment may require additional mechanisms developed in software that are not directly provided by the operating system. If required, those additional mechanisms are not part of the CSP.

2.2.3 Operational Environment of Applications in Client-Server Mode

The requirements for the Operational Environment of the application depend on the application itself. The Operational Environment SHOULD at least protect the integrity of the application code and data.

If a Secure Channel is used as the Trusted Channel, the Operational Environment of the application MUST protect the confidentiality of the credentials used to setup the Secure Channel.

2.3 Entities and Roles

The common types of entities interacting with the CSP are *Applications* and *Human Users*, acting in roles defined in this chapter. As the access and interaction model of the CSP is focused on (administrative) applications those are described in a separate chapter 2.4.

Specific platforms or use-cases implementing a specific life-cycle MAY define further entities, stakeholders and roles that MUST be mapped to applications acting in a roles derived from the ones presented here.

2.3.1 Entity Human Users

The CSP is a security component. The functionality provided directly by the CSP SHOULD be reduced to a minimum for various reasons, e.g.:

- Any additional functionality introduces potential vulnerabilities in their implementation.
- The implementation should be reviewed and evaluated on a regular basis.
- Some of the platforms the CSP is intended to be used on are very restricted.

Therefore, the CSP SHOULD NOT provide an interface for human users. The CSP SHOULD only interact directly with applications. Administrating the CSP is thus done by administrator applications. Those applications MAY interact with human users, either directly or indirectly with a user device, e.g. a terminal.

Note: Applications may still implement user management without using the CSP. It is however not recommended practice.

2.3.1.1 Example: Administrator Authentication

An administrator application interacting with a human administrator performs the following steps to authenticate the external user as an administrator. In this example, the PACE Protocol is used for password based authentication and establishing a secure channel. Details on using the PACE Protocol with the CSP can be found in Section *6.2.1*. As PACE is a cryptographic protocol, the external user is required to use an administrator console, a device implementing the client side of the PACE protocol.

Note: The administrator console may also use a CSP to implement the PACE protocol.

Figure 2 gives an overview on the example.

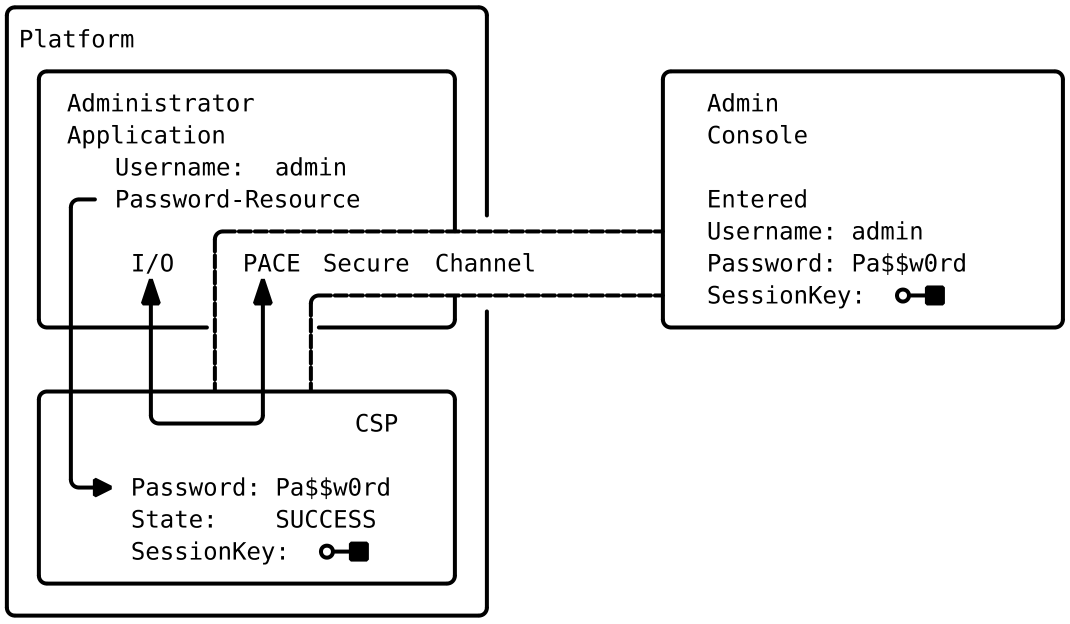


Figure 2: Example: User Authentication with PACE.

The following steps are performed by the Administrator Application:

1. The claimed identity (admin) of the external user has to be determined. This requires the administrator application to maintain a list of valid user names.
2. The correct password resource on the CSP must be selected. This requires the application to map user names to password resources on the CSP.
3. The PACE Protocol is started. This requires the application to setup the protocol instance with the password resource and other parameters that must be negotiated with the administrator console.
4. Protocol data is exchanged between the CSP and the external user. This requires the application to format and forward protocol data.
5. When the protocol is done, the application must check the authentication status of the used password resource, to determine whether the external user was successfully authenticated as administrator.
6. The Secure Channel established by the CSP with the external user may be used by the application to communicate securely with the external user via the CSP.

Thus, applications SHALL manage the identities of their users on their own (Steps 1 and 2). The CSP does not care about, e.g. a user name, that is assigned to a user of an application. The CSP manages user credentials, e.g. stores and verifies passwords (Steps 3 to 5). After a successful authentication of a user, the CSP supports the application by providing security services, e.g. a secure channel (Step 6).

2.3.2 CSP Roles

Although the CSP SHOULD NOT interact directly with human users, some tasks have to be performed by administrators. Administrative tasks, especially if handled by human users, are error-prone and introduce potential mis-configuration and other weaknesses. Therefore, administrative tasks SHOULD also be performed by applications, which MAY interact with human administrators.

Applications with an assigned privileged role are called administrative applications (cf. Section 2.4.3). Such administrative applications SHALL be distinguishable from ordinary user applications by assigning applications administrator roles.

The CSP uses two separate roles for privileged tasks and a third role for unprivileged tasks:

- `ApplicationAdmin`

- `DeviceAdmin`
- `Owner`

Exactly one administrative application SHALL be assigned the role `ApplicationAdmin` and `DeviceAdmin`, respectively.

Note: In the following the role is directly used to indicate that a task is performed by an administrative application in that role, e.g. `ApplicationAdmin` is used instead of “an administrative application in role `ApplicationAdmin`.”

Besides the administrative roles, the CSP uses the role `Owner`. An application is acting in role `Owner` when it makes use of a resource, e.g. a key or a password that is managed by the CSP and assigned to this application. Details on resources and their management can be found in Section *3*. With respect to roles, the ownership of resources (cf. Section *3.1.3*) and access control (cf. Section *3.1.4*) are of particular interest.

The assignment of roles to applications is static. The CSP MUST NOT change the role or privilege of an application when a human user is authenticated via the application, i.e. the application does not gain any additional privileges:

- A user application does not become an administrative application due to authentication of a human user which is recognized as administrator.
- An application is acting as `Owner` of a resource assigned to the application independent of the authentication of the human user that is authorized to use the resource.

Thus, it is up to the implementation of the application, whether a human user is required to perform a certain administrative task or the application performs administrative tasks in an automated or semi-automated way. Policies MAY be used to further restrict applications from using resources in role `Owner`, by requiring additional authentications to be performed before access to a resource is granted. Details on policies can be found in Section *3.1.6*.

2.3.2.1 Application Administrator

The `ApplicationAdmin` performs all administrative tasks related to application management:

- Installation (including updates) of applications in the platform model
- Configuration of applications, i.e. the audit events to be logged.
- Configuration of keys and passwords and their access control rules to be provided by the CSP to applications.
- Initialization of resources, where required, for applications.
- De-configuration of resources
- De-installation of applications in the platform model.

Some of the tasks performed by the `ApplicationAdmin` MAY be further split into dedicated administrator roles, e.g. platform specific operations may be delegated to an `UpdateAgent` role.

2.3.2.2 Device Administrator

The `DeviceAdmin` performs comprehensive device-related administrative tasks:

- Configure a set of CSPs to operate in Cluster Mode
- Import and export of keys and passwords in Cluster Mode.
- Configuring the available cryptographic algorithms and key sizes on a device.
- Configuring and generating global keys, e.g. for key attestation.
- Setting and synchronizing the system time

Some of the tasks performed by the `DeviceAdmin` MAY be further split into dedicated administrator roles, e.g. tasks related to cryptographic operations may be delegated to a `CryptoOfficer` and setting the system time may be delegated to a `TimeKeeper`.

2.3.2.3 Resource Owner

The `Owner` usually performs all tasks related to this resource:

- Setup of the resource, e.g. key generation.
- Usage of the resource, e.g. signature creation.
- Migration of the resource, e.g. public key export.
- Clearance of the resource, e.g. key destruction.

Note: Setup of a resource by the `Owner` requires the resource to be configured beforehand by the `ApplicationAdmin`. The De-configuration of a resource by the `ApplicationAdmin` requires the resource to be cleared beforehand by the `Owner`.

Some of the tasks related to a resource MAY be configured by the `ApplicationAdmin` to be unavailable to the `Owner`, such that those tasks MUST be performed by the `ApplicationAdmin` or `DeviceAdmin`. On the other hand, the `ApplicationAdmin` MAY also configure resources to be available to other applications that are not acting in role `Owner`.

Global resources
Resources that are available to multiple user applications are called global resources. The `Owner` of a global resource is usually the `DeviceAdmin` or another administrative application in a sub-role of the `DeviceAdmin`. To allow other applications to access the resource, the access control rules to `use, setup, move and clear` the resource MUST explicitly be granted denied to other applications per default, unless the implications of potentially untrusted user applications performing sensitive tasks on shared resources have been taken into account.

Details on Access Control Rules can be found in Section *3.1.4*.

2.4 Applications

Applications that perform non-privileged tasks are user applications (cf. Section *2.4.2*) and applications that perform privileged tasks are administrative applications (cf. Section *2.4.3*).

2.4.1 Application Identifier

Every application that is allowed to interact with the CSP is assigned a unique application identifier within the configuration process. This application identifier is used by the CSP to assign resources to applications and to implement access control rules. If a resource is assigned an application identifier as owner, then this application is acting in role `Owner` when using the resource.

Details on application identifiers and ownership of resources can be found in Section *3.1.3*.

The application identifier SHALL also allow to distinguish between user applications and administrative application.

2.4.2 User Applications

User applications may interact with external entities and use services provided by the CSP, e.g. for authenticating users and performing cryptographic operations on behalf of their users, but may not perform any privileged management functions provided by the CSP. The CSP MUST NOT allow a user application to perform administrative management functions. The CSP SHALL limit access of user applications to resources that have been configured for the application or are available to all applications.

The user application is responsible for some management task (owner management functions, cf. Section *2.5*) on the configured resources, but the resources are operated by the CSP, e.g. the credentials of human users may be set and changed by the application (or the `ApplicationAdmin`), but all operations using the credentials are performed by the CSP.

2.4.3 Administrative Applications

Management tasks are in general performed by administrative applications. Those applications are integral parts of the CSP and MUST be certified using the same assurance class as the CSP. To perform a certain management task on the CSP (operational management functions, cf. Section *2.5*), the administrative application MUST be assigned as the respective administrative role as `Owner` (cf. Section *2.3* and Section *3.1.3*). Administrative applications also perform management tasks on the underlying platform (governing management functions, cf. Section *2.5*). In this case, administrative applications SHOULD be operated in Platform Mode (cf. Section *2.1*).

Examples for administrative tasks to be performed by administrative applications include, but are not limited to:

- Management of global resources in role `DeviceAdmin`.
- System time synchronization with external time sources in role `TimeKeeper`.
- Migration of resources within a cluster of CSPs in role `CryptoOfficer`.
- Dynamic allocation of resources in role `ApplicationAdmin`.
- Unattended update installation in role `UpdateAgent`.

Administrative applications are applications that may operate in an automated way that does not require any human interaction. User applications may interact with administrative applications via their public interfaces, e.g. a user application may request an administrative application in role `TimeKeeper` to synchronize the system time or it may request an administrative application in role `ApplicationAdmin` to allocate additional key resources.

The internal and external interfaces of the administrative applications is described in the platform specific parts of this documentation, e.g. part 2 for Secure Elements using JavaCardOS. The expected behavior of the administrative applications is described in the later sections of this document.

2.5 Management Functions

Application management, key management, password management, and system management are in general performed by administrative applications unless the tasks are delegated to the resource owner. Those management functions are further separated into governing, operational and owner management functions:

Governing Management Functions
Management functions that are **not** part of the core functionality of the CSP are *governing management functions*. They MUST be provided by administrative applications, e.g. using the Operational Environment, but may also use the CSP. Governing management functions do not necessarily provide a standardized interface and may be specific to the environment.

Operational Management Functions
Management functions that are directly provided by the CSP via standardized management interfaces are *operational management functions*. The use of those interfaces is in general restricted to administrative applications, however, some operational management functions can also be performed by user applications, see the respective resource management descriptions below for further details.

Owner Management Functions
Management functions that are usually performed by the owner of a resource using standardized functionality of the CSP, but not via the management interfaces, are *owner management functions*.

Only the operational management functions are part of this specification. They are described in Section *4*.

2.5.1 Application Management

Application Management comprises all interactions with applications and their resources. Those interactions are separated into governing management functions and operational management functions. Governing Management Functions are all interactions with the Operational Environment. Operational Management Functions are all interactions with the management interfaces of the CSP.

Application Management is performed by administrative applications in role `ApplicationAdmin` or one the sub-roles.

Note: Application Management also involves interactions with key and password resources. The governing and operational management functions described for Key Management and User Management apply accordingly.

2.5.1.1 Governing Management Functions

The `ApplicationAdmin` is responsible for all interactions with the Operational Environment. Those governing management functions are strictly platform-specific. The governing management functions include the identification of external entities, the validation, installation, update and de-installation of user applications. The `ApplicationAdmin` SHALL use the installation, update, and de-installation mechanisms provided by the Operational Environment. The `ApplicationAdmin` usually also requires administrative privileges in the Operational Environment.

Those governing management functions are interleaved with governing management functions for key management and password management as well as mechanisms provided by the Operational Environment.

2.5.1.2 Operational Management Functions

Only the `ApplicationAdmin` may initiate operational management functions via the `ApplicationManager` interface of the CSP. The `ApplicationManager` (cf. Section *4.1*) provides the following application life cycle operations to the `ApplicationAdmin`:

- Application configuration
- Application de-configuration

There are no operational management functions that can be performed by user applications.

2.5.2 Key Management

Key Management comprises all interactions with key resources. Those interactions are separated into governing management functions, which are all interactions with external entities and operational management functions, which are all interactions with the management interfaces of the CSP.

Key Management is performed by administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

Note: Key Management can also involve interactions with password resources. The governing and operational management functions described for Password Management apply accordingly.

2.5.2.1 Governing Management Functions

Examples for governing management functions that have to be performed by administrative applications include the following use cases:

- Initialization of application key resources, where required by the application issuer. The initialization includes but is not limited to key generation and renewal, as well as the interaction with the infrastructure for key certification. The initialization is performed by the `ApplicationAdmin`.

- Initialization of global key resources, e.g. for device attestation, that can be used by applications. The initialization includes but is not limited to key generation and renewal, as well as the interaction with the infrastructure for key certification. The initialization is performed by the `DeviceAdmin`.
- Setup and management of Cluster Mode and key migration within the cluster is performed by the `DeviceAdmin`.

2.5.2.2 Operational Management Functions

Applications may initiate operational management functions via the `KeyManager` interface. The `KeyManager` (cf. Section *4.2*) provides basic key life cycle operations to applications:

- Key configuration
- Key retrieval
- Key migration
- Key de-configuration

The CSP MUST verify the access control rules and policies for all operational management functions on key resources that are initiated by applications. The operations for key configuration and key de-configuration SHALL NOT be available to user applications. Those operations SHALL be restricted to administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

2.5.2.3 Owner Management Functions

The `Owner` of a key resource is responsible for all application-specific management functions related to key management, e.g. the identification of external entities, mapping key resources to entities, and initiating cryptographic operations. Those owner management functions are often interleaved with owner management functions for password management.

Applications mainly use the key retrieval operations to obtain a `Key` handle that can be used to perform cryptographic operations on the key resource. The following operations are made available via a `Key` (cf. Section *3.3*) handle:

- Key generation
- Key usage
- Key destruction

Depending on the access control rules of a key resource configured by the `ApplicationAdmin`, some owner management functions cannot be performed by the `Owner`, instead they MUST be performed by administrative applications (either in role `ApplicationAdmin` or `DeviceAdmin`) or MAY be performed by other user applications that are not the `Owner` of the key.

2.5.3 Password Management

Password Management comprises all interactions with password resources. Those interactions are separated into governing management functions, which are all interactions with external entities (in general human users) and operational management functions, which are all interactions with the management interfaces of the CSP.

Password Management is performed by administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

> **Note:** Password Management can also involve interactions with key resources. The governing and operational management functions described for Key Management apply accordingly.

2.5.3.1 Governing Management Functions

Examples for governing management functions that have to be performed by administrative applications include the following use cases:

- Initialization of application password resources, where required by the application issuer. The initialization includes but is not limited to setting and re-setting initial passwords. The initialization is performed by the `ApplicationAdmin`.
- Initialization of global password resources, e.g. for human users, that can be used by administrative applications. The initialization includes setting and resetting initial passwords. The initialization is performed by the `DeviceAdmin`.
- Setup and management of Cluster Mode and password migration within the cluster is performed by the `DeviceAdmin`.

2.5.3.2 Operational Management Functions

Applications may initiate operational management functions via the `PasswordManager` interface. The `PasswordManager` (cf. Section *4.3*) provides basic password operations to applications:

- Password configuration
- Password retrieval
- Password migration
- Password de-configuration

The CSP MUST verify the access control rules and policies for all operational management functions on password resources that are initiated by applications. The operations for password configuration and password de-configuration SHALL NOT be available to user applications. Those operations SHALL be restricted to administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

2.5.3.3 Owner Management Functions

The `Owner` of a password resource is responsible for all application-specific management functions related to password management, e.g. the identification of external entities, mapping password resources to entities, and operations for password handling. Those owner management functions are often interleaved with owner management functions for key management.

Examples for owner management functions performed by user applications include the following use cases:

- Changing the password of an authenticated user.
- Resetting the retry counter of a PIN after entering the correct PUK.

Applications mainly use the password retrieval operations to obtain a `Password` handle that can be used to perform verification operations on the password resource. The following operations are made available via a `Password` (Section *3.4*) handle:

- Password setting
- Password verification
- Password resetting

Depending on the access control rules of a password resource configured by the `ApplicationAdmin`, some owner management functions cannot be performed by the `Owner`, instead they MUST be performed by administrative applications (either in role `ApplicationAdmin` or `DeviceAdmin`) or MAY be performed by other user applications that are not the `Owner` of the password.

2.5.4 System Management

System Management comprises all interactions with Operational Environment that are not covered by Application Management. Those interactions are separated into governing management functions, which are all interactions with the Operational Environment and operational management functions, which are all interactions with the management interfaces of the CSP.

System Management is performed by administrative applications in role `DeviceAdmin`.

2.5.4.1 Governing Management Functions

Examples for governing management functions that have to be performed by administrative applications include the following use cases:

- Adjusting and synchronizing the system time with external time sources.

2.5.4.2 Operational Management Functions

There are currently no operational management functions for System Management.

2.6 Life Cycle Integration

The life cycles of the CSP and applications using the CSP SHOULD be synchronized to allow for a secure deployment of the application. Within this specification, the life cycle is described in the following abstract phases:

Development Phase
The *Development Phase* includes all aspects related to the development of the product, including evaluation, certification, and in case of software-based products packaging.

Initialization Phase
The *Initialization Phase* includes the initial setup of the product and the generation or import of credentials and product-specific keying material, e.g. for attestation. In case of software-based products, the initialization also includes the installation of the software package on the underlying platform.

Personalization Phase
The *Personalization Phase* includes the setup of user-specific data, including initial credentials and keying material for users of the product.

Operational Use Phase
The *Operational Use Phase* is application-specific. It also includes the updating the product.

Decommission phase
The *Decommission Phase* includes the destruction of credentials and keying material. In case of software-based production the de-installation of the software on the underlying platform.

2.6.1 CSP Life Cycle

The life cycle of the CSP depends to a large extend on the underlying platform. The life cycle of a smart card based CSP differs from the life cycle of a cloud-based CSP. In case of a composite product, the abstract life cycle MUST be mapped to the life cycle of the underlying platform.

2.6.1.1 CSP Development

The manufacturer is responsible for the development of the CSP. The manufacturer SHALL select suitable platforms for the CSP and take the requirements and implications of the platform(s) into account. The evaluation and certification of the CSP SHOULD include the selected platform, e.g. as composite certificate.

If the CSP is externally developed (and certified) as software independent of a specific platform, the manufacturer is the entity that selects a suitable platform by taking the guidance of the software developer into account.

2.6.1.2 CSP Initialization

The manufacturer is responsible for the initialization of the CSP. The initialization consists of the initial installation of the CSP and the administrative application `DeviceAdmin` on the underlying platform.

The initial setup of the CSP is performed by the `DeviceAdmin` using local configuration mechanisms of the CSP. The `DeviceAdmin` may be provided by the manufacturer of the CSP, by the manufacturer of the underlying platform, or by the operator of the underlying platform. The secure integration of the `DeviceAdmin` into setup procedures of the CSP MUST be considered in the development of the CSP.

The initial credentials for administrators using the `DeviceAdmin` MUST be generated or imported on the CSP and distributed securely to the administrators.

The CSP initialization SHOULD be performed in the secure environment of the manufacturer. If the initialization is performed outside of the secure environment of the manufacturer, then the manufacturer is responsible to ensure that the CSP is installed on a suitable platform and that the platform is in a secure state, e.g. by using mechanisms of the operating system of the underlying platform.

It is RECOMMENDED to generate or import attestation keys and corresponding certificates that can be used to verify that the CSP has been initialized in a trustworthy way. The attestation certificate SHOULD include information on the CSP (e.g. the identity of the manufacturer and the certification of the CSP) and the underlying platform. The attestation MAY include information on the entity acting in role `DeviceAdmin`.

> **Note:** As the role `DeviceAdmin` is given to an application using the CSP, the application has its own life cycle separate from the life cycle of the CSP.

2.6.1.3 CSP Personalization

Administrators in role `DeviceAdmin` are responsible for the personalization of the CSP. The personalization consists of the installation of the administrative application `ApplicationAdmin` on the underlying platform as well as the configuration of the CSP and the underlying platform for the `ApplicationAdmin`. The `ApplicationAdmin` SHOULD be customized for the underlying platform and/or the operator of the underlying platform to allow for a seamless integration into the procedures for operational use. The configuration MAY include the creation of administrative users on the underlying platform. The `DeviceAdmin` MAY generate or import global resources on the CSP, e.g. additional attestation keys or derivation keys. The `DeviceAdmin` MAY setup the CSP to operate in a cluster (cf. Section *3.2.5*).

There are no generic requirements on the environment for the personalization. The `DeviceAdmin` SHOULD use the attestation mechanism of the CSP (if configured in the initialization phase) to verify that the CSP and the underlying platform are in a trustworthy state.

> **Note:** The `ApplicationAdmin` is an application using the CSP, it has its own life cycle independent of the life cycle of the CSP.

2.6.1.4 CSP Operational Use

Administrators in role `ApplicationAdmin` are responsible for the installation, configuration, update, de-configuration and de-installation of user-applications, while the CSP is in operational use.

Administrators in role `DeviceAdmin` are responsible for managing the `ApplicationAdmin`, including updating the application and the management of credentials for administrators in role `ApplicationAdmin`. In cluster mode administrators in role `DeviceAdmin` are additionally responsible for managing the cluster of CSPs, including the addition and removal of CSPs to the cluster.

2.6.1.5 CSP Decommission

Administrators in role `DeviceAdmin` are responsible for the decommissioning of the CSP.

2.6.2 Application Life cycle

With the exception of the application development, the life cycle of the application is within the operational use of the CSP.

2.6.2.1 Application Development

The application issuer is responsible for the development of the application. The application issuer MUST take the requirements imposed by the respective `ApplicationAdmin` into account:

- The platform used for executing the application. The platform cannot be selected by the application issuer. In platform mode, it is the underlying platform of the CSP or, in client-server mode, it is a separate platform administrated by the `ApplicationAdmin`. The evaluation and certification of the application MUST take requirements imposed by the respective platform into account.
- The format of application package including the resource description. The application package MUST be verifiable and installable on the underlying platform and the `ApplicationAdmin` MUST be able to parse the resource description of the application to be able to configure the required resources on the CSP.
- The `IssuerKey` MUST be securely delivered to the `ApplicationAdmin`, to enable the import of resources (in encrypted form) provided by the issuer as part of the application package.

2.6.2.2 Application Initialization

Administrators in role `ApplicationAdmin` are responsible for the initialization of the application. The initialization consists of the verification of the authenticity of the application package, the installation of application on the platform (either on the underlying platform of the CSP or on a separate platform), and the configuration and initialization of the resources on the CSP according to the resource description. The initialization includes the generation, import and export of resources. Resources to be generated and then exported (in encrypted form) SHALL be returned to the application issuer.

Note: The initialization may be separated into configuration and pre-personalization.

2.6.2.3 Application Personalization

The application personalization is application-specific. The application issuer MAY use credentials and keys that were generated and exported by the `ApplicationAdmin` in the initialization to remotely access the installed instance of the application.

2.6.2.4 Application Operational Use

The operational use of the application is application-specific. Administrators in role `ApplicationAdmin` are responsible for updating the application when updates are provided by the application issuer. In cluster mode administrators in role `DeviceAdmin` are responsible for migrating resources of the application between CSPs in the cluster.

2.6.2.5 Application Decommission

Administrators in role `ApplicationAdmin` are responsible for the decommission of the application. The decommission consists of the destruction and de-configuration of resources of the application on the CSP and the de-installation of the application on the platform.

2.7 Example: Application Deployment

Within the following example a signature application is installed on an already deployed Secure Element by a Trusted Service Manager (TSM). The TSM is an external service responsible for the life-cycle management of applications on a specific platform, e.g. applets on Secure Elements. The TSM is using a TSM Application, which is an administrative application in role `ApplicationAdmin` on the CSP-enabled Secure Element. Thus, the TSM is performing the initialization and personalization of the signature application via the TSM Application as management tasks on the CSP.

The CSP used in the example is already in operational use phase. Keying material to be used for the import or export of resources as part of the application personalization MUST have been previously generated by the `DeviceAdmin` within the CSP personalization phase. This and any other requirements imposed by the TSM MUST be taken into account as part of the application development.

Initialization of the signature application:

1. The TSM receives the application code and the CSP resource definition, describing the key and password resources to be provided by the CSP to the application and their configuration and initialization. The TSM verifies the application code and the CSP resource definition.
2. The TSM authenticates to the TSM Application and establishes a secure channel. The TSM Application is an administrative application in role `ApplicationAdmin`.
3. The TSM Application installs the application code received via secure channel from the TSM using the platform installation mechanisms.
4. The TSM Application creates the application resource using the `ApplicationManager` of the CSP.
5. The TSM Application creates the key and password resources and sets the access control rules and other attributes according to the resource definition using the `KeyManager` and `PasswordManager` of the CSP.

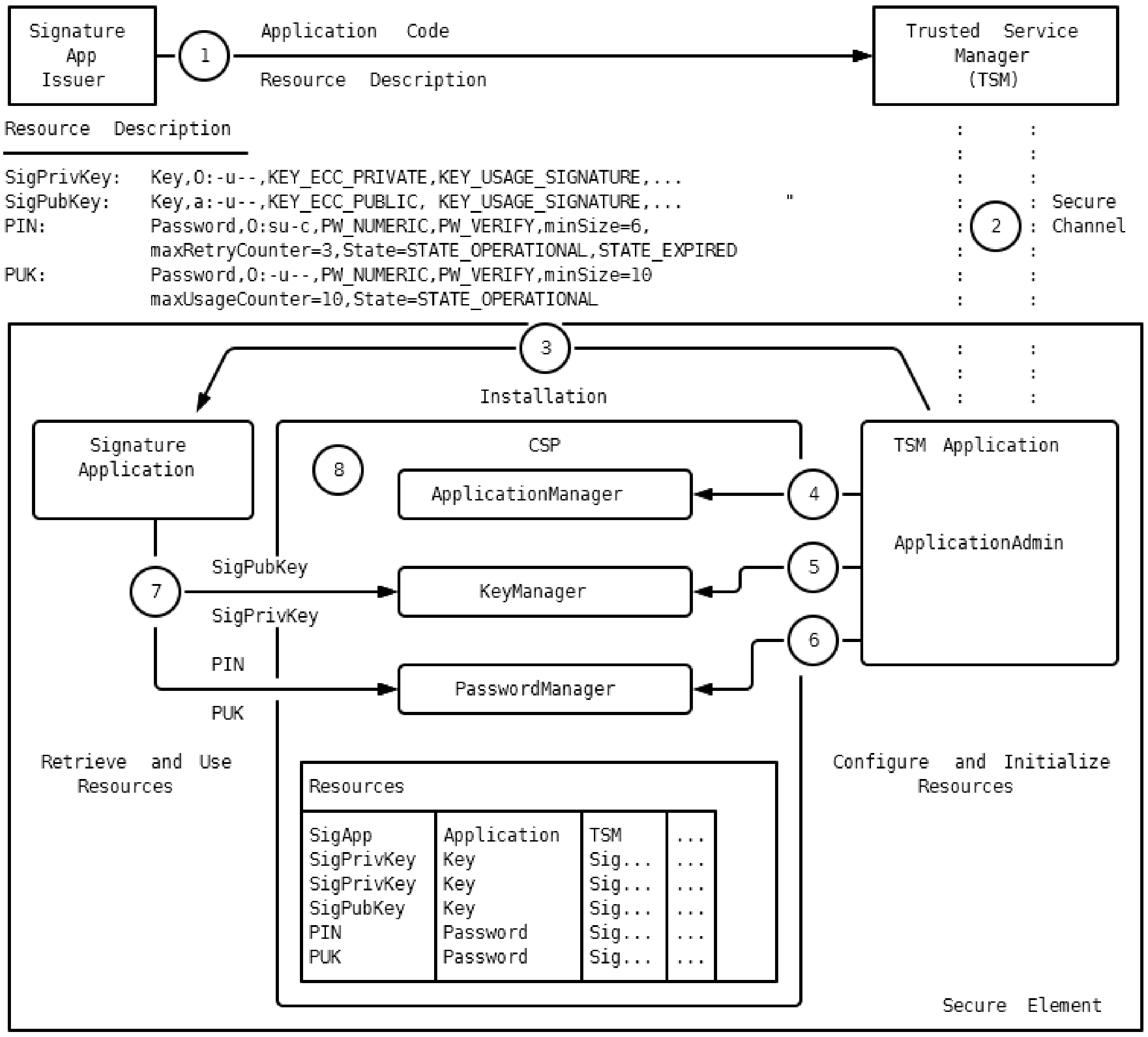
Personalization of the signature application:

6. The TSM Application imports wrapped passwords and wrapped keys provided by the Application Issuer using the `PasswordManager` and the `KeyManager`. Alternatively, the TSM Application may set initial passwords or keys by retrieving `Password` or `Key` handles.
7. The user application retrieves `Key` and `Password` handles via the `KeyManager` and `PasswordManager`, respectively, to perform owner management functions on key and password resources that are assigned to the application.

Operational use of the signature application:

8. The CSP operates the resources on behalf of the user application.

The example is also shown in .


Signature App Issuer
1
Application Code
Resource Description
Trusted Service Manager (TSM)
Resource Description
SigPrivKey: Key,O:-u--,KEY_ECC_PRIVATE,KEY_USAGE_SIGNATURE,...
SigPubKey: Key,a:-u--,KEY_ECC_PUBLIC, KEY_USAGE_SIGNATURE,...
PIN: Password,O:su-c,PW_NUMERIC,PW_VERIFY,minSize=6, maxRetryCounter=3,State=STATE_OPERATIONAL,STATE_EXPIRED
PUK: Password,O:-u--,PW_NUMERIC,PW_VERIFY,minSize=10 maxUsageCounter=10,State=STATE_OPERATIONAL
2
Secure Channel
3
Installation
Signature Application
CSP
8
ApplicationManager
4
TSM Application
ApplicationAdmin
SigPubKey
7
KeyManager
5
SigPrivKey
PIN
6
PasswordManager
PUK
Retrieve and Use Resources
Configure and Initialize Resources
Resources
Secure Element

SigApp	Application	TSM	...
SigPrivKey	Key	Sig...	...
SigPrivKey	Key	Sig...	...
SigPubKey	Key	Sig...	...
PIN	Password	Sig...	...
PUK	Password	Sig...	...

Figure 3: TSM Application Deployment

3 Resources

The CSP is responsible for securely operating the configured resources, i.e. abstract application, key and password objects within the CSP. Resources are always associated with an owner, that is either a user application or an administrative application. Before granting an application access to an operation on a resource, the CSP has to verify the configured access control rules and policies. From the perspective of the CSP, applications are also a resource. By default, an application is owned by itself.

Resources are configured by the `ApplicationAdmin` as described in Section *4.1* and consist of the parameters described in Table *3*.

Table 3: Resource Parameters

Parameter	Description	Avail.
Identifier	An identifier that uniquely identifies the resource.	m
Type	The type of the resource, e.g. an application, a key or a password	m
Owner	The identifier of the application (group) that owns the resource.	m
Access Control	The basic access control rules to restrict access to the resource	m
State	The current state of the resource	m
Policy	Additional policy rules to further restrict access to the resource	o
Audit Events	Security related events of the resource to be audited by the CSP	o
Attributes	A list of attributes specific to the resource.	c
Value	The content of the resource itself. This is usually a reference to an instance of an internal object or data structure of the resource.	m

Applications may retrieve resource objects via the respective operational management functions of the CSP, i.e. using the `KeyManager` (cf. Section *4.2*) or the `PasswordManager` (cf. Section *4.3*). The parameters of the resource may be queried using `getIdentity`, `getType`, `getOwner`, `getAccessControl`, `getPolicy`, and `getAuditEvents`. Furthermore, attribute specific get and set operations are available as described below.

3.1 Parameters

3.1.1 Identifier

Every resource is uniquely identified by two types of resource identifiers:

Application-specific resource Identifier
An application-specific identifier is only valid within the context of an application. Thus, the concatenation of the application identifier (which is also a resource identifier) and the application-specific resource identifier of the resource uniquely identify the resource. Application-specific resource identifiers SHALL be used, when the resource to be identified is not bound to a certain device, e.g. the configuration files of the application issuer use application-specific resource identifiers.

Device-specific resource identifier
A device-specific identifier is only valid within a certain device or a cluster. The device-specific identifier is generated by the CSP when the device is configured. Applications MUST NOT make any assumptions on the assignment of device-specific resource identifiers. In cluster mode, the device-specific identifier MUST also include the device identifier of the CSP that has generated the device-specific identifier.

Applications may use the application-specific resource identifier to query the corresponding device-specific resource identifier. Once the device-specific identifier is known, the application SHOULD use the device-specific identifier.

Global resources SHOULD be made available under their application-specific identifier under the global application namespace.

3.1.2 Type

The CSP knows three types of resources: applications, keys, and passwords. Key resources include all types of keys, i.e. secret keys, private keys, public keys, and certificates, but also elliptic curve domain parameters.

Note: System time is *not* a resource. The system time is available to all applications and managed by an administrative application (cf. Section 2.4.3). The `TimeKeeper` is responsible for synchronizing system time with external time sources.

The type of a resource determines the attributes that can be assigned to a resource.

Application resources also act as proxy to shared system resources.

3.1.3 Owner

The application identifier is used to assign resources to an application. The application is the `Owner` of all resources, where the application identifier is given as resource owner. Thus, a password or key resource may be assigned to a certain application by setting the owner to the respective application identifier.

As applications are also resources applications MUST be assigned an owner.

- User Applications are usually stand-alone applications. In this case the application owns itself, i.e. the application identifier is also given as owner.
- Administrative Applications get enhanced privileges by assigning the respective role (cf. Section 2.3) as owner, i.e. any application that is assigned `ApplicationAdmin` or `DeviceAdmin` as owner, including the sub-roles, `UpdateAgent`, `CryptoOfficer` or `TimeKeeper`, may perform the respective administrative operational management functions.

3.1.4 Access Control

The CSP manages and operates resources on behalf of the application and uses them for security services. The access control rules are defined as a bit mask that allows (1) or forbids (0) an entity in a role to perform operations on the resource, as shown in Table 4.

Note: The access control rules of the CSP are defined analog to UNIX file permission. One may write `O:su-c` as compressed form of `Owner:setup,use,clear` to indicate that access to the operations `setup`, `use`, and `clear` is granted to the `Owner` but access to the `move` operation is denied.

The function `getAccessControlRules` returns the access control rules for the resource (i.e. `Key` or `Password`). The function `setAccessControlRules` SHALL be restricted to resource configuration.

Table 4: Access Control Matrix bit positions.

Role	`setup`	`use`	`move`	`clear`
`any`	0	1	2	3
`Owner`	4	5	6	7
`ApplicationAdmin`	8	9	10	11
`DeviceAdmin`	12	13	14	15

The `Owner` of a configured resources is always an application. Depending on the corresponding access control mask the application itself, an administrative application or even other user applications may perform the respective operation on the assigned resource.

The operations `setup`, `use`, `move` and `clear` are to be mapped to resource specific operations as described in Table 5.
Additional there might be an operation caused by an OS when the whole system is reset. Most of the resources will keep their states after a rest. But some states can be temporary and will not be kept after an reset (e.g. states Authenticated in resource Password).

Table 5: Resource-specific Operations.

Operation	`Application`	`Key`	`Password`
`setup`	Configure Resources	Key (Pair) Generation	Set / Change Password
`use`	Access Application	Cryptographic Operation	Password Verification
`move`	Import / Export Resources	Import / Export Key	Import / Export Password
`clear`	De-configure Resources	Destroy Key (Pair)	Reset Password

3.1.5 State

Resources are associated with a state that is managed by the CSP. The following states are used by the CSP. An overview on the states and their transition for the resources Application, Key and Password are given in Figure 4, Figure 5 *and* Figure 6.

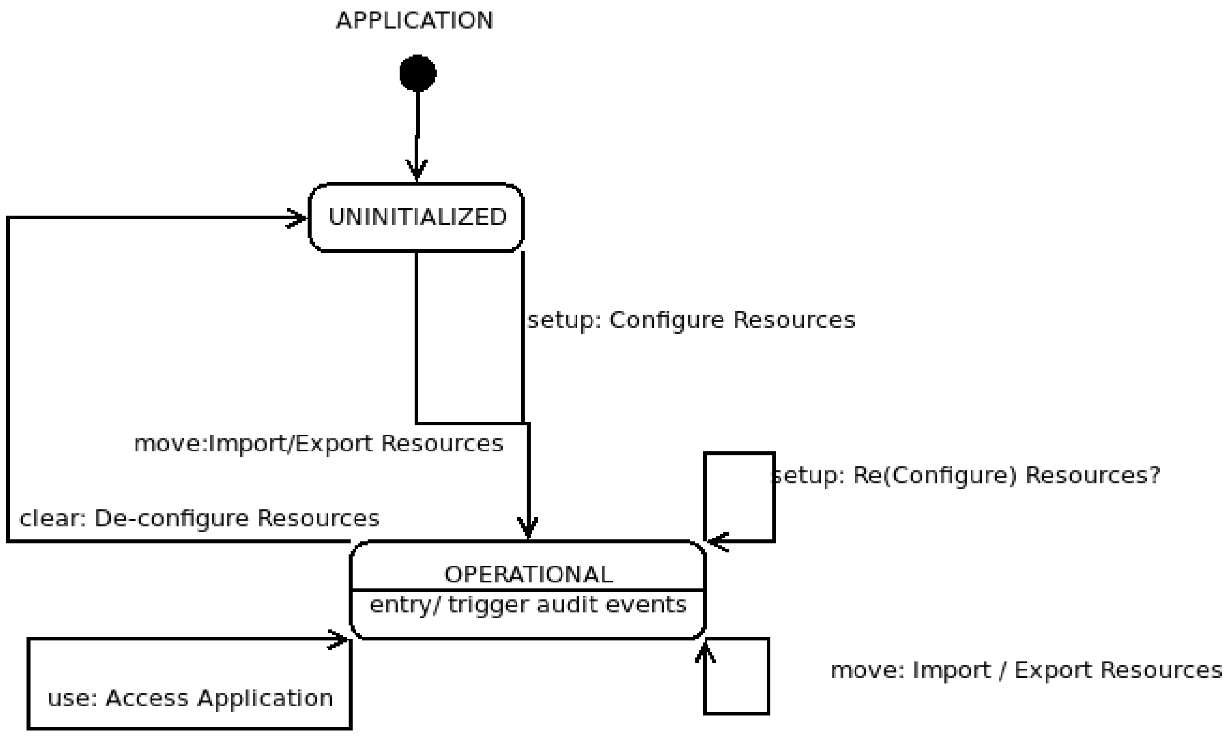

APPLICATION
UNINITIALIZED
setup: Configure Resources
move:Import/Export Resources
setup: Re(Configure) Resources?
clear: De-configure Resources
OPERATIONAL
entry/ trigger audit events
use: Access Application
move: Import / Export Resources

Figure 4: States of resource type 'Application'

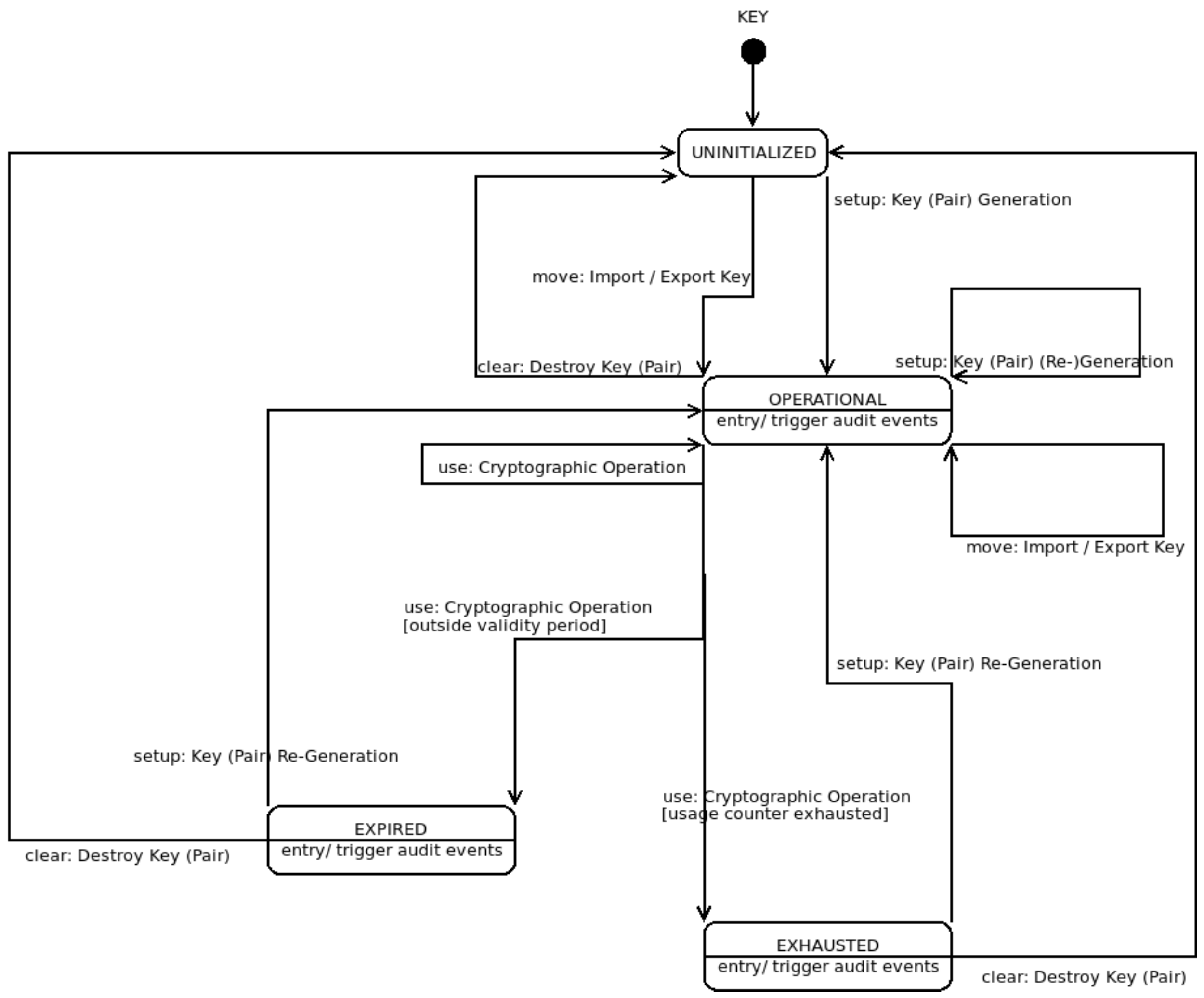

KEY
UNINITIALIZED
setup: Key (Pair) Generation
move: Import / Export Key
clear: Destroy Key (Pair)
setup: Key (Pair) (Re-)Generation
OPERATIONAL
entry/ trigger audit events
use: Cryptographic Operation
move: Import / Export Key
use: Cryptographic Operation
[outside validity period]
setup: Key (Pair) Re-Generation
setup: Key (Pair) Re-Generation
use: Cryptographic Operation
[usage counter exhausted]
EXPIRED
entry/ trigger audit events
clear: Destroy Key (Pair)
EXHAUSTED
entry/ trigger audit events
clear: Destroy Key (Pair)

Figure 5: States of resource type 'Key'

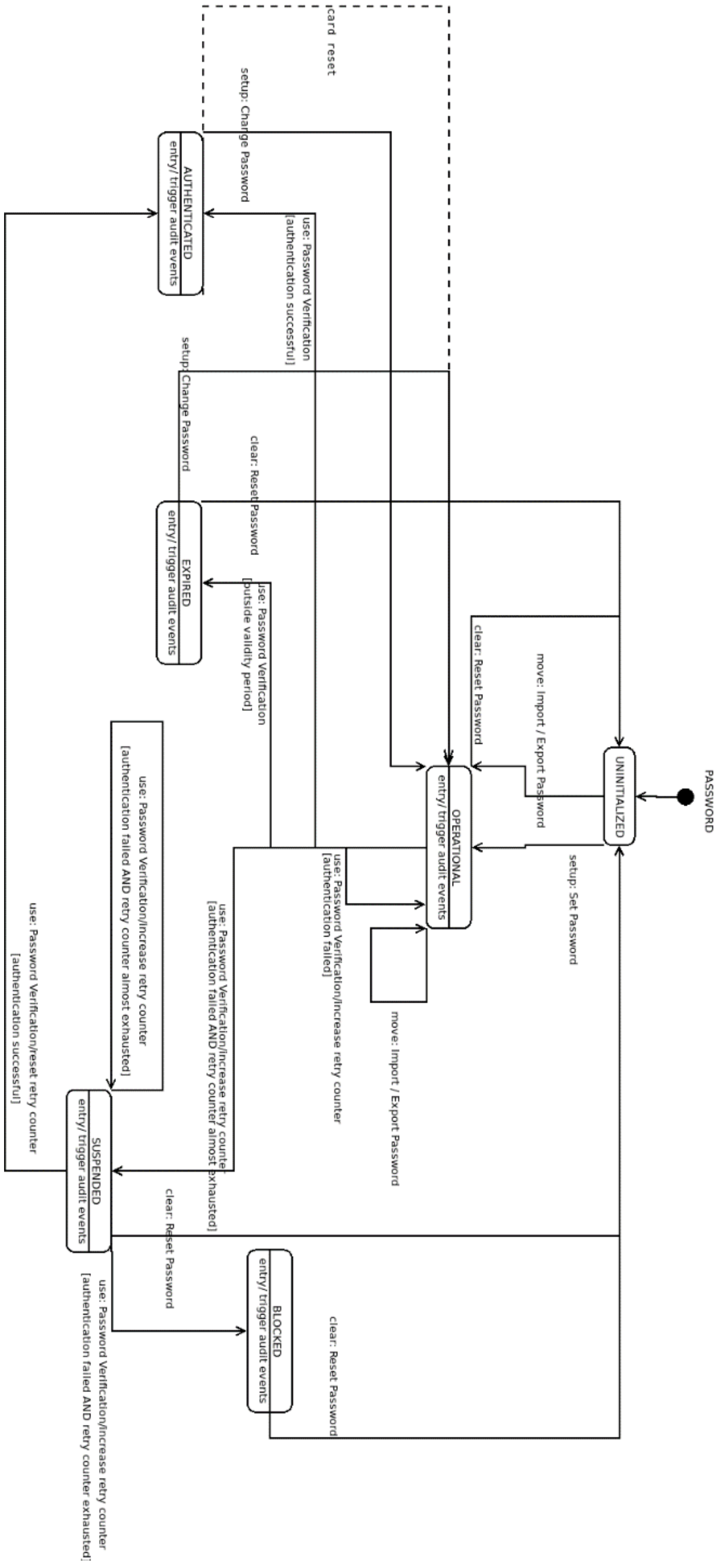

PASSWORD
UNINITIALIZED
setup: Set Password
move: Import / Export Password
clear: Reset Password
OPERATIONAL
entry/ trigger audit events
move: Import / Export Password
use: Password Verification/Increase retry counter
[authentication failed]
card reset
setup: Change Password
AUTHENTICATED
entry/ trigger audit events
use: Password Verification
[authentication successful]
setup: Change Password
clear: Reset Password
EXPIRED
entry/ trigger audit events
use: Password Verification
[outside validity period]
use: Password Verification/Increase retry counter
[authentication failed AND retry counter almost exhausted]
use: Password Verification/Increase retry counter
[authentication failed AND retry counter almost exhausted]
use: Password Verification/reset retry counter
[authentication successful]
SUSPENDED
entry/ trigger audit events
clear: Reset Password
use: Password Verification/Increase retry counter
[authentication failed AND retry counter exhausted]
BLOCKED
entry/ trigger audit events
clear: Reset Password

Figure 6: States of resource type 'Password'

Uninitialized
The initial state of a resource after configuration SHALL be `STATE_UNINITIALIZED`.

- The `setup` operation MUST be used to change the state to `STATE_OPERATIONAL`.
- The `move` operation MAY be used to import the resource and change the state to `STATE_OPERATIONAL`.
- Other operations SHALL NOT be permitted.

Operational
The state operational SHALL be set after initializing the resource.

- The `setup` operation MAY be used to redo the setup of the resource.
- The `use` operation MAY be used perform the operation associated with the resource.
- The `move` operation MAY be used to import / export the resource.
- The `clear` operation MAY be used to reset the state to `STATE_UNINITIALIZED`.
- Entering the state `STATE_OPERATIONAL` SHALL trigger audit events.
- The state `STATE_OPERATIONAL` SHALL be persistent and kept on a power cycle.

Authenticated
If the resource is used for authentication, and the verification was successful, then the state `STATE_AUTHENTICATED` SHALL be set.

- If the resource is used outside of its validity period, instead of state `STATE_AUTHENTICATED` the state `STATE_EXPIRED` SHALL be set.
- Entering the state `STATE_AUTHENTICATED` SHALL trigger policies and audit events.

Expired
If the resource is associated with a validity period, the CSP SHALL change the state to `STATE_EXPIRED` when the resource is used outside of its validity period.

- The `setup` operation MUST be used to re-generate the resource with a new validity period and reset the state `STATE_EXPIRED`.
- Other operations SHALL NOT be permitted.
- Entering the state `STATE_EXPIRED` SHALL trigger audit events.
- The state `STATE_EXPIRED` SHALL be persistent and kept on a power cycle.

Exhausted
If the resource is associated with a limitation on the `use` operations, the CSP SHALL change the state to `STATE_EXHAUSTED` when the limit is exceeded. The state `STATE_OPERATIONAL` SHALL be abandoned.

- The `setup` operation MUST be used to re-generate the resource and reset the state `STATE_EXHAUSTED`.
- Other operations SHALL NOT be permitted.
- Entering the state `STATE_EXHAUSTED` SHALL trigger audit events.
- The state `STATE_EXHAUSTED` SHALL be persistent and kept on a power cycle.

Suspended
If the resource is associated with a limitation on failed `use` operations, the CSP SHALL change the state to `STATE_SUSPENDED` just before the limit is exceeded.

- The `use` operation is unaffected in general by `STATE_SUSPENDED` but MAY be restricted by applying a policy for the `use` operation in state `STATE_SUSPENDED` as described in Section *3.1.6.2*.
- Entering the state `STATE_SUSPENDED` SHALL trigger audit events.
- The state `STATE_SUSPENDED` SHALL be persistent and kept on a power cycle.

Blocked
If the resource is associated with a limitation on failed `use` operations, the CSP SHALL change the state to `STATE_BLOCKED` when the limit is exceeded.

- The `clear` operation MUST be used to reset the state `STATE_BLOCKED`.
- Other operations SHALL NOT be permitted.
- Entering the state `STATE_BLOCKED` SHALL trigger audit events.
- The state `STATE_BLOCKED` SHALL be persistent and kept on a power cycle.

3.1.6 Policy

The OPTIONAL policy can be used to further restrict operations (`setup`, `use`, `move`, and `clear`) on a resource by extending the access control rules to include additional requirements on the authentication status of other resources.

A policy consists of an access control *constraint* and a list of *conditions*.

Constraint
The *constraint* defines how to restrict the access control rules of a resource. A constraint MUST include the resource and the operation to be restricted and MAY contain a state of the resource. The constraint is written as `Resource[:State].operation`.
If the OPTIONAL `[:State]` is omitted, the default state `STATE_OPERATIONAL` SHALL be used.

Conditions
The *conditions* are a list of tuples. Each condition MUST contain a resource and MAY consist a state of that resource. The conditions are written as `(Resource[:State],...)`.
If an OPTIONAL `[:State]` is omitted, the default state `STATE_SUCCESS` SHALL be used.

The CSP SHALL NOT execute the operation on the constrained resource if one or more conditions are not satisfied, even if the (unconstrained) access control rules would allow the execution. The CSP SHALL execute the constrained operation if and only if the access control rules and **all** conditions of the constraint are satisfied.

3.1.6.1 Example: Policy to associate a key with an PIN

A private key resource privkey is associated with the following policy:

```
privkey:STATE_OPERATIONAL.use(PIN:STATE_SUCCESS)
```

The CSP SHALL verify that the password resource PIN is in `STATE_SUCCESS` before access to the `use` operation of the private key is granted. The explicit declaration of the state of the private key and the PIN may be omitted as the states `STATE_OPERATIONAL` and `STATE_SUCCESS`, respectively, are implicitly set.

3.1.6.2 Example: Policy to associate a PIN with a CAN

A password resource PIN is associated with the following policy:

```
PIN:STATE_SUSPENDED.use(CAN:STATE_SUCCESS)
```

The CSP SHALL verify that the password resource CAN is in `STATE_SUCCESS` before access to the `use` operation of the PIN in `STATE_SUSPENDED` is granted. The explicit declaration of the state of the CAN may be omitted as this state is implicitly set to `STATE_SUCCESS`. The explicit declaration of the state of the CAN must not be omitted as the state `STATE_SUSPENDED` is not implicitly set.

3.1.6.3 Policy Timeout

Policies MAY include timeouts on the authentication status, i.e. timeout indicates the time after which the CSP SHALL reset the authentication status of the referenced resource. The CSP SHALL support two different types of timeouts:

SoftTimeout
The CSP SHALL invalidate the conditions of a constrained resource when the constrained resource is inactive for a certain period of time.

HardTimeout
The CSP SHALL invalidate the conditions of a constrained resource after a certain period of time independent of the activity of the constrained resource.

In the example above, the policy `privkey.use(PIN),SoftTimeout=1m` would invalidate the condition `(PIN)` after 1 minute of inactivity of the private key, while the policy `privkey.use(PIN),HardTimeout=1m` would invalidate the condition (PIN) after one minute after successful authentication with the PIN. The authentication state of the PIN SHALL NOT be affected by the invalidation.

Policies MAY also include a counter `Limit` that further restricts the execution of the operation on the constrained resource. The CSP SHALL invalidate the conditions of the constrained resource, when the counter is expired.

In the example above, the policy `privkey.use(PIN),Limit=3` would invalidate the condition (PIN) after three `use` operations of the private key.

The policies to be applied MUST be configured by the `ApplicationAdmin`. The application may only query the policy of a resource with `getPolicy`. If a policy is set, the CSP MUST verify that the conditions are satisfied each time the constrained operation on the resource is executed.

The use of policies is explained in more details in the example described in Section *3.5*.

3.1.7 Audit Events

Operations on resources performed by the CSP are considered security relevant events. Such events may become relevant to an external entity, that has to review the operations that were performed by an application. To produce reliable audit trails, the CSP allows the `ApplicationAdmin` to configure each application with an `Auditor`, which is a separate application that receives audit events of the application under audit. Thus, the `Auditor` is an application that monitors some or all security related operations of the application under audit. The `Auditor` may be a dedicated user application or it may be an administrative application that is able to perform management functions, e.g. suspend the application under audit. The `Auditor` may even be the application under audit itself.

A default `Auditor` SHOULD be provided by the implementation of the CSP. However, applications MAY provide their own application-specific auditor.

The events to be audited MUST be configured by the `ApplicationAdmin`. The CSP distinguishes system events and resource events.

Note: Audit events resulting from operations on resources are always mapped to the application, even if the audit events result directly or indirectly from the authentication of a human user via the application.

3.1.7.1 System Events

System events to be audited are configured in the application resource. System events include:

- Startup and shutdown of the CSP, e.g. following a power cycle
- Update of the system clock
- General error handling, including failed self-checks and failures with preservation of the secure state
- Update of the CSP

3.1.7.2 Resource Events

Resource events to be audited are configured in the respective resource. Resource events include:

- Resource retrieval: success or failure
- Operations on resources: `setup`, `use`, `move`, `clear`
- Change of the resource state: `STATE_AUTHENTICATED`, `STATE_SUCCESS`, `STATE_FAILURE`, `STATE_EXPIRED`, `STATE_EXHAUSTED`, `STATE_BLOCKED`
- Change of replication state: `Primary` or `Replica`, see Section *8*

The use of events is explained in more details in the example described in Section 3.5.

3.2 Application Attributes

Applications have a few attributes as described below that can only be set by the `ApplicationAdmin` when the application is configured. The attributes MUST NOT be readable or even writable by the application.

Table 6 summarizes the keys that may be configured as attributes of an application.

Table 6: Key Attributes of Applications

Key	Usage	Owner	Avail.
`ApplicationKey`	Resource Wrapping (Application)	`ApplicationAdmin`	m
`IssuerKey`	Resource Wrapping (Issuer)	`ApplicationAdmin`	m
`DerivationKey`	Key Derivation	`ApplicationAdmin` `DeviceAdmin`	c
`AttestationKey`	Key Attestation	`ApplicationAdmin` `DeviceAdmin`	o
`ClusterKey`	Cluster Mode	`DeviceAdmin`	o
`AuthenticationKey`	Client-Server Mode	`ApplicationAdmin`	c

3.2.1 Application Key

The `ApplicationKey` is REQUIRED. It is configured by the `ApplicationAdmin` as reference to a randomly generated secret key resource owned by the `ApplicationAdmin`. This key SHALL be used as wrapping key by the CSP if key im- or export is triggered by the application, and access control rules allow the key migration. As the `ApplicationKey` is randomly generated, keys can only be imported by the same instance of the application that has exported the key.

Note: As the `ApplicationAdmin` owns the key, the `ApplicationAdmin` MAY chose not to destroy the key, when an application is re-installed.

3.2.2 Issuer Key

The `IssuerKey` is REQUIRED. It is configured by the `ApplicationAdmin` as a derived key, such that the application issuer and the application share the same key. This key SHALL be used as wrapping key by the CSP if key im- or export is triggered by the `ApplicationAdmin`, and access control rules allow the key migration. As the `IssuerKey` is a derived key, keys can only be imported that have been exported by the issuer and vice versa. The `ApplicationAdmin` is not able to determine the key, as it is generated by the CSP as derived key.

3.2.3 Derivation Key

The `DerivationKey` is CONDITIONAL. If key resources of type `KEY_ECC_DERIVED` are generated, this key MUST be configured by the `ApplicationAdmin` as reference to a secret key resource owned by the `ApplicationAdmin` or the `DeviceAdmin`. This key SHALL be used by the CSP if derived keys are retrieved by the user application (cf. Section 4.2.2.1).

3.2.4 Attestation Key

The `AttestationKey` is OPTIONAL. It is configured by the `ApplicationAdmin` as reference to a private key resource owned by the `ApplicationAdmin` or the `DeviceAdmin.` If the `AttestationKey` is set, it SHOULD be configured to allow third parties to verify that the CSP is in a trustworthy state, i.e. certified according to the Protection Profile CSP [3] or CSPL [4] and initialized (cf. Section 2.6.1.2) and/or personalized (cf. Section *2.6.1.3*) by trustworthy entities using the administrative applications `DeviceAdmin` and/or `ApplicationAdmin`, respectively.

The CSP MUST use the configured `AttestationKey` when the application requests the attestation of a key resource to prove that the key is managed securely by the CSP.

Note: As the application is also configured by a trusted `ApplicationAdmin`, the key attestation indirectly proves that the application and its resources are in a trusted state.

3.2.5 Cluster Key

The `ClusterKey` is OPTIONAL. It is configured by the `ApplicationAdmin` as reference to a key owned by the `DeviceAdmin`. This key SHALL be shared by a group of devices that are part of the same cluster.

This key SHALL be used by the CSP if key im- or export is triggered by the `DeviceAdmin`, and access control rules allow the key migration. As the `ClusterKey` is shared by all devices in Cluster Mode, only those keys can be imported that have been exported by another CSP in the cluster.

It is RECOMMENDED to set up `ClusterKeys` as application-specific keys in the cluster, to ensure that import and export is restricted to the same application.

3.2.6 Authentication Key

The `AuthenticationKey` attribute is CONDITIONAL. It is REQUIRED in client-server mode for explicit authentication and to setup a secure channel (cf. Section *7*). It is configured by the `ApplicationAdmin` as reference to a randomly generated secret key resource owned by the `ApplicationAdmin`.

If an authentication key is set by `ApplicationAdmin`, this key MUST be used, otherwise the CSP MUST reject interaction with the application. If the authentication key is omitted, then the application MUST be operated in platform mode and is implicitly authenticated.

3.2.7 Auditor

The `Auditor` attribute is OPTIONAL. If the attribute is set, then it references an application that may fetch, transform and clear the audit events that are generated by the CSP for this application. If the attribute is set to its own application identifier, then the application becomes its own auditor. If the attribute is omitted, audit events are discarded.

3.3 Key Attributess

The `Key` object represents a key resource that is associated with a number of attributes as specified in Table *7*.

Table 7: Key Attributes

Attribute	Content	Avail.
KeyType	Algorithm associated with the key	m
KeyUsage	Purpose of the key	m
PublicReference	Resource identifier of the corresponding public key REQUIRED for private keys	c
PrivateReference	Resource identifier of the corresponding private key REQUIRED for public keys	c
DomainReference	Resource identifier of the Domain Parameters REQUIRED for elliptic curve public and private keys	c
CertificateReference	Resource identifier of a corresponding certificate	o
UsageCounter	Number of key use operations already performed with the key REQUIRED if maxUsageCounter is set	c

Attribute	Content	Avail.
	REQUIRED to Prepend UsageCounter REQUIRED to Apppend UsageCounter	
maxUsageCounter	Number of key use operations that can be performed with the key	o
Prepend	Internal information to include at the beginning of each key use operation	o
Append	Internal information to include at the end of each key use operation	o
notBefore	Point in time when the key becomes valid REQUIRED if maxValidity is set	c
notAfter	Point in time when the key becomes invalid REQUIRED if maxValidity is set	c
maxValidity	Restricts the validity time [notBefore,notAfter]	r
AllowedAlgorithms	List of allowed algorithms and key sizes	r
Size	Length of the key	m

All key attributes are readable by the application and may be queried using a `get{AttributeName}` function.

3.3.1 Key Type

The only way to set the `KeyType` of a `Key` is to generate or import the key or key pair. The key generation function of the CSP SHALL NOT accept parameters for the key generation that are not contained in the attribute `AllowedAlgorithms`. This attribute SHALL contain a list of algorithm identifiers that unambiguously describe the key or key pair. When a key is generated, the CSP SHALL verify that the requested algorithm is part of the list `AllowedAlgorithms` and generate the key (pair) accordingly.

The attribute `AllowedAlgorithms` SHOULD be set by the `ApplicationAdmin` when the key is configured. If they are omitted, default values set by the `DeviceAdmin` SHALL be used. Until a key is generated it SHALL have `TYPE_KEY_NULL`. The status of a key can also be queried with `isInitialized` which is equivalent to `KeyType` != `TYPE_KEY_NULL`. Table 8 shows the available options.

Note: The attribute name `KeyType` may be omitted in the following as the attribute value, e.g. KEY_AES, unambiguously identifies the attribute.

Table 8: Key Types

Algorithm	Key Type	Description
–	KEY_NULL	Uninitialized
AES128, AES256	KEY_AES	AES Key
SHA256, SHA512	KEY_HASH	KDF or HMAC
Domain Parameter Name	KEY_ECC_DOMAIN	Elliptic Curve Domain Parameters
	KEY_ECC_PUBLIC	Elliptic Curve Public Key
	KEY_ECC_PRIVATE	Elliptic Curve Private Key
	KEY_ECC_DERIVED	Elliptic Curve Derived Private Key
RSA2048,RSA3072,RSA4096	KEY_RSA_PUBLIC	RSA Public Key
	KEY_RSA_PRIVATE	RSA Private Key
–	KEY_CERTIFICATE	Public Key Certificate

3.3.2 Key Usage

The attribute `KeyUsage` defines the purpose of a key object. The `KeyUsage` can only be set by the `ApplicationAdmin` during key configuration. Table 9 shows the available options.

The CSP SHALL NOT allow any cryptographic operations using a key other than indicted by the `KeyUsage`.

Note: The attribute name `KeyUsage` may be omitted in the following as the attribute value, e.g. KEY_USAGE_SIGNATURE, unambiguously identifies the attribute.

Table 9: Key Usages

Key Usage	Description	Key Type	Algorithm
KEY_USAGE_SIGNATURE	MAC Electronic Signature	KEY_AES KEY_HASH KEY_ECC_* KEY_RSA_*	AES-CMAC HMAC-SHA ECDSA-SHA RSA-PSS-SHA
KEY_USAGE_SESSION	Key Wrapping Key Agreement Key Transport	KEY_AES KEY_ECC_* KEY_RSA_*	WRAP-AES ECKA-EG RSA-OAEP
KEY_USAGE_CA1	Chip Authentication 1	KEY_ECC_*	CA1-ECC
KEY_USAGE_CA2	Chip Authentication 2	KEY_ECC_*	CA2-ECC
KEY_USAGE_TA1	Terminal Authentication 1	KEY_ECC_* KEY_RSA_*	TA1-ECC TA1-RSA
KEY_USAGE_TA2	Terminal Authentication 2	KEY_ECC_* KEY_RSA_*	TA2-ECC TA2-RSA
KEY_USAGE_PACE	Domain Parameters for PACE	KEY_ECC_DOMAIN	PACE-ECC

3.3.3 Key (Pair) References

Asymmetric key pairs consist of a public key and a corresponding private key. A key pair occupies at least two key resources, one resource for the public key and another resource for the private key that SHALL be linked to each other by a reference to the corresponding key resource. Elliptic Curve key pairs SHALL additionally have a reference to the Elliptic Curve Domain Parameters. Finally, key resources MAY be associated with one or more certificates stored in separate key resources.

Table *10* summarizes the attributes used to link key resources.

Table 10: Linking Key Resources

Attribute	Key Resource	Usage
`PrivateReference`	KEY_RSA_PUBLIC KEY_ECC_PUBLIC	Key identifier of the corresponding private key resource
`PublicReference`	KEY_RSA_PRIVATE KEY_ECC_PRIVATE	Key identifier of the corresponding public key resource
`DomainReference`	KEY_ECC_PUBLIC KEY_ECC_PRIVATE	Key identifier of the Elliptic Curve Domain Parameters
`CertificateReference`	KEY_RSA_PUBLIC KEY_ECC_PUBLIC KEY_CERTIFICATE	List of key identifiers of corresponding certificate resources

3.3.4 Key Usage Counter

The OPTIONAL attributes `UsageCounter` and `maxUsageCounter` MAY be used to associate a key object with a monotonically increasing usage counter that SHALL be incremented by the CSP each time the key is used for a cryptographic operation.

The function `isKeyUsageCounterEnabled` may be used to query whether the attribute is set. The attributes can only be set by the `ApplicationAdmin` during key configuration.

If the usage counter is exhausted, i.e. the `UsageCounter` has reached `maxUsageCounter`, the CSP MUST NOT allow any usage of the key for cryptographic operations.

3.3.5 Key Validity Period

The CONDITIONAL attributes `notBefore` and `notAfter` are two UNIX timestamps that indicate the validity period of the key. If the attributes are set, the CSP SHALL NOT allow any cryptographic operations using the key outside the validity period.

The attributes are set internally by the CSP when the OPTIONAL attribute `maxValidity` was set by the `ApplicationAdmin` when the key was configured. The attribute `maxValidity` must be a positive integer. If the attribute is set, then the CSP SHALL set the attribute `notBefore` to the UNIX time, when the key is generated, and calculate `notAfter = notBefore + maxValidity`.

The function `hasValidityTimePeriod` may be used to query whether a key is associated with a validity time interval. In this case the function `getValidityTimePeriod` returns the time interval.

3.3.6 Prepend and Append

The CSP includes additional information in the use operations of a key when following OPTIONAL attributes are set:

- `Prepend`: The information to include in the operation SHALL be collected by the CSP at the beginning of the execution of the operation.
- `Append`: The information to include in the operation SHALL be collected by the CSP at the end of the execution of the operation.

The CSP MUST support prepending and appending key usage counters and the system time as shown in Table *11*. The attributes can only be set by the `ApplicationAdmin` during key configuration. The CSP SHALL take the order of prepended and appended information into account as configured by the `ApplicationAdmin`.

Table 11: Prepend and Append Information

Information	Prepend	Append
KeyUsageCounter	Current value	Incremented value
SystemTime	Start of operation	End of operation

3.4 Password Attributes

The `Password` object represents a password resource that is associated with a number of attributes as specified in Table *12*.

Table 12: Password Attributes

Attribute	Content	Avail.
PasswordType	Password character set and rules	m
PasswordUsage	Purpose of the authentication	m
UsageCounter	Number of password use operations already performed with the password REQUIRED if maxUsageCounter is set	c
maxUsageCounter	Number of password use operations that can be performed with the password	o
RetryCounter	Number of consecutive failed password use operations REQUIRED if maxRetryCounter is set	c
maxRetryCounter	Number of consecutive failed password use operations that block the password	o
notBefore	Point in time when the password becomes valid REQUIRED if maxValidity is set	c
notAfter	Point in time when the password becomes invalid REQUIRED if maxValidity is set	c

Attribute	Content	Avail.
maxValidity	Restricts the validity time [notBefore,notAfter]	r
minSize	Minimum password length	r
maxSize	Maximum password length	r
Size	Length of the password	m

All password attributes are readable by the application and may be queried using a `get{AttributeName}` function.

3.4.1 Password Type

The `PasswordType` is set by the `ApplicationAdmin` during password configuration. Table *13* shows the available options.

Note: The attribute name `PasswordType` may be omitted in the following as the attribute value, e.g. PASSWORD_NUMERIC, unambiguously identifies the attribute.

Table 13: Password Types

Password Type	Description
PASSWORD_NULL	Not initialized
PASSWORD_ANY	No rules apply
PASSWORD_NUMERIC	PIN / PUK
PASSWORD_ALPHA	Alphanumeric (0-9, A-Z and a-z)
PASSWORD_UTF8	UTF8 Charset
PASSWORD_STRONG	Enforce password rules

3.4.2 Password Usage

The attribute `PasswordUsage` defines the purpose of a password object. The `PasswordUsage` can only be set by the `ApplicationAdmin` during password configuration. Table *14* shows the available options.

Note: The attribute name `PasswordUsage` may be omitted in the following as the attribute value, e.g. PASSWORD_USAGE_VERIFY, unambiguously identifies the attribute.

Table 14: Password Usages

Password Usage	Description
PASSWORD_USAGE_VERIFY	Password verification by comparison
PASSWORD_USAGE_PACE	Password Authenticated Connection Establishment
PASSWORD_USAGE_SESSION	Password derived key
PASSWORD_USAGE_CLIENT	Client application authentication
PASSWORD_USAGE_SERVER	Server application authentication

3.4.3 Password Usage Counter

The OPTIONAL attributes `UsageCounter` and `MaxUsageCounter` MAY be used to associate a password object with a usage counter that SHALL be incremented by the CSP each time the key is used for an authentication.

The function `isPasswordUsageCounterEnabled` may be used to query whether the attribute is set. The attributes can only be set by the `ApplicationAdmin` during password configuration.

If the usage counter is exhausted, i.e. the `UsageCounter` has reached `MaxUsageCounter`, the CSP MUST NOT allow any usage of the password for authentication.

3.4.4 Password Validity Period

The CONDITIONAL attributes `notBefore` and `notAfter` are two UNIX timestamps that indicate the validity period of the password. If the attributes are set, the CSP SHALL NOT allow any authentication using the password outside the validity period.

The attributes are set internally by the CSP when the OPTIONAL attribute `maxValidity` was set by the `ApplicationAdmin` when the password was configured. If the attribute is set, then the CSP SHALL set the attribute `notbefore` to the UNIX time, when the password is set, and calculate `notAfter = notBefore + maxValidity`.

The function `hasValidityTimePeriod` may be used to query whether a password is associated with a validity time interval. In this case the function `getValidityTimePeriod` returns the time interval.

3.4.5 Retry Counter

For each failed authentication with a password that is associated with a `RetryCounter`, the counter is increased. The counter is reset after a successful authentication. A limitation on failed authentications may be set with the attribute `maxRetryCounter`. If the limit is exceeded the CSP SHALL set the `State` of the password resource to `STATE_BLOCKED` as described in Section *3.1.5*. To unblock the password, the `clear` operation MUST be used. The `clear` operation SHALL allow to reset the `RetryCounter` without resetting the password itself.

It is RECOMMENDED to use a policy to restrict access to the `clear` operation, e.g. to require authentication with a PUK to unblock a PIN.

3.5 Example: Signature Application

To illustrate the intended usage of application, key, and password resources we here exemplarily consider a signature creation device with time-stamping capabilities. The signature creation device consists of three applications:

- ***Signature*** application allowing authenticated external users to sign user data with pre-installed key material.
- ***Logging*** application providing signed and timestamped log messages of audit events produced by the ***Signature*** application.
- ***Time*** application allowing adjustments to the system time of the CSP.

Applications and CSP operate in platform mode.

Note: Public key, private key and domain parameter references and some attribute names are omitted in the example for better readability.

3.5.1 Signature Application

The ***Signature*** user application owns four resources, also shown in Table *15*:

- A pre-installed signature key pair consisting of the private key SigPrivKey and the public key SigPubKey.
- Two pre-installed passwords, PIN and PUK for local authentication.

Table 15: Signature Application resources

Name	Type	Owner	Access	Attributes

Signature	Application	Signature	`any:use`
			`ApplicationAdmin:`
			`setup`
				`Auditor = Logging`

PIN	Password	Signature	`Owner:`
			`setup`
				`PASSWORD_NUMERIC`
				`PASSWORD_USAGE_VERIFY`
				`STATE_EXPIRED`

Name	Type	Owner	Access	Attributes
			`use` `clear`	`minSize=6, maxRetryCounter=3`

PUK	Password	Signature	`Owner:use`	`PASSWORD_NUMERIC`
				`PASSWORD_USAGE_VERIFY`
				`minSize=10, maxUsageCounter=10`

SigPrivKey	Key	Signature	`Owner:use`	`KEY_ECC_PRIVATE`
				`KEY_USAGE_SIGNATURE`
				`PublicReference=SigPubKey`
				`DomainReference=brainpoolP256r1`

SigPubKey	Key	Signature	`any:use`	`KEY_ECC_PUBLIC`
				`KEY_USAGE_SIGNATURE`
				`PrivateReference=SigPrivKey`
				`DomainReference=brainpoolP256r1`

The public and private keys are linked to each other and to the domain parameters that have been configured by the `DeviceAdmin` as global resource.

PIN and PUK are used to authenticate an external human user as legitimate key holder. The inital PIN is a *transport PIN* that is not usable due to STATE_EXPIRED and must be replaced by an *operational PIN* (6 digits) by the key holder before the signature key can be used. The PIN is associated with a retry-counter that blocks the PIN after three authentication failures. Each authentication failure will cause an audit event. The retry counter of the PIN can be reset by successful authentication using the PUK. Each successful authentication with the PUK will cause an audit event.

The application is allowed (access control rule `Owner:use`) to create signatures using the signature private key on behalf of the user as legitimate key holder. Each use of the key for the signature operation will cause an audit event.

The additionally configured polices and events on the resources, shown in Table 16, are enforced by the CSP.

The policies further restrict the ability of the ***Signature*** application to use these resources:

- Usage of the signature private key requires prior authentication of the external user as legitimate key holder. This is enforced by the policy `SigPrivKey.use(PIN)`, which requires successful authentication with the PIN before the `use` operation of the SigPrivKey is allowed for a single (`Limit = 1`) signature operation. The PIN authentication is only valid for 3 minutes (`HardTimeout = 3m`).
- Changing the PIN also requires prior authentication of the external user. This is enforced by the policy `PIN.setup(PIN:STATE_AUTHENTICATED)`, which requires successful authentication with the PIN, even if it is expired, before the `setup` operation of the PIN to change the PIN is allowed.
- Resetting the retry counter of the PIN requires prior authentication with the PUK. This is enforced by the policy `PIN.clear(PUK)`, which requires successful authentication with the PUK before the application may clear the retry counter of the PIN. Note that this policy does not allow the application to change the PIN, which would additionally require the policy `PIN.setup(PUK)`.
- Changing or resetting the PIN is associated with a timeout of 1 minute (`HardTimeout = 1m`).

The CSP is furthermore instructed to provide the following events to the auditor application, which is configured as *Logging*:

- Adjusting the system time. This is enforced by configuring the event `time` of the ***Signature*** application.
- Authentication failure of the PIN. This is enforced by configuring the event `STATE_FAILURE` of the password resource PIN.
- Successful authentication with the PUK. This is enforced by configuring the event `STATE_SUCCESS` of the password resource PUK.

- Any signature creation. This is enforced by configuring the event `use` of the key resource SigPrivKey.

Table 16: Policies and Events of the Signature Application

Name	Policy	Events
Signature		time

PIN	`PIN.clear(PUK)`
	`PIN.setup(PIN:STATE_AUTHENTICATED),`
	`HardTimeout = 1m`
		`STATE_FAILURE`

PUK		`STATE_SUCCESS`

SigPrivKey	`SigPrivKey.use(PIN),Limit = 1,`
	`HardTimeout = 3m`	

3.5.2 Logging Application

The ***Logging*** application owns three resources, also shown in Table *17*:

- A pre-installed signature key pair that is configured for timestamping with a usage counter.
- A pre-installed password for remote authentication of an external human user.

Table 17: Logging Application resources

Name	Type	Owner	Access	Attributes
Logging	Application	Auditor	`any:use`	
AuditorPW	Password	Logging	`Owner:use`	`PASSWORD_UTF8` `PASSWORD_USAGE_PACE`

LogPrivKey	Key	Logging	`Owner:use`	`KEY_ECC_PRIVATE`
				`KEY_USAGE_SIGNATURE`
				`UsageCounter`
				`Append={UsageCounter, SystemTime}`

LogPubKey	Key	Logging	`any:use`	`KEY_ECC_PUBLIC` `KEY_USAGE_SIGNATURE`

The ***Logging*** application fetches, transforms and clears the audit events produced by the ***Signature*** application. The transformation consists of formatting and signing the audit events to produce a provable audit trail consisting of a sequence of numbered, time stamped and then signed log messages. The numbering and time stamping is performed internally by the CSP using the key usage counter and the system time.

Neither polices nor events on the resources are configured.

3.5.3 Time Application

The administrative ***Time*** application adjusts the system time of the CSP. This application does not have any configured resources other than the application resource itself, as shown in Table *18*.

Any external (human) user or internal application that interacts with the ***Time*** application may set the system time.

For details on administrative applications cf. Section *2.4.3*.

Table 18: Time Application resources

Name	Type	Owner	Access	Attributes
Time	Application	TimeKeeper	`any:use`	

4 Operational Management Functions

An overview on the management functions required for the CSP is given in Section 2.5. Operational management functions are the subset of management functions that are directly provided by the CSP via its management interfaces `ApplicationManager`, `KeyManager`, and `PasswordManager`. Those management interfaces can be used by applications to perform management tasks. Most of operational management functions are privileged operations that are restricted to administrative applications, only a subset of those functions are available to user applications.

4.1 Application Manager

Only the configuration and de-configuration of an application resource is handled via the `ApplicationManager`. The CSP SHALL restrict access to the `ApplicationManager` interface to the `ApplicationAdmin`.

Note: The installation, update, and de-installation of the application is a governing management function that is usually performed by the `ApplicationAdmin` using the mechanisms of the underlying platform.

4.1.1 Application Configuration

Application configuration consists of creating the application resource and setting application-specific attributes.

- The `configure` operation creates a new application resource and sets the
  - application identifier,
  - the owner,
  - the access control rules,
  - the reference to the application key,
  - the reference to the issuer key,
  - the reference to the CONDITIONAL derivation key,
  - the reference to the OPTIONAL attestation key, and
  - the OPTIONAL auditor attribute of the application.
- The `setAuthenticationKey` operation activates the Client-Server Mode and sets the authentication key to be used to setup a secure channel
- The `setClusterKey` operation activates the Cluster mode and sets the cluster key for key and password wrapping in the cluster.
- The `addEvent` operation MAY be used to include one or more system events to be audited for a given application identifier.

4.1.2 Application De-configuration

Application de-configuration means removing the application resource completely.

- The `delete` operation removes the application resource of a given application identifier and all other resources that are owned by the application identifier.

4.2 Key Manager

The `KeyManager` interface provides functions for managing the life-cycle of a key resource: key configuration, key retrieval, key migration, and key de-configuration.

4.2.1 Key Configuration

Key configuration consists of creating the key resource and setting application-specific attributes. Key configuration MUST be restricted to administrative applications in role `ApplicationAdmin`.

- The `configure` operation creates a new key resource and sets the following attributes:
  - the application-specific key identifier,
  - the owner,
  - the access control rules,
  - the key usage, and
  - the OPTIONAL attributes `UsageCounter`, `maxUsageCounter`, and `maxValidity` of the key.
- The configure operation returns a device-specific key identifier.
- The `addAlgorithm` operation MAY be used to include one or more algorithm and key size to the list of allowed algorithms and allowed key sizes of a previously configured key using its key identifier.
- The `addEvent` operation MAY be used to include one or more resource-specific events to be audited for a configured key using its key identifier.
- The `addPolicy` operation MAY be used to include one or more policies on the operations of a configured key using its key identifier. The policy consists of the key operation to be further restricted and a resource identifier that MUST be in state authenticated to allow the restricted operation. The policy MAY contain `SoftTimeout`, `HardTimeout`, and `Count` to further restrict the policy.
- The `prependUsageCounter` and `appendUsageCounter` operations MAY be used to include the value of the key usage counter in the key operation.
- The `prependSystemTime` and `appendSystemTime` operations MAY be used to include the value of the key usage counter in the key operation.

Key configuration does not generate any key material. The configured key SHALL have a `KeyType` of `KEY_TYPE_NULL`.

If the `ApplicationAdmin` has to pre-install key material, the key MUST be either explicitly generated or imported.

- To generate a key, the `KeyManager` interface MUST be used to retrieve a `Key` object before generating the key.
- To import a key, the `KeyManager` interface MUST be used to migrate keys.

4.2.2 Key Retrieval

Operations with a key resource can only be performed after the key has been retrieved. The `KeyManager` offers the operation `getKey` to retrieve a `Key` object by its application-specific identifier or by its device-specific identifier. The CSP MUST check the access control rules (cf. Section *3.1.4*) to verify that the application retrieving the key is either the `Owner` of the key resource or the access control rules of the key resource allow operations to be performed by applications that are not the `Owner`, i.e. operations may be performed by `any` or by administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

The cryptographic operations, including key generation and key usage are described in Section *5*.

4.2.2.1 Derived Keys

Key resources usually represent rather static keys that are once generated and used by the user application for the validity time (if any) of the key. Only when an expired key has to be replaced, the corresponding key resource changes by generating a new key. Key migration, as described below, allows for some flexibility by using more than one key in the same key resource. This approach however requires an external infrastructure where keys are stored.

The `KeyManager` therefore also offers the operation `deriveKey` for elliptic curve keys of type `KEY_ECC_DERIVED`. The operation retrieves an ad-hoc generated key for an application-defined context. The CSP MUST ensure that the generated key is strictly context-specific.

- Exactly the same key MUST always be re-produced in the same context.
- A key generated in one context MUST NOT be generated in any other context.

Depending on the configuration of the application, the CSP SHALL interpret the context either device-specific or application-specific by including the `DerivationKey` (cf. Section *3.2.3*) in the key generation (cf. Section *5.1.2*):

- Device-specific context: the same application on two different devices produces different keys.
- Application-specific context: the same application on two different devices produces identical keys.

4.2.2.2 Transient Keys

Transient keys are keys that are internally generated by the CSP that are not made available directly to the user application.

4.2.3 Key Migration

Key migration allows key resources to be swapped in and out of the CSP. Key migration may be triggered by user applications in roles `Owner` and `any` as well as by administrative applications in roles `ApplicationAdmin` and `DeviceAdmin`. The CSP MUST verify that the application triggering key export or import is allowed to perform key migration by the access control rules of the key resource.

Note: Although public keys are usually not sensitive, the access control rules also apply to key references containing public keys.

The CSP MUST NOT allow the export of uninitialized keys. When secret keys or private keys are exported or imported, the CSP MUST protect the key cryptographically using the respective key wrapping key as described below.

The import and export of public keys is less critical. The handling of public keys and certificates is described in Section *4.2.4* below.

4.2.3.1 User Applications

When a user application triggers export or import of secret or private keys, the CSP SHALL use the `ApplicationKey` for key wrapping (cf. Section *3.2.1*).

- For key export, the CSP MUST associate the key to be wrapped with the device-specific key identifier.
- For key import, the CSP MUST match the wrapped device-specific key identifier to the device-specific key identifier of the key resource to be used before importing the key.

The key attributes MUST NOT be exported or imported as the key can only be re-imported into the same key resource. Thus, if a key is associated with a usage counter, the counter is unaffected by import and export.

4.2.3.2 Application Administrator

An administrative application in role `ApplicationAdmin` MAY use key export and import to configure the application with keys provided by the application issuer. When the `ApplicationAdmin` triggers the export or import of secret or private keys, the CSP SHALL use the `IssuerKey` for key wrapping (cf. Section *3.2.2*).

- For key export, the CSP MUST associate the key to be wrapped with the application-specific key identifier and the key attributes.
- For key import, the CSP MUST match the wrapped application-specific key identifier and the key attributes before importing the key.

Application-specific key identifiers are used instead of device-specific identifiers as the (wrapped) keys are to be managed by the application issuer. The application issuer is not able to interpret the internal device-specific key identifiers used by the CSP. Therefore, the CSP MUST map the internal device-specific identifiers to external application-specific identifiers and vice-versa. When importing keys with attributes the CSP MUST ensure that the imported attributes are not in conflict to the already configured attributes. This due diligence performed by the CSP ensures the minimization of potential misconfiguration by application issuer and `ApplicationAdmin`.

4.2.3.3 Device Administrator

An administrative application in role `DeviceAdmin` MAY use key export and import to support clustering. Each CSP in the Cluster SHALL have a `Primary` resource table and `Replicas` of the resources of other CSPs in the cluster stored in separate resource tables.

When the `DeviceAdmin` triggers the export or import of keys, the CSP SHALL use the `ClusterKey` for key wrapping (cf. Section *3.2.5*).

- The CSP MUST allow export of keys in the `Primary` resource table.
- The CSP MUST NOT allow export of keys in a `Replica` resource table.
- The CSP MUST associate the keys to be exported with the device identifier, the device-specific key identifier, and the key attributes.

The `DeviceAdmin` MAY explicitly promote or degrade a key when it is exported or imported:

- Promote a key in a `Replica` resource table when it is exported. The CSP SHALL move the key from the `Replica` to the `Primary` resource table before it is exported.
- Degrade a key in the `Primary` resource table when it is exported to a new `Primary` CSP. The CSP SHALL use the device identifier of the new `Primary` and move the key from the `Primary` to the respective `Replica` resource table after it is exported.
- Promote a key to the `Primary` resource table when it is imported. The CSP SHALL store the key in the `Primary` resource table instead of the respective `Replica` resource table indicated by the device identifier.

Details on CSP Cluster Mode can be found in Section *8*.

4.2.4 Public Key Handling

Public keys are public data in general and therefore less restrictions apply to handling public keys. Nevertheless, the access control rules also apply to public keys, i.e. the CSP MUST NOT allow the im- or export of a public key if the access control rule of the key resource does not allow the `move` operation.

4.2.4.1 Public Key Export

When exporting a public key, the CSP SHALL ensure that public key is exported in an unambiguous format, e.g. in case of an elliptic curve public key, the encoded key SHALL include the domain parameters. It is RECOMMENDED to export public keys as certificates, however the procedures for issuing certificates are application-specific and have to be implemented by a user application as owner management function or by and administrative application as governing management function. The CSP supports certification procedures by providing a key attestation mechanism as described below.

Once a public key is linked to a certificate, the CSP SHALL provide the link as `CertificateReference` in the attributes of the key resource of the public key.

4.2.4.2 Key Attestation

Key attestation proves that a (private) key is managed securely by issuing an attestation certificate. The CSP MUST verify that the private key was generated by the CSP or by another CSP in the same cluster before issuing an attestation certificate.

The CSP SHALL include the following information in the certificate:

- the public key
- all relevant attributes of the key resource, e.g. key usage, validity period, and access control rules as appropriate,
- application-provided information, e.g. a challenge received from an external entity,
- the application-specific identifier of the key,
- the application identifier of the owner of the key resource,
- the unique identity of the CSP.

The certificate SHALL be signed internally by the CSP using the OPTIONAL attestation key (cf. Section *3.2.4*) configured for the application. If no attestation key is configured, then the CSP SHALL use the corresponding private key to generate a self-signed certificate.

4.2.4.3 Public Key Import

When importing a raw public key the CSP MUST perform the following checks and reject the import otherwise.

- The key resource where the public key is imported is of the correct type.
- The key resource is not linked to a private key resource.
- The encoding of the public key to be imported in unambiguous.
- The parameters of the public key match the configured parameters of the key resource.
- The public key passes the cryptographic validity checks.

4.2.4.4 Certificate Import

The CSP SHALL support CV Certificates as defined in [5]. Support for X.509 certificates is OPTIONAL.

The CSP SHALL verify a certificate before it is imported and made available as a key resource of type `KEY_CERTIFICATE`. The certificate validation procedure for CV Certificates MUST follow [5]. The CSP

SHALL use the Certificate Authority Reference of the certificate to be imported and the Certificate Holder Reference of the certificates in the key resources to construct and validate the certificate chain.

After successful import, the CSP SHALL provide the processed certificate metadata as attributes in the key resource:

- Key Usage
- Certificate Authority Reference
- Certificate Holder Reference
- Effective Role
- Effective Authorization
- Certificate validity period
- Certificate Extensions

The CSP SHALL set the `CertificateReference` attribute of the key resource used to import the certificate to link to the key resource holding the certificate of issuer of the certificate, i.e. the certificate authority.

4.2.5 Key De-Configuration

The `destroyKey` operation MUST be restricted to the `ApplicationAdmin`. The function destroys a key resource permanently, including the deallocation and reclaim of the memory used by the resource.

The `KeyManager` MUST verify that the `Key` is cleared by the application before the key resource can be de-configured. To clear a key, the `KeyManager` provides the operation `clearKey` that resets the key resource to an uninitialized state, i.e. key resource attributes SHALL be reset to the initially configured state.

Note: The operations `destroyKey` and `clearKey` have different purposes. The operation `clearKey` supports the owner management functions of user applications. To refresh an expired key, the user application resets the key resource holding the expired key to an uninitialized state and may then generate a new key. The operation destroy key is used by the `ApplicationAdmin`, e.g. when the user application is de-installed.

4.3 Password Manager

The `PasswordManager` interface provides functions for managing the life-cycle of a password resource: password configuration, password retrieval, password migration, and password destruction.

4.3.1 Password Configuration

Password configuration consists of creating the password resource and setting application-specific attributes. Password configuration MUST be restricted to administrative applications in role `ApplicationAdmin`.

- The `configure` operation creates a new password resource and sets the following attributes
  - the application-specific password identifier,
  - the owner,
  - the access control rules,
  - the password type, and
  - the OPTIONAL or RECOMMENDED attributes `UsageCounter`, `maxUsageCounter`, `minSize`, `maxSize`, and `maxValidity` of the password.
- The configure operation returns a device-specific password identifier.
- The `addEvent` operation MAY be used to include one or more resource-specific events to be audited for a configured password using its password identifier.
- The `addPolicy` operation MAY be used to include one or more policies on the operations of a configured password using its password identifier. The policy consists of the password operation to be further restricted and a device-specific resource identifier that MUST be in state authenticated to allow the restricted operation. The policy MAY contain `SoftTimeout`, `HardTimeout`, and `Limit` to further restrict the policy.

Password configuration does not set any (default) password. The configured key SHALL have a `PasswordType` of `PASSWORD_TYPE_NULL`.

If the `ApplicationAdmin` has to pre-install default or transport passwords, the password MUST be either explicitly set or imported.

- To set a password, the `PasswordMananger` interface MUST be used to retrieve a `Password` object before setting the password.
- To import a password, the `PasswordManager` interface MUST be used to migrate passwords.

4.3.2 Password Retrieval

Operations with a password resource can only be performed after the password has been retrieved. The `PasswordManager` offers the operation `getPassword` to retrieve a `Password` object by its application-specific identifier or by its device-specific identifier. The CSP MUST check the access control rules (cf. Section *3.1.4*) to verify that application retrieving the password is either the `Owner` of the password resource or the access control rules of the password resource allow operations to be performed by applications that are not the `Owner`, i.e. operations may be performed by `any` or administrative applications in role `ApplicationAdmin` or `DeviceAdmin`.

4.3.3 Password Migration

Password migration allows password resources to be swapped in and out of the CSP. Password migration may be triggered by user applications in roles `Owner` and `any` as well as by administrative applications in roles `ApplicationAdmin` and `DeviceAdmin`. The CSP MUST verify that the application triggering password export or import is allowed to perform password migration by the access control rules of the key resource.

The CSP MUST not allow the export of uninitialized password. When passwords are exported or imported, the CSP MUST protect the password cryptographically using the respective key as described below.

4.3.3.1 User Applications

When a user application triggers export or import of password, the CSP SHALL use the `ApplicationKey` for password wrapping (cf. Section *3.2.1*).

- For password export, the CSP MUST associate the password to be wrapped with the device-specific key identifier.
- For password import, the CSP MUST match the wrapped device-specific password identifier to the device-specific password identifier of the password resource to be used before importing the key.

The password attributes MUST NOT be exported or imported as the password can only be re-imported into the same password resource. Thus, if a password is associated with a retry or usage counter, the counter is unaffected by import and export.

4.3.3.2 Application Administrator

An administrative application in role `ApplicationAdmin` MAY use password export and import to configure the application with passwords provided by or to the application issuer. When the `ApplicationAdmin` triggers the export or import of passwords, the CSP SHALL use the `IssuerKey` for password wrapping (cf. Section *3.2.2*).

- For password export, the CSP MUST associate the password to be wrapped with the application-specific password identifier and the password attributes.
- For password import, the CSP MUST match the wrapped application-specific password identifier and the password attributes before importing the password.

Application-specific password identifiers are used instead of device-specific identifiers as the (wrapped) passwords are to be managed by the application issuer. The application issuer is not able to interpret the internal device-specific password identifiers used by the CSP. Therefore, the CSP MUST map the internal device-specific identifiers to external application-specific identifiers and vice-versa. When importing passwords with attributes the CSP MUST ensure that the imported attributes are not in conflict to the already configured attributes. This due diligence performed by the CSP ensures the minimization of potential misconfiguration by application issuer and `ApplicationAdmin`.

4.3.3.3 Device Administrator

An administrative application in role `DeviceAdmin` MAY use password export and import to support clustering. Each CSP in the Cluster SHALL have a `Primary` resource table and `Replicas` of the resources of other CSPs in the cluster stored in separate resource tables.

When the `DeviceAdmin` triggers the export or import of passwords, the CSP SHALL use the `ClusterKey` for password wrapping (cf. Section *3.2.5*).

- The CSP MUST allow export of password in the `Primary` resource table.
- The CSP MUST NOT allow export of passwords in a `Replica` resource table.
- The CSP MUST associate the passwords to be exported with the device identifier, the device-specific password identifier, and the password attributes.

The `DeviceAdmin` MAY explicitly promote or degrade a password when it is exported or imported:

- Promote a password in a `Replica` resource table when it is exported. The CSP SHALL move the password from the `Replica` to the `Primary` resource table before it is exported.
- Degrade a password in the `Primary` resource table when it is exported to a new `Primary` CSP. The CSP SHALL use the device identifier of the new `Primary` and move the password from the `Primary` to the respective `Replica` resource table after it is exported.
- Promote a password to the `Primary` resource table when it is imported. The CSP SHALL store the password in the `Primary` resource table instead of the respective `Replica` resource table indicated by the device identifier.

Details on CSP Cluster Mode can be found in Section *8*.

4.3.4 Password De-Configuration

The `destroyPassword` operation MUST be restricted to the `ApplicationAdmin`. The function destroys a password resource permanently, including the deallocation and reclaim of the memory used by the resource.

5 Cryptographic Operations

The CSP provides the following cryptographic primitives and protocols:

- Key Generation
- Signatures and Timestamping
- Session Protection
- Identification and Authentication Protocols

Note: The CSP provides cryptographic operations only in a self-contained way, such that the risk of choosing insecure combinations of primitives or parameters is reduced.

5.1 Key Generation

Key generation is triggered by the user application or by the `ApplicationAdmin` to pre-generate keys, but performed internally by the CSP. The application MAY select the algorithm for key generation according to the list `AllowedAlgorithms` of the key resource. If the application omits the algorithm, then the first algorithm of `AllowedAlgorithms` SHALL be used. If `AllowedAlgorithms` is not configured, default algorithms SHALL be used. The defaults MUST be configured by the `DeviceAdmin`.

Note: The list of `AllowedAlgorithms` SHOULD be configured to contain algorithms ordered by preference.

The mapping of algorithms to key parameters is straightforward and performed internally by the CSP (cf. Table *8*). For elliptic curve key pairs, the name of the domain parameter SHALL be used as algorithm. The configuration of key resources for domain parameters is REQUIRED prior to the generation of elliptic curve key pairs.

5.1.1 Elliptic Curve Domain Parameters

Domain parameters to be supported by the CSP are shown in Table *19*. The supported domain parameters SHALL be configured by the `DeviceAdmin`. The (application-specific) identifier of the key resource SHALL match the name of the domain parameter for key generation.

Domain parameters SHOULD also include the preferred hash function to be used for signatures and key derivation.

Table 19: Domain Parameters

Domain Parameters	Avail.
brainpoolP256r1	m
brainpoolP256t1	o
brainpoolP384r1	m
brainpoolP384t1	o
brainpoolP512r1	c
brainpoolP512t1	o
Curve P-256	m
Curve P-384	m
Curve P-521	c
Curve25519	o

The curve parameters can be found in RFC5639 [6], FIPS186-4 [7].

5.1.2 Elliptic Curve Derived Keys

For derived keys (cf. Section *4.2.2.1*), it is RECOMMENDED to use a deterministic random number generator of class DRG.4 [8] to generate keys. The seed to be used for key generation SHALL be derived from the context and the `DerivationKey` (cf. Section *3.2.3*).

5.2 Signatures

The CSP supports message authentication codes and asymmetric signatures via the `Signature` interface.

5.2.1 Initialization

A `Signature` is initialized with a `Key` and parameters as shown in Table *20*. The signature algorithm to be used is automatically determined by the CSP by the `KeyType` as described in Section *3.3.1*.

The initialization may contain the following parameters:

- A `Key` with usage `KEY_USAGE_SIGNATURE` and MODE. The latter selects one row of Table *20*.

  After initialization either operation sign and timestamping or signature verification can be conducted. CSP MUST check if the provided KeyType fits with the desired operation. For example if a key of type KEY_*_PUBLIC was provided and the operation signature generation is started, and error should be thrown.

5.2.2 Signature Generation and Timestamping

Signatures are generated by calling the `sign` operation, which calculates the hash value, performs the cryptographic operations, and formats the signature according to the selected signature suite. The application MAY also use the `update` operation prior to the `sign` operation to update the hash function. After the sign operation, the `Signature` returns to the initialized state.

If information is to be prepended, the CSP SHALL collect and include the information when the first operation is executed after the initialization, i.e. the first call to either `update` or `sign`.

If information is to be appended, the CSP SHALL collect and include the information when `sign` is called and the hash value is calculated.

In case a signature or message authentication code requires an initialization vector, this initialization vector should be generated randomly by the CSP and provided as additional output.

5.2.3 Signature Verification

Signatures are verified by calling the verify operation. This operation takes an input value the data to be verified as well as other meta-data, and recalculates the signature with the key that was provided during initialization. The operation returns TRUE if the signature verifies, and FALSE, otherwise.

Additional meta-data are for example an initialization vector for verifying a message authentication code

5.2.4 Signature Suites

The CSP internally selects the appropriate signature suites for the selected mode. Table *20* lists the signature suites to be supported by the CSP. Details on the algorithms can be found in RFC 8017 [9], TR-03111 [10] ISO 9797-1 [11], ISO 9797-2 [12], and Special Publication 800-38D [13]. The appropriate SHA2 hash function of ISO 101183 [14] SHOULD be selected corresponding to the strength of the used `Key`.

Table 20: Signature Suites

Algorithm	Mode	Hash	Format	Avail.
RSA	RSASSA-PKCS1-v1_5	SHA2	EMSA-PKCS1-v1_5	m
	RSASSA-PSS	SHA2	EMSA-PSS	c

Algorithm	Mode	Hash	Format	Avail.
ECDSA	ECDSA-SHA2	SHA2	X9.62	m
	ECDSA	external	X9.62	o
	ECDSA-Plain-SHA2	SHA2	TR-03111	m
	ECDSA-Plain	external	TR-03111	o
EC-Schnorr	EC-Schnorr-SHA2	SHA2	TR-03111	o
AES	AES-CMAC	none	ISO 9797-1[2]	m
	AES-GMAC	none	SP800-38D	o
HMAC	HMAC-SHA2	SHA2	ISO 9797-2	m

5.3 Session Handling

The CSP provides mechanisms to protect the integrity and/or confidentiality of user data using appropriate transient session keys operated by the CSP. The `Session` interface may be used by the application, once initialized to `wrap` and `unwrap` data.

- The `wrap` operation encrypts the plaintext and authenticates the ciphertext.
- The `unwrap` operation verifies the integrity of the ciphertext and decrypts the ciphertext.

The wrap and unwrap operations have additional operations initWrap and initUnwrap. These set the mode of wrapping and unwrapping, i.e. encrypt-then-mac, encrypt only or mac-only.

The `Session` to be protected may be either stream-oriented or block-oriented. In block-oriented mode random access SHALL be supported by the CSP.

Note: While a `Session` is often used to protect communication, it may also be used to protect the integrity and/or confidentiallity of data handled by the user application.

When derived session keys are used, the CSP SHOULD re-generate session keys depending on the position in stream oriented-mode or on the index in block-oriented mode. When session keys cannot be re-generated, the CSP MUST limit the amount of data that is processed with `Session`.

5.3.1 Session Protection Keys

The generation of transient session keys for content protection MUST be performed internally by the CSP using either a `Key` or a `Password` provided by the application with usage `KEY_USAGE_SESSION` or `PASSWORD_USAGE_SESSION`. The generation or derivation of session keys depends on the mode set by the application. Depending on the `KeyType` the following algorithms are supported.

5.3.1.1 Key Agreement

Key Agreement SHOULD be used for keys of type `KEY_ECC_*`, if only a single key is used. For more than one `Key` the alternative Key Transport MUST be used.

Transient keys are generated using ephemeral-static ECDH also known as ElGamal Key Agreement (ECKA-EG) according to [10]. ECKA-EG always requires two elliptic curve key pairs, a static key pair and an ephemeral key pair generated using the elliptic curve domain parameters of the static key pair.

The initialization may contain the following data:

- A single `Key` of type `KEY_ECC_PUBLIC` of a recipient. The CSP SHALL perform the following steps:
  - transparently generate an ephemeral key pair on the same elliptic curve,
  - calculate the shared secret,
  - derive the transient session keys, and

[2] ISO9797-1 Method 5 using padding method 2

  - output the ephemeral public key as initialization data.
- A `Key` of type `KEY_ECC_PRIVATE` and initialization data. The CSP SHALL perform the following steps:
  - interpret the initialization data as ephemeral elliptic curve public key, otherwise try key transport,
  - verify and temporarily import the ephemeral public key,
  - calculate the shared secret, and
  - derive the transient session keys.

5.3.1.2 Key Transport

Key Transport SHALL be used for keys of type `KEY_RSA_*`. Use of Key Transport for keys of type `KEY_ECC_*` is CONDITIONAL. Key Transport MUST be used if multiple public keys are used, for single keys of type `KEY_ECC_*` the use of Key Agreement is RECOMMENDED.

Transient keys are either generated directly as randomly chosen keys or session keys are derived from a randomly generated seed. The session keys or the seed are encrypted or decrypted using RSA EME-OAEP [9] or ECKA-EG [10].

The initialization may contain the following data:

- One or more `Keys` of type `KEY_RSA_PUBLIC` or `Key_ECC_PUBLIC` of the recipients. The CSP SHALL perform the following steps:
  - transparently generate transient session keys (either directly or indirectly by deriving keys from a random seed),
  - encrypt the session keys or the seed with each public key, and
  - output the encrypted session keys or the encrypted seed as initialization data.
- A `Key` of type `KEY_RSA_PRIVATE` or `KEY_ECC_PRIVATE` and initialization data. The CSP SHALL perform the following steps:
  - interpret the initialization data as one or more encrypted session keys or encrypted seeds,
  - select the ciphertext corresponding to the given private key reference
  - verify the integrity of the ciphertext, and
  - decrypt the transient session keys or the seed and derive session keys.

5.3.1.3 Key Wrapping

Key Wrapping SHALL be used for keys of type `KEY_AES`.

Key Wrapping is similar to key transport, but instead of asymmetric keys, a pre-shared secret key is used to wrap the random session keys. In this case AES Key Wrapping according to RFC 3394 [15] is used.

The initialization may contain the following data:

- One or more `Keys` of type `KEY_AES` . The CSP SHALL perform the following steps:
  - transparently generate transient session keys (either directly or indirectly by deriving keys from a random seed),
  - encrypt the session keys or the seed with each secret key, and
  - output the encrypted session keys or the encrypted seed as initialization data.
- A `Key` of type `KEY_AES` and initialization data. The CSP SHALL perform the following steps:
  - interpret the initialization data as one or more encrypted session keys or encrypted seeds,
  - select the ciphertext corresponding to the given secret key reference
  - verify the integrity of the ciphertext, and
  - decrypt the transient session keys or the seed and derive session keys.

5.3.1.4 Password-based Key Derivation

Password-based Key Derivation SHALL be used for passwords of type `PASSWORD_STRONG`.

Password-based Key Derivation is similar to key wrapping, but instead of symmetric keys, a pre-shared password is used to first derive a secret key which is then used to encrypt the random session keys. RFC 8018 [16] SHALL be used for key derivation.

The initialization may contain the following data:

- One or more `Passwords` of type `PASSWORD_STRONG`. The CSP SHALL perform the following steps:
  - derive a transient AES key from each password,
  - transparently generate transient session keys (either directly or indirectly by deriving keys from a random seed),
  - encrypt the session keys or the seed with each secret key, and
  - output the encrypted session keys or the encrypted seed as initialization data.
- A `Password` of type `PASSWORD_STRONG` and initialization data. The CSP SHALL perform the following steps:
  - verify that the password is in state authenticated,
  - derive an transient AES key from the password,
  - interpret the initialization data as one or more encrypted session keys or encrypted seeds,
  - select the ciphertext corresponding to the given secret key reference
  - verify the integrity of the ciphertext, and
  - decrypt the transient session keys or the seed and derive session keys.

5.3.2 Cipher Suites

The CSP internally selects the appropriate cipher suites and session handling for the selected mode. Table 21 lists the cipher suites to be supported by the CSP.

Note: The cipher suites only applies to the transient session key. Session establishment often requires the use of identification and authentication protocols as described in Section 6.

Table 21: Cipher Suites

Protocol	Cipher	Mode	Integrity	KDF	Avail.
Secure Messaging	AES128	CBC	CMAC	X9.63	m
TLS	AES128	GCM	(GMAC)	SHA256	c
	AES256	GCM	(GMAC)	SHA384	c
	AES128	CTR	CMAC	SHA256	c
S/MIME	AES128	CBC	none	HKDF/ none	o
	AES128	GCM	(GMAC)	HKDF/ none	o
SSH	AES128	CTR	HMAC-SHA256	SHA256	o
	AES256	CTR	HMAC-SHA512	SHA512	o

6 Authentication and Identification Protocols

The application interacts with the external device and uses the `Protocol` interface to forward protocol data between the external device and the CSP. The application SHOULD NOT actively take part in the protocol execution, however the application MAY extract or re-format protocol messages. The protocol is solely implemented by the external device and the CSP.

6.1 Protocol Steps

A `Protocol` consists of three phases:

1. **Initialization:** The user application identifies the external device and negotiates the protocol and parameters.
2. **Authentication:** The CSP and the external device interact in the protocol.
3. **Session Establishment:** Depending on the protocol session keys MAY be derived.

6.1.1 Initialization

The application prepares the CSP for protocol execution. The user application determines the identity of the user to be authenticated, negotiates protocol parameters and, if required, imports resources of the user to be used in the protocol.

The resources to be used for protocol execution are selected by the application. If external identifiers for resources have to be mapped to internal resource identifiers, the mapping MUST be performed by the application. To simplify the mapping, it is RECOMMENDED to use application-specific resource identifiers consistently for internal and external identification of resources.

6.1.2 Authentication

The external device and the CSP interact in the protocol. The application forwards protocol data using `processAuthentication`. After executing the protocol the CSP SHALL set the authentication status (success or failure) of the used resource(s) accordingly to allow the application extended access to resources according to their policies (cf. Section *3.1.6*).

Within the authentication phase the external device and the CSP MAY also setup session keys. Those keys are ephemeral and SHOULD NOT be made available as key resources to the application in platform mode.

6.1.3 Session Establishment

After a successful execution of the authentication or identification protocol further communication between the external device and the user application MAY be protected by establishing a secure channel. The secure channel is based on the `Session` interface (cf. Section *5.3*). Details on the secure channel are described in Section *7*.

6.2 Available Protocols

6.2.1 PACE

The CSP MUST support Password Authenticated Connection Establishment (PACE) using Generic Mapping [5] in chip and terminal mode.

The CSP MUST establish a session after a successful execution of PACE.

6.2.1.1 Chip Mode

The user application MUST provide resources as described in Table 22 to initialize PACE in chip mode.

Table 22: Parameters of PACE in Chip Mode

Name	Type	Attribute	Avail.
Reference Password	Password	`PasswordUsage = PASSWORD_USAGE_PACE`	m
Domain Parameter	Key	`KeyType = KEY_ECC_DOMAIN` `KeyUsage = KEY_USAGE_PACE`	m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application is therefore restricted to the elliptic curve(s) that are configured by the `ApplicationAdmin`. The negotiation of parameters and/or the mapping of external user identifiers to password resources MUST be performed by the user application as owner management function.

6.2.1.2 Terminal Mode

The user application MUST provide resources as described in Table 23 to initialize PACE in terminal mode.

Table 23: Parameters of PACE in Terminal Mode

Name	Type	Attribute	Avail.
Entered Password	Password	`PasswordUsage = PASSWORD_USAGE_PACE`	o
Domain Parameter	Key	`KeyType = KEY_ECC_DOMAIN` `KeyUsage = KEY_USAGE_PACE`	m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application is therefore restricted to the elliptic curve(s) that are configured by the `ApplicationAdmin`. The negotiation of parameters and/or the mapping of external user identifiers to password resources MUST be performed by the user application as owner management function. The `Password` MAY be replaced by user input without setting a password resource.

Note: If the OPTIONAL `Password` parameter is not used, the neither Policies (cf. Section 3.1.6) nor Audit (cf. Section 3.1.7) can be used for authentication with PACE.

6.2.2 Terminal Authentication

The CSP MUST support Terminal Authentication in Version 1 (TA1) and Version 2 (TA2) [5] in chip and terminal mode.

Terminal Authentication cannot be used to establish a session. A session MAY be established by using Chip Authentication in combination with Terminal Authentication.

6.2.2.1 Chip Mode

The user application MUST provide resources as described in Table 24 to initialize Terminal Authentication in chip mode.

Table 24: Parameters of Terminal Authentication in Chip Mode

Name	Type	Attribute	Avail.
Ephemeral Terminal Public Key	Key	`KeyType = KEY_ECC_PUBLIC` `KeyUsage = KEY_USAGE_CA1/2`	m

Name	Type	Attribute	Avail.

Static Terminal Public Key	Key	`KeyType = KEY_CERTIFICATE`
		`KeyUsage = KEY_USAGE_TA1/2`
			m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application is therefore restricted to use a Static Terminal Public Key that has been successfully imported from a Terminal certificate by the CSP, starting at a trusted root certificate configured by the `ApplicationAdmin`. The retrieval of the certificate chain MUST be performed by the user application as owner management function. It is RECOMMENDED that the user application looks up the Certificate Holder References of the configured root certificates and makes the information available to the other user application in terminal mode, which has to construct the certificate chain.

The Ephemeral Terminal Public Key MUST also be imported by the user application for Chip Authentication (cf. Section *6.2.3.1*).

Note: In version 2 of the protocols Terminal Authentication is performed before Chip Authentication.

6.2.2.2 Terminal Mode

The user application MUST provide resources as described in Table *25* to initialize Terminal Authentication in terminal mode.

Table 25: Parameters of Terminal Authentication in Terminal Mode

Name	Type	Attribute	Avail.

Ephemeral Terminal Public Key	Key	`KeyType = KEY_ECC_PUBLIC`
		`KeyUsage = KEY_USAGE_CA1/2`
			m

Static Terminal Private Key	Key	`KeyType = KEY_*_PRIVATE`
		`KeyUsage = KEY_USAGE_TA1/2`
			m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application is therefore restricted to use a Static Terminal Private Key that has been configured by the `ApplicationAdmin`. It is RECOMMENDED to request the Certificate Holder References of trusted root certificates from the other user application in chip mode and use this information to construct a certificate chain.

The Ephemeral Terminal Public Key MUST be generated by the user application as part of Chip Authentication (cf. Section *6.2.3.2*).

Note: In version 2 of the protocols Terminal Authentication is performed before Chip Authentication.

6.2.3 Chip Authentication

CSP MUST support Chip Authentication in Version 1 (CA1) and Version 2 (CA2) [5] in chip and terminal mode.

The CSP MUST establish a session after successful execution of Chip Authentication.

6.2.3.1 Chip Mode

The user application MUST provide resources as described in Table *26* to initialize Chip Authentication in chip mode.

Table 26: Parameters of Chip Authentication in Chip Mode

Name	Type	Attribute	Avail.

Ephemeral Terminal Public Key	Key	`KeyType = KEY_ECC_PUBLIC`
		`KeyUsage = KEY_USAGE_CA1/2`
			m

Name	Type	Attribute	Avail.

Static Chip Private Key	Key	`KeyType = KEY_ECC_PRIVATE`
		`KeyUsage = KEY_USAGE_CA1/2`
			m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application is therefore restricted to use a Static Chip Private Key that has been configured by the `ApplicationAdmin`. The Ephemeral Terminal Public Key MUST be requested from the other user application in terminal mode. The Ephemeral Terminal Public Key MUST be generated on the same elliptic curve as the Static Chip Private Key. It is RECOMMENDED to configure both key resources with a `DomainReference` to the same key resource of the domain parameters. In this case the CSP MUST reject the import of the Terminal Ephemeral Public Key when the domain parameters are incorrect.

6.2.3.2 Terminal Mode

The user application MUST provide resources as described in Table 27 to initialize Chip Authentication in terminal mode.

Table 27: Parameters of Chip Authentication in Terminal Mode

Name	Type	Attribute	Avail.

Ephemeral Terminal Private Key	Key	`KeyType = KEY_ECC_PRIVATE`
		`KeyUsage = KEY_USAGE_CA1/2`
			m

Static Chip Public Key	Key	`KeyType = KEY_ECC_PUBLIC`
		`KeyUsage = KEY_USAGE_CA1/2`
			m

The selection of the parameters has to be performed by the user application. The CSP SHALL NOT accept any parameters that are REQUIRED but not configured as resources with suitable attributes. The user application must generate an Ephemeral Chip Private Key on the same Elliptic Curve as the Static Chip Public Key, however, it is also restricted to the parameters configured by the `ApplicationAdmin`.

6.3 Combination of Protocols

While some of the Authentication Protocols MAY be used stand-alone, it is often REQUIRED to execute the protocols in combination. This can be implemented by configuring Policies (cf. Section 3.1.6) on the resources.

To restrict the execution of Chip Authentication after a successful authentication with PACE, the Static Chip Private Key MUST be configured with a policy to require prior authentication with a password resource using PACE. To further restrict the execution of Chip Authentication after a successful authentication of the Terminal (i.e. version 2 of the protocol), the Static Chip Private Key MUST be configured with an additional policy to require prior authentication of the key resource holding the static Terminal Public Key (Certificate).

7 Secure Channel

Secure communication between a User, an Application and the CSP is established by the usage of a Secure Channel. In this chapter, different use cases of secure communication between these entities are discussed, i.e. CSP <-> CSP, CSP <-> Application and CSP <-> Application <-> User.

Two different use cases are distinguished: A Secure Channel is REQUIRED between an application in Client-Server Mode and CSP and RECOMMENDED between an external user who transparently communicates with the CSP via an application.

7.1 Application Secure Channel

A Secure Channel between an application and the CSP is REQUIRED in Client-Server Mode. The Secure Channel MUST be set up using the key resource referenced by the `AuthenticationKey` attribute (cf. Section *3.2.6*) of the application resource. The key reference attributes SHALL also indicate the secure channel protocol including the authentication mechanism and the session key derivation.

The application MUST implement the client protocol, the CSP MUST implement the server protocol. Both sides, application and CSP, MUST operate (i.e. generate, use, and destroy) session keys on their own.

7.2 User Secure Channel

An external user can either be a human user or a device. Setting up a secure channel is always assumed to be implemented by a device, even if the authentication is based on a password. Therefore, it is always assumed that the secure channel is established by a device.

- A secure channel between an external human user and the CSP is RECOMMENDED for password-based user authentication. Use of passwords without additional protection SHOULD be avoided unless in a secure environment (cf. Section *2.2*). The Secure Channel SHALL be set up using a password resource identifier provided by the application. The password resource is usually owned by the application, i.e. the mapping of the external user to the password resource is handled by the application (cf. Section *2.5.3*).
- A secure channel between an external device and the CSP is RECOMMENDED for key-based device authentication. The Secure Channel MUST be set up using a key resource provided by the application. The key resource is usually owned by the application, i.e. the mapping of the external device to the key resource is handled by the application (cf. Section *2.5.2*).

A Secure Channel SHOULD be established by using the `Protocol` interface of the CSP as described in Section *6*.

7.2.1 Platform Mode

The application MAY interact with the external device via a secure channel using the session keys that are bound to the instance of the `Protocol`. The application uses `wrap` and `unwrap` on outgoing and incoming messages, respectively. The CSP SHALL operate (i.e. generate, use, and destroy) session keys on behalf of the application.

7.2.2 Client-Server Mode

In Client-Server Mode, the user application MUST anyway operate session keys for the application secure channel to the CSP. This implies that the User Secure Channel is tunneled through the Platform Secure Channel. The CSP then actively transciphers all messages received from the User Device, i.e. the messages are en- and decrypted as follows using two Session Keys shared with the CSP, the User Session Key and the User Application Session Key:

1. The User Device encrypts and authenticates the plaintext with the User Session Key and sends the ciphertext to the User Application

2. The User Application receives the ciphertext, additionally encrypts and authenticates the ciphertext with the Application Session Key and sends it to the CSP.
3. The CSP transciphers the message:
    1. Verifies and decrypts the received ciphertext using the Application Session Key.
    2. Verifies and decrypts the resulting ciphertext using the User Session Key.
    3. Encrypts and authenticates the resulting plaintext using the Application Session Key and returns the ciphertext to the User Application.
4. The User Application receives, verifies, and decrypts the ciphertext using the Application Session Key.

To return a message from the User Application to the User Device, the same steps in opposite direction are performed. The transcipher process is also shown in Figure 7. As transciphering is relatively inefficient, the user application may request and operate the User Session Keys on its own.

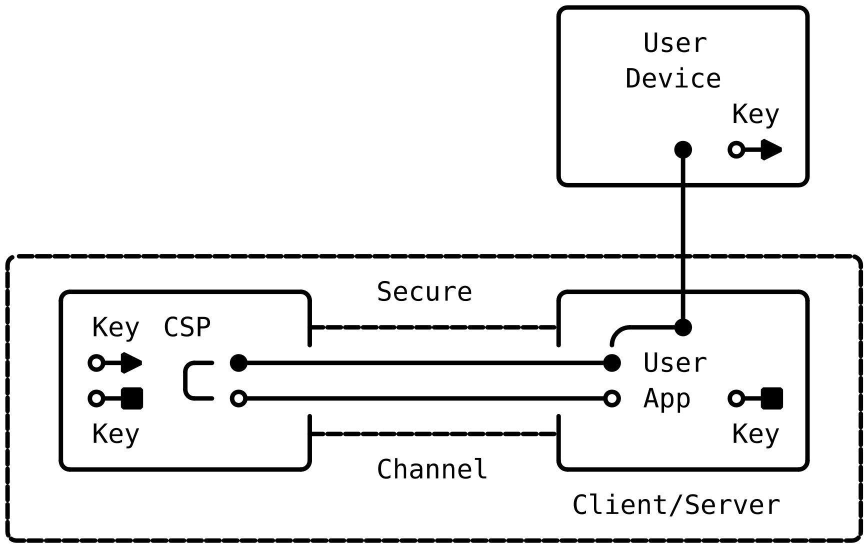


Figure 7: Indirect User Secure Channel

Therefore, instead of transciphering the User Secure Channel via the Application Secure Channel, the CSP MAY provide the session keys of the User Secure Channel to the user application. In this case, the user application MUST operate the session keys of the User Secure Channel without the CSP. The Direct User Secure Channel is shown in .

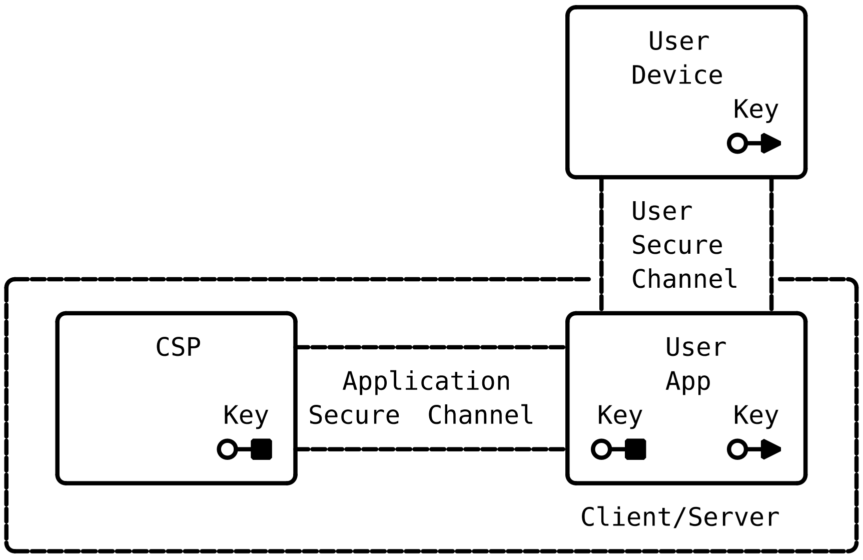


Figure 8: Direct User Secure Channel

8 Cluster Mode

In Cluster Mode the CSP allows to distribute key and password resources to multiple CSPs operated in a cluster aiming at improved performance or availability. To enable key and password distribution, a cluster consisting of several CSPs must be set up accordingly, i.e. the `DeviceAdmin` MUST configure `ClusterKey` key resources (cf. Section *3.2.5*) to be used for resource migration.

Implementation of the Cluster Mode is otional.

For each resource managed by a cluster of CSPs, exactly one CSP MUST be responsible for this resource. This CSP is called Primary, with respect to this resource. Only the Primary MAY distribute this resource to other CSPs in the cluster. The receiving CSP is then acting as Replica with respect to the resource and may use the resource within the limitations implied by the attributes (e.g. usage, validity, etc.).

8.1 User Applications

User applications SHOULD NOT notice any significant difference neither between a single CSP and a cluster of CSPs nor between a `Primary` and a `Replica` resource in cluster mode. User applications retrieve a `Key` or `Password` object via the `KeyManager` or `PasswordManager`, respectively, and perform operations according to the access control rules and policies.

If the resource is associated with a counter, a `Replica` MUST NOT allow any use of the resource that impacts the counter. The `Replica` MAY transparently forward the use operation to the `Primary` or return a failure.

8.2 Administrative Cluster Application

All administrative operations related to the cluster MUST be performed by administrative cluster applications in role `DeviceAdmin`. This cluster application is responsible for distributing resources within the cluster and managing `Primary` and `Replica` status of resources. While it is in general RECOMMENDED to operate administrative applications in Platform Mode, the cluster application SHOULD use a hybrid approach using both, the Platform Mode for local governing management functions and the Client-Server Mode for remote governing management functions. If the cluster application interacts in Client-Server Mode with a remote CSP, the `AuthenticationKey` of the cluster application MUST be used for authentication and establishing a secure channel to the remote CSP (cf. Section *3.2.6*). While an application in Client-Server Mode usually has to operate the session keys and the secure channel on its own (cf. Section *7.1*), due to the hybrid approach, the cluster application always has access to a CSP in Platform Mode.

Therefore the cluster application SHOULD use the local CSP to establish the secure channel with the remote CSP. The hybrid approach is shown in .

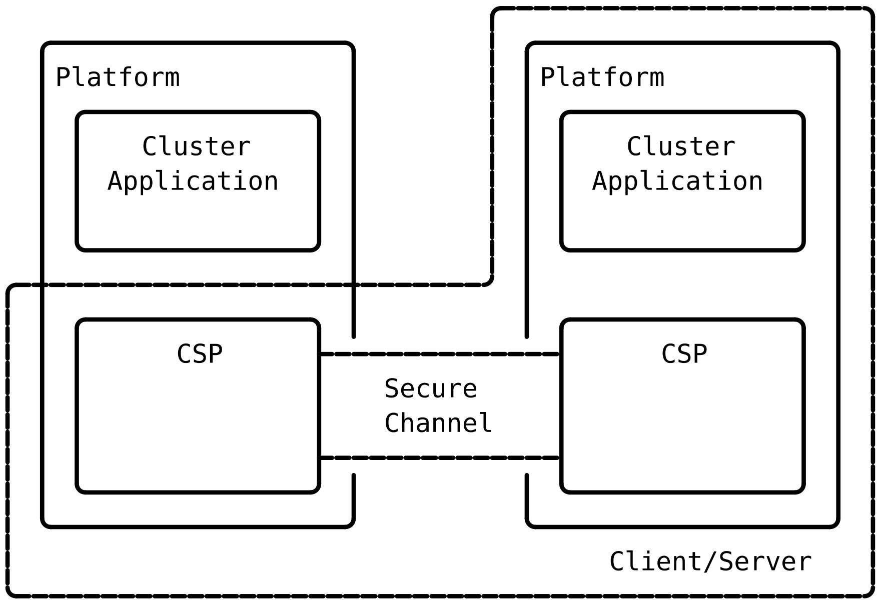


Figure 9: Cluster Application

8.2.1 Distributing Resources

The cluster application uses the `KeyManager` and the `PasswordManager` for key and password migration as described in Section *4.2.3* and Section *4.3.3*, respectively.

- The cluster application exports the resource to be distributed on the `Primary` CSP .
- The cluster application imports the exported resource on all `Replica` CSPs.

For resource distribution it is REQUIRED that all CSPs are configured with the same user application as `Owner` of the resource. The user application MUST be configured with the same `ClusterKey` (cf. Section *3.2.5*).

The CSP SHALL support the cluster application by producing audit events for failed resource lookups of user applications. Thus, if the cluster application is assigned to be `Auditor` of a user application, the cluster application receives information on missing resources of a user application and may request the resource as `Replica` from the `Primary` CSP.

The procedures for determining the `Primary` CSP and the communication between the administrative cluster applications are out of scope.

8.2.2 Changing Primary and Replica

The cluster application may promote a `Replica` to become the new `Primary` of a given resource. To switch `Primary` and `Replica` of a resource the following steps MUST be performed.

- If the current `Primary` is still available,
  - the cluster application MUST export and degrade the key or password resource to become `Replica`. The CSP SHALL produce an audit event for the degradation.
  - The cluster application SHALL import and promote the key or password resource to become `Primary` on the new CSP. The CSP SHALL produce an audit event for the promotion.
- If the current `Primary` is permanently unavailable,

  - the cluster application MUST export and promote the key or password resource on a `Replica` to become the new `Primary`. The CSP SHALL produce an audit event for the promotion.
- The cluster application SHALL adjust the `Primary` of the resource by re-importing the resource on all `Replica`.

The CSP SHALL support the cluster application by producing audit events for degradations and promotions. Thus, if the cluster application is assigned to be `Auditor` of a user application, the cluster application also receives information on `Primary` and `Replica` status of resources.

The cluster application SHOULD produce audit logs allow external entities to validate the correct operation of the cluster.

The procedures for selecting the new `Primary` CSP and the communication between the cluster applications are out of scope.

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