FIDO UAF Android Protected Confirmation Assertion Format

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The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

This document defines the assertion format "APCV1CBOR" in order to use Android Protected Confirmation for FIDO UAF Transaction Confirmation.

Status of This Document

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1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

1.1 Key Words

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

2. Overview

This section is non-normative.

This document defines the assertion format "APCV1CBOR" in order to use Android Protected Confirmation for FIDO Transaction Confirmation.

3. Data Structures for APCV1CBOR

This section is normative.

3.1 Registration Assertion

The registration assertion for the assertion format "APCV1CBOR" contains an object as specified in section 5.2.1 in [UAFAuthnrCommands], with the following specifics:

1. Only Surrogate Basic Attestation is supported. The extension "fido.uaf.android.key_attestation" [UAFRegistry] MUST be present.
2. The signature field (TAG_SIGNATURE) SHALL have zero bytes length, since the key cannot be used to create a self-signature.

3.2 Authentication Assertion

The authentication assertion is a TLV structure containing a CBOR encoded to-be-signed object:

TLV Structure		Description
1	UINT16 Tag	TAG_APCV1CBOR_AUTH_ASSERTION
1.1	UINT16 Length	Length of the structure.
1.2	UINT16 Tag	TAG_APCV1CBOR_SIGNED_DATA
1.2.1	UINT16 Length	Length of the structure.
1.2.2	UINT8 tbsData	The serialized Android Protected Confirmation CBOR object.
1.3	UINT16 Tag	TAG_AAID
1.3.1	UINT16 Length	Length of AAID
1.3.2	UINT8[] AAID	Authenticator Attestation ID
1.4	UINT16 Tag	TAG_KEYID
1.4.1	UINT16 Length	Length of KeyID
1.4.2	UINT8[]	(binary value of) KeyID

	KeyID	
1.5	UINT16 Tag	TAG_SIGNATURE
1.5.1	UINT16 Length	Length of Signature
1.5.2	UINT8[] Signature	Signature calculated using UAuth.priv over tbsData - *not* including any TAGs nor the KeyID and AAID.

NOTE

Only the data in `tbsData` is included in the signature computation. All other fields are essentially unauthenticated and are treated as 'hints' only.

4. Processing Rules

This section is normative.

4.1 Registration Response Processing Rules for ASM

Refer to [UAFAuthnrCommands] document for more information about the TAGs and structure mentioned in this paragraph.

1. Locate authenticator using `authenticatorIndex`. If the authenticator cannot be located, then fail with `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.
2. If a user is already enrolled with this authenticator (such as biometric enrollment, PIN setup, etc. for example) then the ASM MUST request that the authenticator verifies the user.

   NOTE

   If the authenticator supports `UserVerificationToken` (see [UAFAuthnrCommands]), then the ASM must obtain this token in order to later include it with the `Register` command.

   If the user is locked out (e.g. too many failed attempts to get verified) and the authenticator cannot automatically trigger unblocking, return `UAF_ASM_STATUS_USER_LOCKOUT`.

   - If verification fails, return `UAF_ASM_STATUS_ACCESS_DENIED`
3. If the user is not enrolled with the authenticator then take the user through the enrollment process.
   - If neither the ASM nor the Authenticator can trigger the enrollment process, return `UAF_ASM_STATUS_USER_NOT_ENROLLED`.
   - If enrollment fails, return `UAF_ASM_STATUS_ACCESS_DENIED`
4. Hash the provided `RegisterIn.finalChallenge` using the authenticator-specific hash function (`FinalChallengeHash`)

   An authenticator's preferred hash function information MUST meet the algorithm defined in the

AuthenticatorInfo.authenticationAlgorithm field.

5. Generate a key pair with apropriate protection settings and mark it for use with Android Protected Confirmation, see https://developer.android.com/training/articles/security-android-protected-confirmation.
6. Create a TAG_AUTHENTICATOR_ASSERTION structure containing a TAG_UAFV1_REG_ASSERTION object with the following specifics:
    1. set signature of Surrogate Basic Attestation to 0 bytes length
    2. add the Android Hardware Key Attestation extension
7. If the authenticator is a bound authenticator
    1. Store CallerID (see [UAFASM]), AppID, TAG_KEYHANDLE, TAG_KEYID and CurrentTimestamp in the ASM's database.

    > NOTE
    >
    > What data an ASM will store at this stage depends on underlying authenticator's architecture. For example some authenticators might store AppID, KeyHandle, KeyID inside their own secure storage. In this case ASM doesn't have to store these data in its database.

8. Create a RegisterOut object
    1. Set RegisterOut.assertionScheme according to "APCV1CBOR"
    2. Encode the content of TAG_AUTHENTICATOR_ASSERTION (i.e. TAG_UAFV1_REG_ASSERTION) in base64url format and set as RegisterOut.assertion as described in section "Data Structures for APCV1CBOR".
    3. Return RegisterOut object

4.2 Registration Response Processing Rules for FIDO Server

Instead of skipping the assertion as described in step 6.9, follow these rules:

1. if a.assertionScheme == "APCV1CBOR" AND a.assertion.TAG_UAFV1_REG_ASSERTION contains TAG_UAFV1_KRD as first element:
    1. Obtain Metadata(AAID).AttestationType for the AAID and make sure that a.assertion.TAG_UAFV1_REG_ASSERTION contains the most preferred attestation tag specified in field MatchCriteria.attestationTypes in RegistrationRequest.policy (if this field is present).
        - If a.assertion.TAG_UAFV1_REG_ASSERTION doesn't contain the preferred attestation - it is RECOMMENDED to skip this assertion and continue with next one
    2. Make sure that a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.FinalChallengeHash == FCHash
        - If comparison fails - continue with next assertion
    3. Obtain Metadata(AAID).AuthenticatorVersion for the AAID and make sure that it is lower or equal to a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.AuthenticatorVersion.
        - If Metadata(AAID).AuthenticatorVersion is higher (i.e. the authenticator firmware is outdated), it is RECOMMENDED to assume increased risk. See sections "StatusReport

dictionary" and "Metadata TOC object Processing Rules" in [FIDOMetadataService] for more details on this.

4. Check whether `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.RegCounter` is 0 since it is not supported in this assertion scheme.
    - If `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.RegCounter` is non-zero, this assertion might be skipped and processing will continue with next one
5. Make sure `a.assertion.TAG_UAFV1_REG_ASSERTION` contains an object of type `ATTESTATION_BASIC_SURROGATE`
    1. There is no real attestation for the AAID, so we just assume the AAID is the real one.
    2. If entry `AttestationRootCertificates` for the AAID in the metadata is not empty - continue with next assertion (as the AAID obviously is expecting a different attestation method).
    3. Verify that extension "fido.uaf.android.key_attestation" is present and check whether it is positively verified according to its server processing rules as specified [UAFRegistry].
        - If verification fails – continue with next assertion
    4. Verify that the attestation statement included in that extension includes the flag `TRUSTED_CONFIRMATION_REQUIRED` indicating that the key will be restricted to sign valid transaction confirmation assertions (see https://developer.android.com/training/articles/security-key-attestation and https://developer.android.com/training/articles/security-android-protected-confirmation).
        - If verification fails – continue with next assertion
    5. Mark assertion as positively verified
6. Extract `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.PublicKey` into PublicKey, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.KeyID` into KeyID, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.SignCounter` into SignCounter, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_ASSERTION_INFO.authenticatorVersion` into AuthenticatorVersion, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_AAID` into AAID.

4.3 Authentication Response Generation Rules for ASM

See [UAFASM] for details of the ASM API.

1. if this is a bound authenticator, verify `callerid` against the one stored at registration time and return `UAF_ASM_STATUS_ACCESS_DENIED` if it doesn't match.
2. The ASM MUST request the authenticator to verify the user.
3. Hash the provided `AuthenticateIn.finalChallenge` using the preferred authenticator-specific hash function (`FinalChallengeHash`).

    The authenticator's preferred hash function information MUST meet the algorithm defined in the `AuthenticatorInfo.authenticationAlgorithm` field.

4. If AuthenticateIn.keyIDs is not empty,
    1. If this is a bound authenticator, then look up ASM's database with `AuthenticateIn.appID` and `AuthenticateIn.keyIDs` and obtain the KeyHandles associated with it.
        - Return `UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY` if the related key disappeared permanently from the authenticator.

            `UAF_ASM_STATUS_ACCESS_DENIED`

Return if no entry has been found.

2. If this is a roaming authenticator, then treat `AuthenticateIn.keyIDs` as KeyHandles

5. If AuthenticateIn.keyIDs is empty, lookup all KeyHandles matching this request.
6. If multiple KeyHandles exist that match this request, show the related distinct usernames and ask the user to choose a single username. Remember the KeyHandle related to this key.
7. Call `ConfirmationPrompt.Builder` and pass the transactionText as parameter to method `setPromptText` see also https://developer.android.com/training/articles/security-android-protected-confirmation.
8. Pass the `FinalChallengeHash` as parameter to method `setExtraData`, see also https://developer.android.com/training/articles/security-android-protected-confirmation
9. Call `build` method of the ConfirmationPrompt and then call method `presentPrompt` providing an appropriate callback that will sign the `dataThatWasConfirmed` with the key identified by the KeyHandle remembered earlier.
10. Create `TAG_APCV1CBOR_AUTH_ASSERTION` structure.
    1. Copy the serialized `dataThatWasConfirmed` CBOR object into field `tbsData`.
    2. Copy `AAID` and `KeyID` into the respective TLV fields.
    3. Copy `signature` into the `TAG_SIGNATURE` field.
11. Create the `AuthenticateOut` object
    1. Set `AuthenticateOut.assertionScheme` to "APCV1CBOR"
    2. Encode the content of `TAG_APCV1CBOR_AUTH_ASSERTION` in base64url format and set as `AuthenticateOut.assertion`
    3. Return the `AuthenticateOut` object

The authenticator metadata statement MUST truly indicate the type of transaction confirmation display implementation. Typically the "Transaction Confirmation Display" flag will be set to `TRANSACTION_CONFIRMATION_DISPLAY_ANY` (bitwise) or `TRANSACTION_CONFIRMATION_DISPLAY_PRIVILEGED_SOFTWARE`.

4.4 Authentication Response Processing Rules for FIDO Server

Instead of skipping the assertion according to step 6.6. in section 3.5.7.5 [UAFProtocol], follow these rules:

NOTE

The extraData in tbsData.dataThatWasConfirmed is the finalChallengeHash as computed by the ASM. The promptText in tbsData.dataThatWasConfirmed is the AuthenticateIn.Transaction.content value. AuthenticateIn.Transaction.contentType is "text/plain".

1. if `a.assertionScheme` == "APCV1CBOR" AND `a.assertion` startes with a valid CBOR structure as defined in section 3.2 Authentication Assertion, then
    1. set `tbsData` to the CBOR object contained in `a.assertion.tbsData`.
    2. Verify the AAID against the AAID stored in the user's record at time of Registration.
        - If comparison fails – continue with next assertion
    3. Locate `UAuth.pub` associated with (`a.assertion.AAID`, `a.assertion.KeyID`) in the user's record.

    - If such record doesn't exist - continue with next assertion
4. Locate authenticator specific authentication algorithms from authenticator metadata (field `AuthenticationAlgs`)
5. If `fcp` is of type FinalChallengeParams, then hash `AuthenticationResponse.FinalChallengeParams` using the hashing algorithm suitable for this authenticator type. Look up the hash algorithm in authenticator Metadata, field `AuthenticationAlgs`. It is the hash algorithm associated with the first entry related to a constant with prefix ALG_SIGN.
    - `FCHash = hash(AuthenticationResponse.FinalChallengeParams)`
6. If `fcp` is of type ClientData, then hash `AuthenticationResponse.fcParams` using hashing algorithm specified in `fcp.hashAlg`.
    - `FCHash = hash(AuthenticationResponse.fcParams)`
7. Make sure that `tbsData.dataThatWasConfirmed.extraData` == `FCHash`
    - If comparison fails – continue with next assertion
8. Make sure there is a transaction cached on Relying Party side in the list `cachedTransactions`.
    - If not – continue with next assertion

> NOTE
>
> The `promtpText` included in this `AuthenticationResponse` must match the transaction content specified in the related `AuthenticationRequest`. As FIDO doesn't mandate any specific FIDO Server API, the transaction content could be cached by any relying party software component, e.g. the FIDO Server or the relying party Web Application.

9. Make sure that `tbsData.dataThatWasConfirmed.promptText` is included in the list `cachedTransactions`
    - If it's not in the list – continue with next assertion
10. Use the `UAuth.pub` key found in step 1.2 and the appropriate authentication algorithm to verify the signature `a.assertion.Signature` of the to-be-signed object `tbsData`.
    1. If signature verification fails – continue with next assertion

5. Example for FIDO Metadata Statement

This section is non-normative.

This example Authenticator has the following characteristics:

- Authenticator implementing transaction confirmation display using TrustedUI (i.e. in TEE)
- Leveraging TEE backed key store and user verification
- Only fingerprint based user verification is implemented - no alternative password

EXAMPLE 1: MetadataStatement for UAF Authenticator

```
{
  "description": "FIDO Alliance Sample UAF Authenticator supporting Android Protected
Confirmation",
    "aaid": "1234#5679",
    "authenticatorVersion": 2,
    "upv": [
      { "major": 1, "minor": 2 }
    ],
    "assertionScheme": "APCV1CBOR",
    "authenticationAlgorithm": 1,
    "publicKeyAlgAndEncoding": 256,
    "attestationTypes": [15880],
    "userVerificationDetails": [
      [{
        "userVerification": 2,
        "baDesc": {
          "selfAttestedFAR": 0.00002,
          "maxRetries": 5,
          "blockSlowdown": 30,
          "maxTemplates": 5
        }
      }]
    ],
    "keyProtection": 6,
    "isKeyRestricted": true,
    "matcherProtection": 2,
    "cryptoStrength": 128,
    "operatingEnv": "TEEs based on ARM TrustZone HW",
    "attachmentHint": 1,
    "isSecondFactorOnly": false,
    "tcDisplay": 5,
    "tcDisplayContentType": "text/plain",
    "attestationRootCertificates": [ ],
    "supportedExtensions": [{
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         "data": "{ \"attestationRootCertificates\": [
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      5qVA1rwUyJqXAlnzkiai/gHSD7RkTyihogAAAABJRU5ErkJggg=="
 }
```

A. References

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The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

This specification defines a mapping of FIDO UAF Authenticator commands to Application Protocol Data Units (APDUs) thus facilitating UAF authenticators based on Secure Elements.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

This document has been reviewed by FIDO Alliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

The notation `base64url(byte[8..64])` reads as 8-64 bytes of data encoded in base64url, "Base 64 Encoding with URL and Filename Safe Alphabet" [RFC4648] *without padding*.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

All TLV structures defined in this document MUST be encoded in little-endian format.

All APDU defined in this document MUST be encoded as defined in [ISOIEC-7816-4-2013].

1.1 Key Words

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

2. Introduction

This section is non-normative.

This specification defines the interface between the FIDO UAF Authenticator Specific Module (ASM) [UAFASM] and authenticators based upon "Secure Element" technology. The applicable secure element form factors are UICC (SIM card), embedded Secure Element (eSE), µSD, NFC card, and USB token. Their common characteristic is they communicate using Application Programming Data Units (APDU) in compliance with [ISOIEC-7816-4-2013].

Implementation of this specification is optional in the UAF framework, however, products claiming to implement the transport of UAF messages over APDUs should implement it.

This specification first describes the various fashions in which Secure Elements can be incorporated into UAF authenticator implementations — known as *SE-based authenticators* or just *SE authenticators* — and which components are responsible for handling user verification as well as cryptographic operations. The specification then describes the overall architecture of an SE-based authenticator stack from the ASM down to the secure element, the role of the "UAF Applet" running in the secure element, and outlines the nominal communication flow between the ASM and the SE. It then defines the mapping of UAF Authenticator commands to APDUs, as well as the FIDO-specific variants of the VERIFY APDU command.

NOTE

This specification does not define how an SE-based authenticator stack may be implemented, e.g., its integration with TEE or biometric sensors. However, SE-based authenticator vendors should reflect such implementation characteristics in the authenticator metadata such that FIDO Relying Parties wishing to be informed of said characteristics may have access to it.

3. SE-based Authenticator Implementation Use Cases

This section is non-normative.

Secure elements can be leveraged in different scenarios in the UAF technology. It can support user gestures (used to unlock access to FIDO credentials) or it can be involved in the actual cryptographic operations related to FIDO authentication. In this specification, we will be considering the following SE-based authenticator implementation use cases:

1. The Secure Element (SE) *is* the (silent) Authenticator.
2. The SE is part of the Authenticator which is composed of a Trusted Application (TEE) based User Verification component, potentially a TEE based transaction confirmation display and the crypto kernel inside the SE (***Hybrid SE Authenticator***).
3. The authenticator (Hybrid SE Authenticator) consists of
   - the SE implementing the matcher and the crypto kernel
   - and a specific software module (e.g. running on the FIDO User Device) to capture the user verification data (e.g. PIN, Face, Fingerprint).

3.1 Hybrid SE Authenticator

In FIDO UAF, the access to credentials for performing the actual authentication can be protected by a user verification step. This user verification step can be based on a PIN, a biometric or other methods. The authenticator functionality might be implemented in different components, including combinations such as TEE and SE, or fingerprint sensor and SE. In that case the SE implements only a part of the authenticator functionality.

NOTE

The reason for using such hybrid configuration is that Secure Elements do not have any user interface and hence cannot directly distinguish physical user interaction from programmatic communication (e.g. by malware). The ability to require a physical user interaction that cannot be emulated by malware is essential for protecting against scalable attacks (see [FIDOSecRef]). On the other hand, TEEs (or biometric sensors implemented in separate hardware) which can provide a trusted user interface typically do not offer the same level of key protection as Secure Elements.

Strictly spoken, a Hybrid SE Authenticator (voluntarily) uses the Authenticator Command interface [UAFAuthnrCommands] *inside* the authenticator, e.g. between the crypto kernel and the user verification component.

Examples of Hybrid SE authenticators are:

1. User PIN code capture and verification are implemented entirely in a TEE relying on Trusted User Interface and secure storage capabilities of the TEE and, once the PIN code is verified, the FIDO UAF crypto operations are performed in the SE.
2. User fingerprint is captured via a fingerprint sensor, the fingerprint match is performed in the TEE, relying on matching algorithms. Once the fingerprint has been positively checked, the cryptographic operations are executed in the Secure Element.
3. The user verification is implemented as match-on-chip in separate hardware and FIDO UAF cryptographic operations are implemented in the SE.

In all those cases, the hybrid nature of the authenticator will be managed by the software-based host, regardless of its nature (TEE, SW, Biometric sensor..). There are a number of possible interactions between the ASM and the SE actually implementing the verification and the cryptographic operations to consider within those use cases.

1. PIN user verification where the user interaction for the PIN entry is performed externally to the SE. The PIN may then be passed within a VERIFY command to the SE, followed by the actual cryptographic operations (such as the Register and Sign UAF authenticator commands).
2. Biometric user verification where the sample capture and matching is performed externally to the SE (e.g. in TEE or in a match-on-chip FP sensor). This would then only need to send to the SE the actual cryptographic operation needed in this session (such as the Register and Sign UAF authenticator commands).
3. User verification sample (Faceprint, Fingerprint..) capture is performed externally to the SE. The sample is then sent to a match-on-card applet in the SE that behaves as a global PIN to enable access to the cryptographic operation required within this session.

3.1.1 Architecture of the Hybrid SE Authenticator

In order to support an Hybrid SE Authenticator, a dedicated software-based host MUST be created which knows how the SE applet works. The communication between the SE applet and the host is defined based on [ISOIEC-7816-4-2013]. Whether a PC or mobile device the architecture is still the same, as defined below:

- `Application Layer` : This component is responsible for acquiring the user verification sample and mapping UAF commands to APDU commands.
- `Communication layer` : This is the [ISOIEC-7816-4-2013] APDUs interface, which provides methods to list and select readers, connect to a Secure Element and interact with it.
- `SE Access OS APIs` : OMA, PC/SC, NFC API, CCID…
- `Secure Element` : UICC, micro SD, eSE, Dual Interface card…

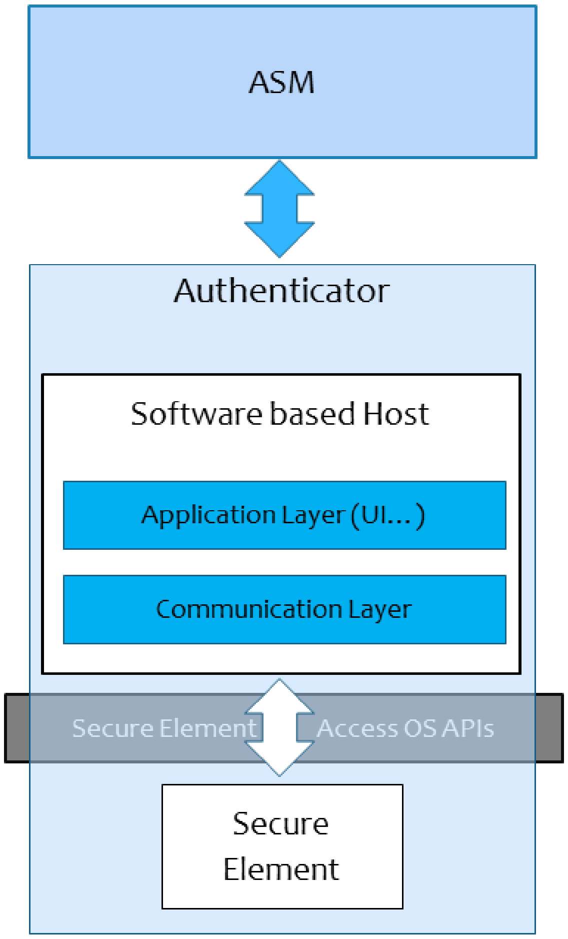


Fig. 1 Architecture of Hybrid SE Authenticator

APDU command-response paire are handled as indicated in [ISOIEC-7816-4-2013].

3.1.2 Communication flow between the ASM and the Hybrid SE Authenticator

The host is the entity communicating with the SE and which knows how the SE and the applet running in the SE can be accessed. The host could be a Trusted Application (TA) which runs inside a TEE or simply an application which runs in the normal world.

The following diagram illustrates how the Host of the Hybrid SE Authenticator MAY map the UAF commands to APDU commands. In this diagram, the User Verification Module is considered inside the SE applet.

NOTE

If the User Verification Module is inside the Host, for example in the context of the TEE, the `UserVerificationToken` shall be generated in the Host and not in the SE. As a result step 6 (Figure 2) should be executed in the Host instead of the SE.

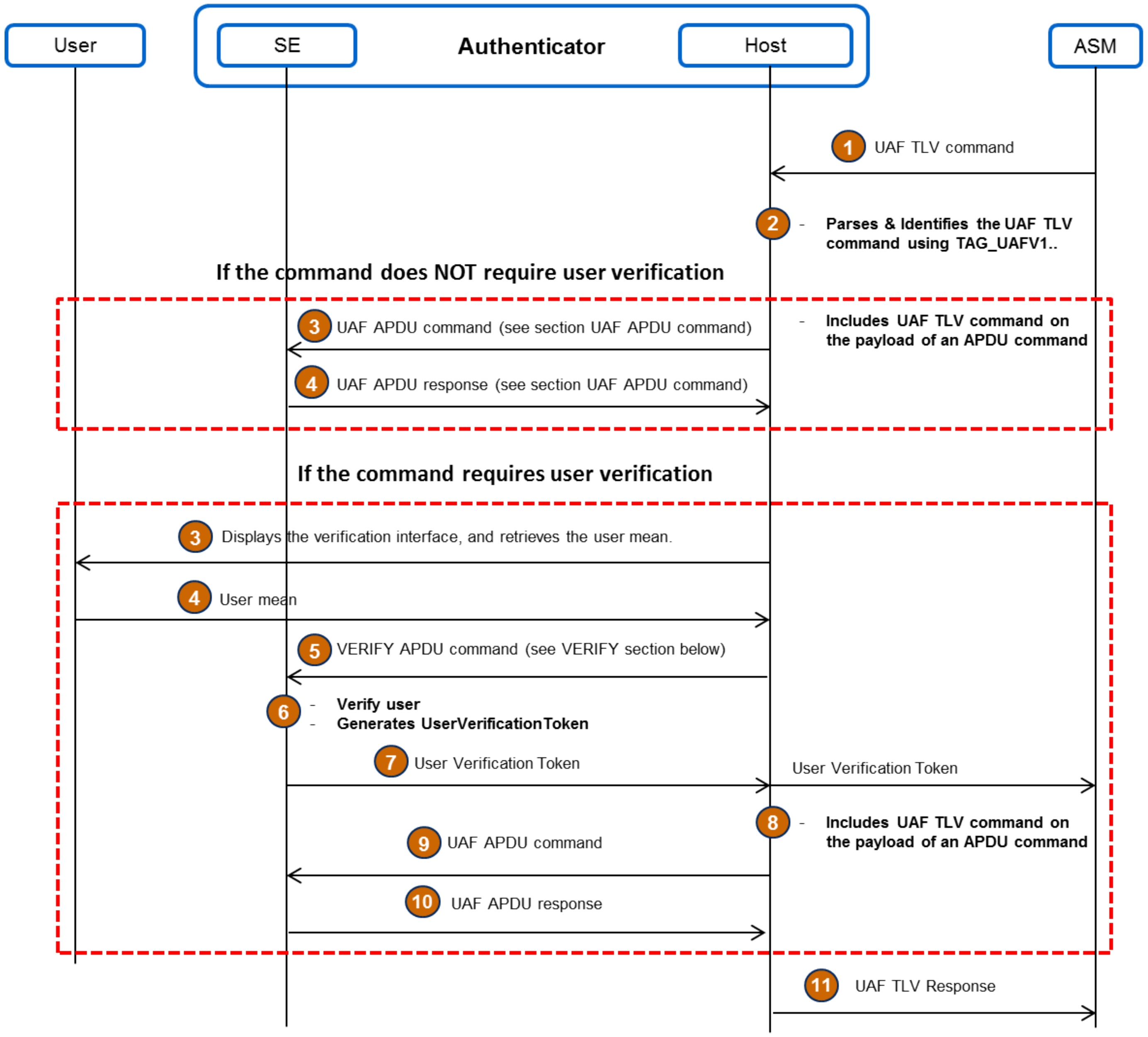

User
SE
Authenticator
Host
ASM
1 UAF TLV command
2 - Parses & Identifies the UAF TLV command using TAG_UAFV1..
If the command does NOT require user verification
3 UAF APDU command (see section UAF APDU command)
- Includes UAF TLV command on the payload of an APDU command
4 UAF APDU response (see section UAF APDU command)
If the command requires user verification
3 Displays the verification interface, and retrieves the user mean.
4 User mean
5 VERIFY APDU command (see VERIFY section below)
6 - Verify user
- Generates UserVerificationToken
7 User Verification Token
User Verification Token
8 - Includes UAF TLV command on the payload of an APDU command
9 UAF APDU command
10 UAF APDU response
11 UAF TLV Response

Fig. 2 Communication flow between the ASM and the Hybrid SE Authenticator

4. FIDO UAF Applet and APDU commands

This section is normative.

4.1 UAF Applet in the Authenticator

4.1.1 Application Identifier

The FIDO UAF AID is defined in [UAFRegistry].

4.1.2 User Verification

The User verification is based on the submission of a PIN/password (i.e., knowledge based) or a biometric template (i.e., biometric based).

In this document, the envisaged user verification methods are PIN and biometric based.

4.1.3 Cryptographic operations

The SE applet must be able to perform a set of cryptographic operations, such as key generation and signature computation. The cryptographic operations are defined in [UAFAuthnrCommands]. The SE applet must be able also to create data structures that can be parsed by FIDO Server. The SE applet SHALL use the cryptographic algorithms indicated in [UAFRegistry].

4.2 APDU Commands for FIDO UAF

4.2.1 Class byte coding

CLA indicates the class of the command.

Commands	CLA
SELECT, VERIFY (ISO Version), GET RESPONSE (ISO Version)	0x00
VERIFY, UAF, GET RESPONSE	0x80

Table 1: Class byte coding

NOTE

If the payload of an APDU command is longer than 255 bytes, command chaining as described in [ISOIEC-7816-4-2013] should be used, even though CLA is proprietary.

4.2.2 APDU command "UAF"

4.2.2.1 Mapping between FIDO UAF authenticator commands and APDU commands

This section describes the mapping between FIDO UAF authenticator commands and APDU commands.

The mapping consists of encapsulating the entire UAF Authenticator Command in the payload of the APDU command, and the UAF Authenticator Command response in the payload of the APDU Response.

The host SHALL set the INS byte to **“0x36”** for all UAF commands The SE SHALL read the UAF command number and data from the payload in the data part of the command.

The payload of the APDU command is encoded according to [UAFAuthnrCommands], the first 2 bytes of each command are the UAF command number. Upon command reception, the SE applet MUST parse the first TLV tag (2 bytes) and figure out which UAF command is being issued. The SE applet SHALL parse the rest of the FIDO Authenticator Command payload according to [UAFAuthnrCommands].

The mapping of UAF Authenticator Commands to APDU commands is defined in the following table:

CLA	INS	P1	P2	Lc	Data In	Le
Proprietary(See Table 1)	0x36	0x00	0x00	Variable	UAF Authenticator Command structure	None

Table 2: UAF APDU command

The UAF Authenticator Command structures are defined in part 6.2 of [UAFAuthnrCommands].

NOTE

If the `UserVerificationToken` is supported, The ASM must set the `TAG_USERVERIFY_TOKEN` flag in the value of the `UserVerificationToken`, received previously contained in either a `Register` or `Sign` command. Please refer to the **FIG 1** in Use-Case section.

4.2.2.2 Response message and status conditions of an "UAF" APDU command

The status word of an "UAF" APDU response is handled at the Host level; the host must interpret and map the status word based on the table below.

If the status word is equals to **“9000”**, the host shall return back to the ASM the entire data field of the APDU response. It the status word is “61xx”, the host shall issue `GET RESPONSE` (see below) until no more data is available, concatenate these response parts and then return the entire response. Otherwise, the host has to build an UAF TLV response with the mapped status codes `TAG_STATUS_CODE`, using the following table.

For example, if the status word returned by the Applet is **“6A88”**, the host shall put `UAF_CMD_STATUS_USER_NOT_ENROLLED` in the status codes of the UAF TLV response.

APDU STATUS CODE	FIDO UAF STATUS CODE	NAME	DESCRIPTION
9000	0x00	UAF_CMD_STATUS_OK	Success.
61xx	0x00	UAF_CMD_STATUS_OK	Success, xx bytes available for GET RESPONSE.
6982	0x02	UAF_CMD_STATUS_ACCESS_DENIED	Access to this operation is denied.
6A88	0x03	UAF_CMD_STATUS_USER_NOT_ENROLLED	User is not enrolled with the authenticator.
N/A	0x04	UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT	Transaction content cannot be rendered.
N/A	0x05	UAF_CMD_STATUS_USER_CANCELLED	User has cancelled the operation.
6400	0x06	UAF_CMD_STATUS_CMD_NOT_SUPPORTED	Command not supported.
6A81	0x07	UAF_CMD_STATUS_ATTESTATION_NOT_SUPPORTED	Required attestation not supported.
6A80	0x08	UAF_CMD_STATUS_PARAMS_INVALID	The request was rejected due to an incorrect data field.
6983	0x09	UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY	The UAuth key which is relevant for this command disappeared from the authenticator and cannot be restored.
N/A	0x0a	UAF_CMD_STATUS_TIMEOUT	The operation in the authenticator took longer than expected.
N/A	0x0e	UAF_CMD_STATUS_USER_NOT_RESPONSIVE	The user took too long to follow an instruction.
6A84	0x0f	UAF_CMD_STATUS_INSUFFICIENT_RESOURCES	Insufficient resources in the authenticator to perform the requested task.
63C0	0x10	UAF_CMD_STATUS_USER_LOCKOUT	The operation failed because the user is locked out and the authenticator cannot automatically trigger an action to change that.
All other codes	0x01	UAF_CMD_STATUS_ERR_UNKNOWN	An unknown error

Table 3: Mapping between APDU Status Codes and FIDO Status Codes [UAFAuthnrCommands]

The response message of an UAF APDU command is defined in the following table :

Data field	SW1 - SW2
not present	**“6982”** – The request was rejected due to user verification being required. **“6A80”** – The request was rejected due to an incorrect data field. **“6A81”** – Required attestation not supported **“6A88”** – The user is not enrolled with the SE **“6400”** – Execution error, undefined UAF command **“6983”** – Authentication data not usable, Auth key disappeared

UAF Authenticator Command response [UAFAuthnrCommands]	**“61xx”** – Success, xx bytes available for GET RESPONSE. **“9000”** – Success

Table 4: Response message of an "UAF" APDU command

4.2.3 APDU Command "SELECT"

A successful SELECT AID allows the host to know that the applet is active in the SE, and to open a logical channel with this end.

In Android smartphones apps are not allowed to use the basic channel to the SIM because this channel is reserved for the baseband processor and the GSM/UMTS/LTE activities. In this case the app must select the applet in a logical channel.

The host must send a `SELECT APDU` command to the SE applet before any others commands.

As a result, the command for selecting the applet using the FIDO UAF AID is :

CLA	INS	P1	P2	Lc	Data In	Le
0x00	0xA4	0x04	0x0C	0x08	0xA000000647AF0001	No response data is requested if the SELECT command's "Le" field is absent. Otherwise, if the "Le" field is present, vendor-proprietary data is being requested.

Table 5: SELECT AID command

4.2.4 APDU Command "VERIFY"

This command is used to request access rights using a PIN or Biometric sample. The SE applet shall verify the sample data given by the Host against the reference PIN or Biometric held in the SE.

Please refer to [ISOIEC-7816-4-2013] and [ISOIEC-19794] for Personal verification through biometric methods.

If the verification is successful and `UserVerificationToken` is supported by the SE applet, a token SHALL be generated and sent to the Host. Without having this token, the Host cannot invoke special UAF commands such as Register or Sign.

The support of `UserVerificationToken` can be checked by examining the contents of the `GetInfo` response in the `AuthenticatorType` TAG or the response of `SELECT APDU` command [UAFAuthnrCommands].

Refer to [FIDOGlossary] for more information about `UserVerificationToken`.

4.2.4.1 Command structure

CLA	INS	P1	P2	Lc	Data In	Le
ISO or Proprietary: see [ISOIEC-7816-4-2013]	0x20 (for PIN) or 0x21 (for biometry)	0x00	0x00	Variable	Verification data	None or expected Le for `UserVerificationToken`

Table 6: VERIFY command encoding for PIN verification

4.2.4.2 Response message and status conditions

Data Out	SW1 - SW2
Absent (ISO-Variant) or `UserVerificationToken` (proprietary)	See [ISOIEC-7816-4-2013]

Table 7: Response message and status conditions

NOTE

An SE applet that does not support `UserVerificationToken`, may use the [ISOIEC-7816-4-2013] VERIFY command. In this case, the VERIFY command must be securely bound to `Register` and `Sign` commands, so a secure bound method shall be implemented in the SE applet, such as Secure Messaging.

4.3 Managing Long APDU Commands and Responses

If a Secure Element is able to send a complete response (e.g. extended length APDU, block chaining), `GET RESPONSE` APDU command SHALL be used, as defined in `ISO Variant` section. Otherwise, the proprietary solution SHALL be used, as defined in section `Proprietary Variant`.

4.3.1 ISO Variant

The [ISOIEC-7816-4-2013] GET RESPONSE command is used in order to retrieve big data returned by APDU command "UAF".

4.3.2 Proprietary Variant

In order to avoid using Get Response APDU command which is not supported by all devices and terminals, a propriatry method is defined for managing the long data answers at application level.

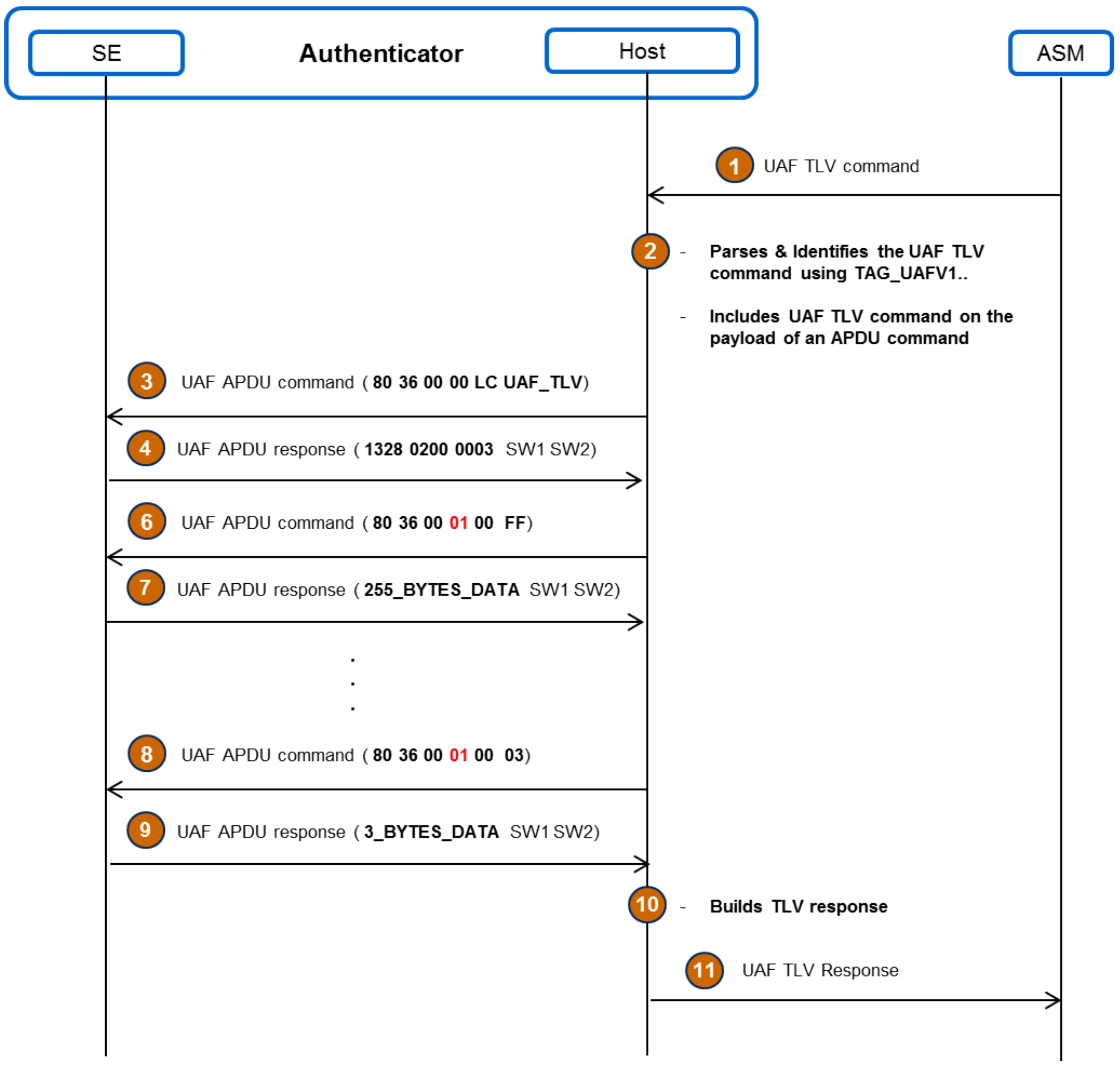
When using the proprietary variant, the response to the UAF APDU command SHALL include the Tag **"0x2813"**, that specifies the length of the response.

Response Data Out description

Tag	**0x2813**
Length	variable (2 bytes)
Value	Expected data length (2 bytes)

In the case where the data does not fit into a single Data Out message, the host SHALL repeat the "UAF" command with P2 = 1 value mentioning this is a repetition of the incoming APDU to get all the data. This process SHALL be repeated until the entire data are collected by the host.

Here is an example of an APDU Response which contains more than 255 bytes in the payload.



SE
Authenticator
Host
ASM
1 UAF TLV command
2 - Parses & Identifies the UAF TLV command using TAG_UAFV1..
- Includes UAF TLV command on the payload of an APDU command
3 UAF APDU command (80 36 00 00 LC UAF_TLV)
4 UAF APDU response (1328 0200 0003 SW1 SW2)
6 UAF APDU command (80 36 00 01 00 FF)
7 UAF APDU response (255_BYTES_DATA SW1 SW2)
8 UAF APDU command (80 36 00 01 00 03)
9 UAF APDU response (3_BYTES_DATA SW1 SW2)
10 - Builds TLV response
11 UAF TLV Response

Fig. 3 Long APDU management using the defined proprietary method

NOTE

The host shall support both versions of Get Response APDU command, and figure out which command must be sent to the Applet by parsing the response of the UAF APDU command. If the UAF APDU command response contains the Tag **"0x2813"**, the host must send a proprietary Get Response APDU command, otherwise the host must send the ISO variant of Get Response APDU command.

5. Security considerations

This section is non-normative.

Guaranteeing trust and security in a fragmented architecture such as the one levering on SE is a challenge that the Host has to address regardless of its nature (TEE or Software based), which results in different challenges from a security and architecture perspective. One could list the following ones:

- use of a trusted user interface to enter a PIN on the device,
- secure transmission of PIN or fingerprint minutiae,

- minutiae extraction format,
- integrity of data transmitted between a Host and a SE.

Hence, we will only consider here, security challenges affecting the interface between the Host and the SE.

A possible way to maintain the integrity and confidentiality when APDUs commands are exchanged is to enable a secure channel between the Host and the SE. While this is left to implementation, there are several technologies allowing to build a secure channel between a SE and a devices, that may be implemented.

- Secure channel between a trusted application in a TEE and an applet in a SE [GlobalPlatform-TEE-SE].
- Secure channel between a device and an applet in a secure element [GlobalPlatform-Card].
- Secure channel between a device and a SE [ETSI-Secure-Channel].

A. References

A.1 Normative references

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FIDO UAF Authenticator-Specific Module API

FIDO Alliance Proposed Standard 20 October 2020

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Abstract

UAF authenticators may be connected to a user device via various physical interfaces (SPI, USB, Bluetooth, etc). The UAF Authenticator-Specific Module (ASM) is a software interface on top of UAF authenticators which gives a standardized way for FIDO UAF Clients to detect and access the functionality of UAF authenticators and hides internal communication complexity from FIDO UAF Client.

This document describes the internal functionality of ASMs, defines the UAF ASM API and explains how FIDO UAF Clients should use the API.

This document's intended audience is FIDO authenticator and FIDO FIDO UAF Client vendors.

Status of This Document

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

DOM APIs are described using the ECMAScript [ECMA-262] bindings for WebIDL [WebIDL-ED].

The notation base64url refers to "Base 64 Encoding with URL and Filename Safe Alphabet" [RFC4648] *without padding*.

Following [WebIDL-ED], dictionary members are optional unless they are explicitly marked as `required`.

WebIDL dictionary members MUST NOT have a value of null.

Unless otherwise specified, if a WebIDL dictionary member is DOMString, it MUST NOT be empty.

Unless otherwise specified, if a WebIDL dictionary member is a List, it MUST NOT be an empty list.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

NOTE

Note: Certain dictionary members need to be present in order to comply with FIDO requirements. Such members are marked in the WebIDL definitions found in this document, as `required`. The keyword `required` has been introduced by [WebIDL-ED], which is a work-in-progress. If you are using a WebIDL parser which implements [WebIDL], then you may remove the keyword `required` from your WebIDL and use other means to ensure those fields are present.

1.1 Key Words

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

2. Overview

This section is non-normative.

UAF authenticators may be connected to a user device via various physical interfaces (SPI, USB, Bluetooth, etc.). The UAF Authenticator-Specific module (ASM) is a software interface on top of UAF authenticators which gives a standardized way for FIDO UAF Clients to detect and access the functionality of UAF authenticators, and hides internal communication complexity from clients.

The ASM is a platform-specific software component offering an API to FIDO UAF Clients, enabling them to discover and communicate with one or more available authenticators.

A single ASM may report on behalf of multiple authenticators.

The intended audience for this document is FIDO UAF authenticator and FIDO UAF Client vendors.

NOTE

Platform vendors might choose to not expose the ASM API defined in this document to applications. They might instead choose to expose ASM functionality through some other API (such as, for example, the Android KeyStore API, or iOS KeyChain API). In these cases it's important to make sure that the underlying ASM communicates with the FIDO UAF authenticator in a manner defined in this document.

The FIDO UAF protocol and its various operations is described in the FIDO UAF Protocol Specification [UAFProtocol]. The following simplified architecture diagram illustrates the interactions and actors this document is concerned with:

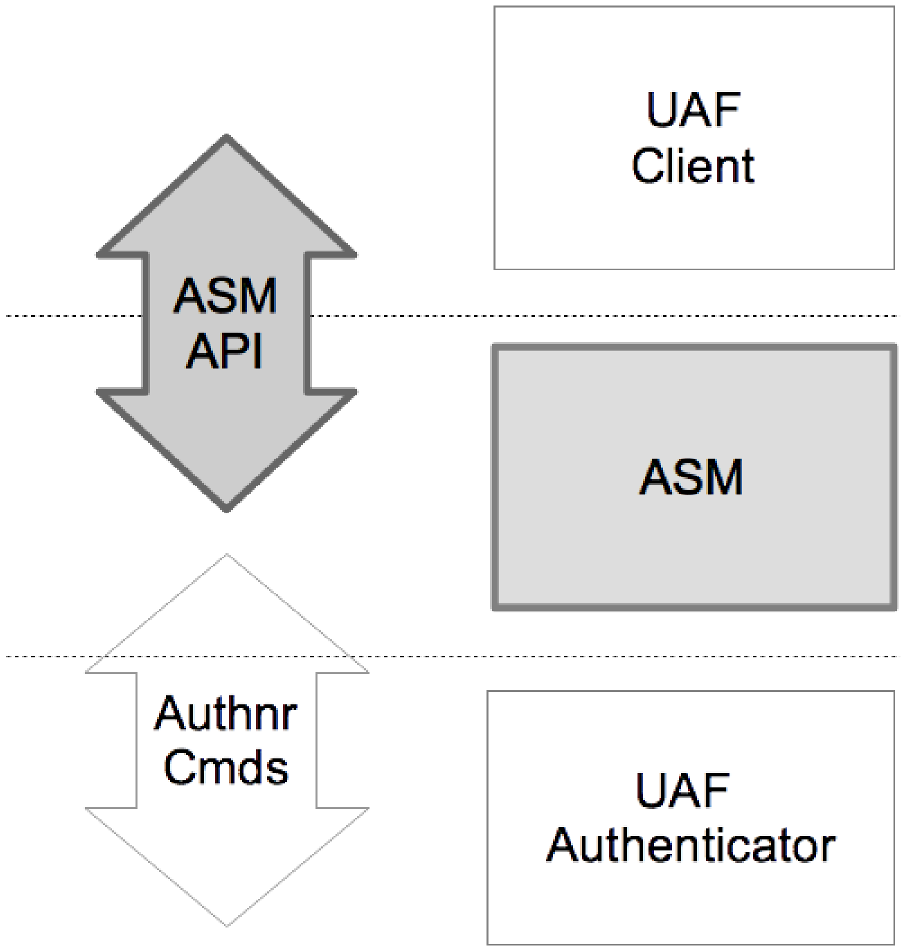

Fig. 1 UAF ASM API Architecture

2.1 Code Example format

ASM requests and responses are presented in WebIDL format.

3. ASM Requests and Responses

This section is normative.

The ASM API is defined in terms of JSON-formatted [ECMA-404] request and reply messages. In order to send a request to an ASM, a FIDO UAF Client creates an appropriate object (e.g., in ECMAscript), "stringifies" it (also known as serialization) into a JSON-formated string, and sends it to the ASM. The ASM de-serializes the JSON-formatted string, processes the request, constructs a response, stringifies it, returning it as a JSON-formatted string.

NOTE

The ASM request processing rules in this document explicitly assume that the underlying authenticator implements the "UAFV1TLV" assertion scheme (e.g. references to TLVs and tags) as described in [UAFProtocol]. If an authenticator supports a different assertion scheme then the corresponding processing rules must be replaced with appropriate assertion scheme-specific rules.

Authenticator implementers MAY create custom authenticator command interfaces other than the one defined in [UAFAuthnrCommands]. Such implementations are not required to implement the exact message-specific processing steps described in this section. However,

1. the command interfaces MUST present the ASM with external behavior equivalent to that described below in order for the ASM to properly respond to the client request messages (e.g. returning appropriate UAF status codes for specific conditions).
2. all authenticator implementations MUST support an assertion scheme as defined [UAFRegistry] and MUST return the related objects, i.e. `TAG_UAFV1_REG_ASSERTION` and `TAG_UAFV1_AUTH_ASSERTION` as defined in [UAFAuthnrCommands].

3.1 Request enum

WebIDL

```
enum Request {
    "GetInfo",
    "Register",
    "Authenticate",
    "Deregister",
    "GetRegistrations",
    "OpenSettings"
};
```

Enumeration description	
`GetInfo`	GetInfo
`Register`	Register
`Authenticate`	Authenticate
`Deregister`	Deregister
`GetRegistrations`	GetRegistrations
`OpenSettings`	OpenSettings

3.2 StatusCode Interface

If the ASM needs to return an error received from the authenticator, it SHALL map the status code received from the authenticator to the appropriate ASM status code as specified here.

If the ASM doesn't understand the authenticator's status code, it SHALL treat it as `UAF_CMD_STATUS_ERR_UNKNOWN` and map it to `UAF_ASM_STATUS_ERROR` if it cannot be handled otherwise.

If the caller of the ASM interface (i.e. the FIDO Client) doesn't understand a status code returned by the ASM, it SHALL treat it as `UAF_ASM_STATUS_ERROR`. This might occur when new error codes are introduced.

WebIDL

```
interface StatusCode {
    const short UAF_ASM_STATUS_OK = 0x00;
    const short UAF_ASM_STATUS_ERROR = 0x01;
    const short UAF_ASM_STATUS_ACCESS_DENIED = 0x02;
    const short UAF_ASM_STATUS_USER_CANCELLED = 0x03;
    const short UAF_ASM_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT = 0x04;
    const short UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY = 0x09;
    const short UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED = 0x0b;
    const short UAF_ASM_STATUS_USER_NOT_RESPONSIVE = 0x0e;
    const short UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES = 0x0f;
    const short UAF_ASM_STATUS_USER_LOCKOUT = 0x10;
    const short UAF_ASM_STATUS_USER_NOT_ENROLLED = 0x11;
    const short UAF_ASM_STATUS_SYSTEM_INTERRUPTED = 0x12;
};
```

3.2.1 Constants

UAF_ASM_STATUS_OK of type short
No error condition encountered.

UAF_ASM_STATUS_ERROR of type short
An unknown error has been encountered during the processing.

UAF_ASM_STATUS_ACCESS_DENIED of type short
Access to this request is denied.

UAF_ASM_STATUS_USER_CANCELLED of type short
Indicates that user explicitly canceled the request.

UAF_ASM_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT of type short
Transaction content cannot be rendered, e.g. format doesn't fit authenticator's need.

UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY of type short
Indicates that the UAuth key disappeared from the authenticator and canot be restored.

UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED of type short
Indicates that the authenticator is no longer connected to the ASM.

UAF_ASM_STATUS_USER_NOT_RESPONSIVE of type short
The user took too long to follow an instruction, e.g. didn't swipe the finger within the accepted time.

UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES of type short
Insufficient resources in the authenticator to perform the requested task.

UAF_ASM_STATUS_USER_LOCKOUT of type short
The operation failed because the user is locked out and the authenticator cannot automatically trigger an action to change that. Typically the user would have to enter an alternative password (formally: undergo some other alternative user verification method) to re-enable the use of the main user verification method.

> NOTE
>
> Any method the user can use to (re-) enable the main user verification method is considered an alternative user verification method and must be properly declared as such. For example, if the user can enter an alternative password to re-enable the use of fingerprints or to add additional fingers, the authenticator obviously supports fingerprint *or* password based user verification.

UAF_ASM_STATUS_USER_NOT_ENROLLED of type short
The operation failed because the user is not enrolled to the authenticator and the authenticator cannot automatically trigger user enrollment.

UAF_ASM_STATUS_SYSTEM_INTERRUPTED of type short
Indicates that the system interrupted the operation. Retry might make sense.

3.2.2 Mapping Authenticator Status Codes to ASM Status Codes

Authenticators are returning a status code in their responses to the ASM. The ASM needs to act on those responses and also map the status code returned by the authenticator to an ASM status code.

The mapping of authenticator status codes to ASM status codes is specified here:

Authenticator Status Code	ASM Status Code	Comment
`UAF_CMD_STATUS_OK`	`UAF_ASM_STATUS_OK`	Pass-through success status.
`UAF_CMD_STATUS_ERR_UNKNOWN`	`UAF_ASM_STATUS_ERROR`	Pass-through unspecific error status.
`UAF_CMD_STATUS_ACCESS_DENIED`	`UAF_ASM_STATUS_ACCESS_DENIED`	Pass-through status code.
`UAF_CMD_STATUS_USER_NOT_ENROLLED`	`UAF_ASM_STATUS_USER_NOT_ENROLLED (or UAF_ASM_STATUS_ACCESS_DENIED in some situations)`	According to [UAFAuthnrCommands], this might occur at the *Sign* command or at the *Register* command if the authenticator cannot automatically trigger user enrollment. The mapping depends on the command as follows. In the case of "Register" command, the error is mapped to UAF_ASM_STATUS_USER_NOT_ENROLLED in order to tell the calling FIDO Client the there is an authenticator present but the user enrollment needs to be triggered outside the authenticator. In the case of the "Sign" command, the Uauth key needs to be protected by one of the authenticator's user verification methods at all times. So if this error occurs it is considered an internal error and hence mapped to UAF_ASM_STATUS_ACCESS_DENIED.
`UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT`	`UAF_ASM_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT`	Pass-through status code as it indicates a problem to be resolved by the entity providing the transaction text.
`UAF_CMD_STATUS_USER_CANCELLED`	`UAF_ASM_STATUS_USER_CANCELLED`	Map to `UAF_ASM_STATUS_USER_CANCELLED`.
`UAF_CMD_STATUS_CMD_NOT_SUPPORTED`	`UAF_ASM_STATUS_OK` or `UAF_ASM_STATUS_ERROR`	If the ASM is able to handle that command on behalf of the authenticator (e.g. removing the key handle in the case of *Dereg* command for a bound authenticator), the `UAF_ASM_STATUS_OK` must be returned. Map the status code to `UAF_ASM_STATUS_ERROR` otherwise.
`UAF_CMD_STATUS_ATTESTATION_NOT_SUPPORTED`	`UAF_ASM_STATUS_ERROR`	Indicates an ASM issue as the ASM has obviously not requested one of the supported attestation types indicated in the authenticator's response to the *GetInfo* command.
`UAF_CMD_STATUS_PARAMS_INVALID`	`UAF_ASM_STATUS_ERROR`	Indicates an ASM issue as the ASM has obviously not provided the correct parameters to the authenticator when sending the

		command.
UAF_CMD_STATUS_KEY_ DISAPPEARED_PERMANENTLY	UAF_ASM_STATUS_KEY_ DISAPPEARED_PERMANENTLY	Pass-through status code. It indicates that the Uauth key disappeared permanently and the RP App might want to trigger re-registration of the authenticator.
UAF_STATUS_CMD_TIMEOUT	UAF_ASM_STATUS_ERROR	Retry operation and map to UAF_ASM_STATUS_ERROR if the problem persists.
UAF_CMD_STATUS_USER _NOT_RESPONSIVE	UAF_ASM_STATUS_USER _NOT_RESPONSIVE	Pass-through status code. The RP App might want to retry the operation once the user pays attention to the application again.
UAF_CMD_STATUS_ INSUFFICIENT_RESOURCES	UAF_ASM_STATUS_INSUFFICIENT _AUTHENTICATOR_RESOURCES	Pass-through status code.
UAF_CMD_STATUS_USER_LOCKOUT	UAF_ASM_STATUS_USER_LOCKOUT	Pass-through status code.
Any other status code	UAF_ASM_STATUS_ERROR	Map any unknown error code to UAF_ASM_STATUS_ERROR. This might happen when an ASM communicates with an authenticator implementing a newer UAF specification than the ASM.

3.3 ASMRequest Dictionary

All ASM requests are represented as ASMRequest objects.

WebIDL

```
dictionary ASMRequest {
    required Request requestType;
    Version          asmVersion;
    unsigned short   authenticatorIndex;
    object           args;
    Extension[]      exts;
};
```

3.3.1 Dictionary ASMRequest Members

requestType of type required Request
: Request type

asmVersion of type Version
: ASM message version to be used with this request. For the definition of the Version dictionary see [UAFProtocol]. The ***asmVersion*** MUST be 1.2 (i.e. major version is 1 and minor version is 2) for this version of the specification.

authenticatorIndex of type unsigned short
: Refer to the GetInfo request for more details. Field authenticatorIndex MUST NOT be set for GetInfo request.

args of type object
: Request-specific arguments. If set, this attribute MAY take one of the following types:

- RegisterIn

- AuthenticateIn
- DeregisterIn

exts of type array of Extension
: List of UAF extensions. For the definition of the Extension dictionary see [UAFProtocol].

3.4 ASMResponse Dictionary

All ASM responses are represented as ASMResponse objects.

WebIDL

```
dictionary ASMResponse {
    required short statusCode;
    object         responseData;
    Extension[]    exts;
};
```

3.4.1 Dictionary ASMResponse Members

statusCode of type required short
: MUST contain one of the values defined in the StatusCode interface

responseData of type object
: Request-specific response data. This attribute MUST have one of the following types:

- GetInfoOut
- RegisterOut
- AuthenticateOut
- GetRegistrationOut

exts of type array of Extension
: List of UAF extensions. For the definition of the Extension dictionary see [UAFProtocol].

3.5 GetInfo Request

Return information about available authenticators.

1. Enumerate all of the authenticators this ASM supports
2. Collect information about all of them
3. Assign indices to them (authenticatorIndex)
4. Return the information to the caller

NOTE

Where possible, an authenticatorIndex should be a persistent identifier that uniquely identifies an authenticator over time, even if it is repeatedly disconnected and reconnected. This avoids possible confusion if the set of available authenticators changes between a GetInfo request and subsequent ASM requests, and allows a FIDO client to perform caching of information about removable authenticators for a better user experience.

NOTE

> It is up to the ASM to decide whether authenticators which are disconnected temporarily will be reported or not. However, if disconnected authenticators are reported, the FIDO Client might trigger an operation via the ASM on those. The ASM will have to notify the user to connect the authenticator and report an appropriate error if the authenticator isn't connected in time.

For a GetInfo request, the following `ASMRequest` member(s) MUST have the following value(s). The remaining `ASMRequest` members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `GetInfo`

For a GetInfo response, the following `ASMResponse` member(s) MUST have the following value(s). The remaining `ASMResponse` members SHOULD be omitted:

- `ASMResponse.statusCode` MUST have one of the following values
  - `UAF_ASM_STATUS_OK`
  - `UAF_ASM_STATUS_ERROR`
- `ASMResponse.responseData` MUST be an object of type `GetInfoOut`. In the case of an error the values of the fields might be empty (e.g. array with no members).

See section 3.2.2 Mapping Authenticator Status Codes to ASM Status Codes for details on the mapping of authenticator status codes to ASM status codes.

3.5.1 GetInfoOut Dictionary

WebIDL

```
dictionary GetInfoOut {
    required AuthenticatorInfo[] Authenticators;
};
```

3.5.1.1 Dictionary `GetInfoOut` Members

`Authenticators` of type array of required AuthenticatorInfo
: List of authenticators reported by the current ASM. MAY be empty an empty list.

3.5.2 AuthenticatorInfo Dictionary

WebIDL

```
dictionary AuthenticatorInfo {
    required unsigned short          authenticatorIndex;
    required Version[]               asmVersions;
    required boolean                 isUserEnrolled;
    required boolean                 hasSettings;
    required AAID                    aaid;
    required DOMString               assertionScheme;
    required unsigned short          authenticationAlgorithm;
    required unsigned short[]        attestationTypes;
    required unsigned long           userVerification;
    required unsigned short          keyProtection;
    required unsigned short          matcherProtection;
    required unsigned long           attachmentHint;
    required boolean                 isSecondFactorOnly;
    required boolean                 isRoamingAuthenticator;
    required DOMString[]             supportedExtensionIDs;
    required unsigned short          tcDisplay;
    DOMString                        tcDisplayContentType;
    DisplayPNGCharacteristicsDescriptor[] tcDisplayPNGCharacteristics;
    DOMString                             title;
    DOMString                             description;
    DOMString                             icon;
};
```

3.5.2.1 Dictionary ***`AuthenticatorInfo`*** *Members*

`authenticatorIndex` of type required unsigned short
: Authenticator index. Unique, within the scope of all authenticators reported by the ASM, index referring to an authenticator. This index is used by the UAF Client to refer to the appropriate authenticator in further requests.

`asmVersions` of type array of required Version
: A list of ASM Versions that this authenticator can be used with. For the definition of the `Version` dictionary see [UAFProtocol].

`isUserEnrolled` of type required boolean
: Indicates whether a user is enrolled with this authenticator. Authenticators which don't have user verification technology MUST always return true. Bound authenticators which support different profiles per operating system (OS) user MUST report enrollment status for the current OS user.

`hasSettings` of type required boolean
: A boolean value indicating whether the authenticator has its own settings. If so, then a FIDO UAF Client can launch these settings by sending a `OpenSettings` request.

`aaid` of type required AAID
: The "Authenticator Attestation ID" (AAID), which identifies the type and batch of the authenticator. See [UAFProtocol] for the definition of the AAID structure.

`assertionScheme` of type required DOMString
: The assertion scheme the authenticator uses for attested data and signatures.

  AssertionScheme identifiers are defined in the UAF Protocol specification [UAFProtocol].

`authenticationAlgorithm` of type required unsigned short
: Indicates the authentication algorithm that the authenticator uses. Authentication algorithm identifiers are defined in are defined in [FIDORegistry] with `ALG_` prefix.

`attestationTypes` of type array of required unsigned short
: Indicates attestation types supported by the authenticator. Attestation type TAGs are defined in [UAFRegistry] with `TAG_ATTESTATION` prefix

`userVerification` of type required unsigned long
: A set of bit flags indicating the user verification method(s) supported by the authenticator. The algorithm for combining the flags is defined in [UAFProtocol], section 3.1.12.1. The values are defined by the `USER_VERIFY` constants in [FIDORegistry].

`keyProtection` of type required unsigned short
: A set of bit flags indicating the key protections used by the authenticator. The values are defined by the `KEY_PROTECTION` constants in [FIDORegistry].

`matcherProtection` of type required unsigned short
: A set of bit flags indicating the matcher protections used by the authenticator. The values are defined by the `MATCHER_PROTECTION` constants in [FIDORegistry].

`attachmentHint` of type required unsigned long
: A set of bit flags indicating how the authenticator is currently connected to the system hosting the FIDO

UAF Client software. The values are defined by the `ATTACHMENT_HINT` constants defined in [FIDORegistry].

> NOTE
>
> Because the connection state and topology of an authenticator may be transient, these values are only hints that can be used by server-supplied policy to guide the user experience, e.g. to prefer a device that is connected and ready for authenticating or confirming a low-value transaction, rather than one that is more secure but requires more user effort. These values are not reflected in authenticator metadata and cannot be relied on by the relying party, although some models of authenticator may provide attested measurements with similar semantics as part of UAF protocol messages.

`isSecondFactorOnly` of type required boolean
Indicates whether the authenticator can be used only as a second factor.

`isRoamingAuthenticator` of type required boolean
Indicates whether this is a roaming authenticator or not.

`supportedExtensionIDs` of type array of required DOMString
List of supported UAF extension IDs. MAY be an empty list.

`tcDisplay` of type required unsigned short
A set of bit flags indicating the availability and type of the authenticator's transaction confirmation display. The values are defined by the `TRANSACTION_CONFIRMATION_DISPLAY` constants in [FIDORegistry].

This value MUST be 0 if transaction confirmation is not supported by the authenticator.

`tcDisplayContentType` of type DOMString
Supported transaction content type [FIDOMetadataStatement].

This value MUST be present if transaction confirmation is supported, i.e. `tcDisplay` is non-zero.

`tcDisplayPNGCharacteristics` of type array of DisplayPNGCharacteristicsDescriptor
Supported transaction Portable Network Graphic (PNG) type [FIDOMetadataStatement]. For the definition of the `DisplayPNGCharacteristicsDescriptor` structure see [FIDOMetadataStatement].

This list MUST be present if PNG-image based transaction confirmation is supported, i.e. `tcDisplay` is non-zero and `tcDisplayContentType` is `image/png`.

`title` of type DOMString
A human-readable short title for the authenticator. It should be localized for the current locale.

> NOTE
>
> If the ASM doesn't return a title, the FIDO UAF Client must provide a title to the calling App. See section "Authenticator interface" in [UAFAppAPIAndTransport].

`description` of type DOMString
Human-readable longer description of what the authenticator represents.

> NOTE
>
> This text should be localized for current locale.

The text is intended to be displayed to the user. It might deviate from the description specified in the metadata statement for the authenticator [FIDOMetadataStatement].

If the ASM doesn't return a description, the FIDO UAF Client will provide a description to the calling application. See section "Authenticator interface" in [UAFAppAPIAndTransport].

`icon` of type DOMString
Portable Network Graphic (PNG) format image file representing the icon encoded as a data: url [RFC2397].

NOTE

If the ASM doesn't return an icon, the FIDO UAF Client will provide a default icon to the calling application. See section "Authenticator interface" in [UAFAppAPIAndTransport].

3.6 Register Request

Verify the user and return an authenticator-generated UAF registration assertion.

For a Register request, the following **`ASMRequest`** member(s) MUST have the following value(s). The remaining **`ASMRequest`** members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `Register`
- `ASMRequest.asmVersion` MUST be set to the desired version
- `ASMRequest.authenticatorIndex` MUST be set to the target authenticator index
- `ASMRequest.args` MUST be set to an object of type `RegisterIn`
- `ASMRequest.exts` MAY include some extensions to be processed by the ASM or the by Authenticator.

For a Register response, the following **`ASMResponse`** member(s) MUST have the following value(s). The remaining **`ASMResponse`** members SHOULD be omitted:

- `ASMResponse.statusCode` MUST have one of the following values:
  - `UAF_ASM_STATUS_OK`
  - `UAF_ASM_STATUS_ERROR`
  - `UAF_ASM_STATUS_ACCESS_DENIED`
  - `UAF_ASM_STATUS_USER_CANCELLED`
  - `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`
  - `UAF_ASM_STATUS_USER_NOT_RESPONSIVE`
  - `UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES`
  - `UAF_ASM_STATUS_USER_LOCKOUT`
  - `UAF_ASM_STATUS_USER_NOT_ENROLLED`
- `ASMResponse.responseData` MUST be an object of type `RegisterOut`. In the case of an error the values of the fields might be empty (e.g. empty strings).

3.6.1 RegisterIn Object

WebIDL

```
dictionary RegisterIn {
    required DOMString      appID;
    required DOMString      username;
    required DOMString      finalChallenge;
    required unsigned short attestationType;
};
```

3.6.1.1 Dictionary `RegisterIn` Members

`appID` of type required DOMString
: The FIDO server Application Identity.

`username` of type required DOMString
: Human-readable user account name

`finalChallenge` of type required DOMString
: base64url-encoded challenge data [RFC4648]

`attestationType` of type required unsigned short
: Single requested attestation type

3.6.2 RegisterOut Object

WebIDL

```
dictionary RegisterOut {
    required DOMString assertion;
    required DOMString assertionScheme;
};
```

3.6.2.1 Dictionary `RegisterOut` Members

`assertion` of type required DOMString
: FIDO UAF authenticator registration assertion, base64url-encoded

`assertionScheme` of type required DOMString
: Assertion scheme.

  AssertionScheme identifiers are defined in the UAF Protocol specification [UAFProtocol].

3.6.3 Detailed Description for Processing the Register Request

Refer to [UAFAuthnrCommands] document for more information about the TAGs and structure mentioned in this paragraph.

1. Locate authenticator using `authenticatorIndex`. If the authenticator cannot be located, then fail with `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.
2. If a user is already enrolled with this authenticator (such as biometric enrollment, PIN setup, etc. for example) then the ASM MUST request that the authenticator verifies the user.

   NOTE

   If the authenticator supports `UserVerificationToken` (see [UAFAuthnrCommands]), then the ASM must obtain this token in order to later include it with the `Register` command.

If the user is locked out (e.g. too many failed attempts to get verified) and the authenticator cannot automatically trigger unblocking, return `UAF_ASM_STATUS_USER_LOCKOUT`.

    - If verification fails, return `UAF_ASM_STATUS_ACCESS_DENIED`

3. If the user is not enrolled with the authenticator then take the user through the enrollment process.
    - If neither the ASM nor the Authenticator can trigger the enrollment process, return `UAF_ASM_STATUS_USER_NOT_ENROLLED`.
    - If enrollment fails, return `UAF_ASM_STATUS_ACCESS_DENIED`
4. Verify whether registerIn.appID and the appID included in the finalChallenge parameter are identical. The registerIn.finalChallenge value needs to be (1) base64url decoded and (2) parsed into a JSON object first.
    - If verification fails, return `UAF_ASM_STATUS_ACCESS_DENIED`
5. Construct `KHAccessToken` (see section KHAccessToken for more details)
6. Hash the provided `RegisterIn.finalChallenge` using the authenticator-specific hash function (`FinalChallengeHash`)

   An authenticator's preferred hash function information MUST meet the algorithm defined in the `AuthenticatorInfo.authenticationAlgorithm` field.

7. Create a `TAG_UAFV1_REGISTER_CMD` structure and pass it to the authenticator
    1. Copy `FinalChallengeHash`, `KHAccessToken`, `RegisterIn.Username`, `UserVerificationToken`, `RegisterIn.AppID`, `RegisterIn.AttestationType`
        1. Depending on `AuthenticatorType` some arguments may be optional. Refer to [UAFAuthnrCommands] for more information on authenticator types and their required arguments.
    2. Add the extensions from the `ASMRequest.exts` dictionary appropriately to the `TAG_UAFV1_REGISTER_CMD` as `TAG_EXTENSION` object.
8. Invoke the command and receive the response. If the authenticator returns an error, handle that error appropriately. If the connection to the authenticator gets lost and cannot be restored, return `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`. If the operation finally fails, map the authenticator error code to the the appropriate ASM error code (see section 3.2.2 Mapping Authenticator Status Codes to ASM Status Codes for details).
9. Parse `TAG_UAFV1_REGISTER_CMD_RESP`
    1. Parse the content of `TAG_AUTHENTICATOR_ASSERTION` (e.g. `TAG_UAFV1_REG_ASSERTION`) and extract `TAG_KEYID`
10. If the authenticator is a bound authenticator
    1. Store `CallerID`, `AppID`, `TAG_KEYHANDLE`, `TAG_KEYID` and `CurrentTimestamp` in the ASM's database.

    NOTE

    What data an ASM will store at this stage depends on underlying authenticator's architecture. For example some authenticators might store AppID, KeyHandle, KeyID inside their own secure storage. In this case ASM doesn't have to store these data in its database.

11. Create a `RegisterOut` object
    1. Set `RegisterOut.assertionScheme` according to `AuthenticatorInfo.assertionScheme`
    2. Encode the content of `TAG_AUTHENTICATOR_ASSERTION` (e.g. `TAG_UAFV1_REG_ASSERTION`) in base64url format and set as `RegisterOut.assertion`.
    3. Return `RegisterOut` object

3.7 Authenticate Request

Verify the user and return authenticator-generated UAF authentication assertion.

For an Authenticate request, the following **`ASMRequest`** member(s) MUST have the following value(s). The remaining **`ASMRequest`** members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `Authenticate`.
- `ASMRequest.asmVersion` MUST be set to the desired version.
- `ASMRequest.authenticatorIndex` MUST be set to the target authenticator index.
- `ASMRequest.args` MUST be set to an object of type `AuthenticateIn`
- `ASMRequest.exts` MAY include some extensions to be processed by the ASM or the by Authenticator.

For an Authenticate response, the following **`ASMResponse`** member(s) MUST have the following value(s). The remaining **`ASMResponse`** members SHOULD be omitted:

- `ASMResponse.statusCode` MUST have one of the following values:
    - `UAF_ASM_STATUS_OK`
    - `UAF_ASM_STATUS_ERROR`
    - `UAF_ASM_STATUS_ACCESS_DENIED`
    - `UAF_ASM_STATUS_USER_CANCELLED`
    - `UAF_ASM_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT`
    - `UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY`
    - `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`
    - `UAF_ASM_STATUS_USER_NOT_RESPONSIVE`
    - `UAF_ASM_STATUS_USER_LOCKOUT`
    - `UAF_ASM_STATUS_USER_NOT_ENROLLED`
- `ASMResponse.responseData` MUST be an object of type `AuthenticateOut`. In the case of an error the values of the fields might be empty (e.g. empty strings).

3.7.1 AuthenticateIn Object

WebIDL

```
dictionary AuthenticateIn {
    required DOMString appID;
    DOMString[]        keyIDs;
    required DOMString finalChallenge;
    Transaction[]      transaction;
};
```

*3.7.1.1 Dictionary **`AuthenticateIn`** Members*

`appID` of type required DOMString
  appID string

`keyIDs` of type array of DOMString
  base64url [RFC4648] encoded keyIDs

`finalChallenge` of type required DOMString
  base64url [RFC4648] encoded final challenge

`transaction` of type array of *Transaction*
  An array of transaction data to be confirmed by user. If multiple transactions are provided, then the ASM

MUST select the one that best matches the current display characteristics.

NOTE

This may, for example, depend on whether user's device is positioned horizontally or vertically at the moment of transaction.

3.7.2 Transaction Object

WebIDL

```
dictionary Transaction {
    required DOMString                    contentType;
    required DOMString                    content;
    DisplayPNGCharacteristicsDescriptor tcDisplayPNGCharacteristics;
};
```

3.7.2.1 Dictionary `Transaction` Members

`contentType` of type required DOMString
: Contains the MIME Content-Type supported by the authenticator according to its metadata statement (see [FIDOMetadataStatement])

`content` of type required DOMString
: Contains the base64url-encoded [RFC4648] transaction content according to the `contentType` to be shown to the user.

`tcDisplayPNGCharacteristics` of type DisplayPNGCharacteristicsDescriptor
: Transaction content PNG characteristics. For the definition of the `DisplayPNGCharacteristicsDescriptor` structure See [FIDOMetadataStatement].

3.7.3 AuthenticateOut Object

WebIDL

```
dictionary AuthenticateOut {
    required DOMString assertion;
    required DOMString assertionScheme;
};
```

3.7.3.1 Dictionary `AuthenticateOut` Members

`assertion` of type required DOMString
: Authenticator UAF authentication assertion.

`assertionScheme` of type required DOMString
: Assertion scheme

3.7.4 Detailed Description for Processing the Authenticate Request

Refer to the [UAFAuthnrCommands] document for more information about the TAGs and structure mentioned in this paragraph.

1. Locate the authenticator using `authenticatorIndex`. If the authenticator cannot be located, then fail with

`UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.

2. If no user is enrolled with this authenticator (such as biometric enrollment, PIN setup, etc.), return `UAF_ASM_STATUS_ACCESS_DENIED`
3. The ASM MUST request the authenticator to verify the user.
   - If the user is locked out (e.g. too many failed attempts to get verified) and the authenticator cannot automatically trigger unblocking, return `UAF_ASM_STATUS_USER_LOCKOUT`.
   - If verification fails, return `UAF_ASM_STATUS_ACCESS_DENIED`

   > NOTE
   >
   > If the authenticator supports `UserVerificationToken` (see [UAFAuthnrCommands]), the ASM must obtain this token in order to later pass to `Sign` command.

4. Construct `KHAccessToken` (see section KHAccessToken for more details)
5. Hash the provided `AuthenticateIn.finalChallenge` using an authenticator-specific hash function (`FinalChallengeHash`).

   The authenticator's preferred hash function information MUST meet the algorithm defined in the `AuthenticatorInfo.authenticationAlgorithm` field.

6. If this is a Second Factor authenticator and `AuthenticateIn.keyIDs` is empty, then return `UAF_ASM_STATUS_ACCESS_DENIED`
7. If AuthenticateIn.keyIDs is not empty,
   1. If this is a bound authenticator, then look up ASM's database with `AuthenticateIn.appID` and `AuthenticateIn.keyIDs` and obtain the KeyHandles associated with it.
      - Return `UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY` if the related key disappeared permanently from the authenticator.
      - Return `UAF_ASM_STATUS_ACCESS_DENIED` if no entry has been found.
   2. If this is a roaming authenticator, then treat `AuthenticateIn.keyIDs` as KeyHandles
8. Create `TAG_UAFV1_SIGN_CMD` structure and pass it to the authenticator.
   1. Copy `AuthenticateIn.AppID`, `AuthenticateIn.Transaction.content` (if not empty), `FinalChallengeHash`, `KHAccessToken`, `UserVerificationToken`, `KeyHandles`
      - Depending on AuthenticatorType some arguments may be optional. Refer to [UAFAuthnrCommands] for more information on authenticator types and their required arguments.
      - If multiple transactions are provided, select the one that best matches the current display characteristics.

        > NOTE
        >
        > This may, for example, depend on whether user's device is positioned horizontally or vertically at the moment of transaction.

      - Decode the base64url encoded `AuthenticateIn.Transaction.content` before passing it to the authenticator
   2. Add the extensions from the `ASMRequest.exts` dictionary appropriately to the `TAG_UAFV1_REGISTER_CMD` as `TAG_EXTENSION` object.
9. Invoke the command and receive the response. If the authenticator returns an error, handle that error appropriately. If the connection to the authenticator gets lost and cannot be restored, return

`UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`. If the operation finally fails, map the authenticator error code to the appropriate ASM error code (see section 3.2.2 Mapping Authenticator Status Codes to ASM Status Codes for details).

10. Parse `TAG_UAFV1_SIGN_CMD_RESP`
    - If it's a first-factor authenticator and the response includes `TAG_USERNAME_AND_KEYHANDLE`, then
        1. Extract usernames from `TAG_USERNAME_AND_KEYHANDLE` fields
        2. If two or more equal usernames are found, then choose the one which has registered most recently

            > NOTE
            >
            > After this step, a first-factor bound authenticator which stores KeyHandles inside the ASM's database may delete the redundant KeyHandles from the ASM's database. This avoids having unusable (old) private key in the authenticator which (surprisingly) might become active after deregistering the newly generated one.

        3. Show remaining distinct usernames and ask the user to choose a single username
        4. Set `TAG_UAFV1_SIGN_CMD.KeyHandles` to the single KeyHandle associated with the selected username.
        5. Go to step #8 and send a new `TAG_UAFV1_SIGN_CMD command`
11. Create the `AuthenticateOut` object
    1. Set `AuthenticateOut.assertionScheme` as `AuthenticatorInfo.assertionScheme`
    2. Encode the content of `TAG_AUTHENTICATOR_ASSERTION` (e.g. `TAG_UAFV1_AUTH_ASSERTION`) in base64url format and set as `AuthenticateOut.assertion`
    3. Return the `AuthenticateOut` object

> NOTE
>
> Some authenticators might support "Transaction Confirmation Display" functionality not inside the authenticator but within the boundaries of the ASM. Typically these are software based Transaction Confirmation Displays. When processing the `Sign` command with a given transaction such ASM should show transaction content in its own UI and after user confirms it -- pass the content to authenticator so that the authenticator includes it in the final assertion.
>
> See [FIDORegistry] for flags describing Transaction Confirmation Display type.

The authenticator metadata statement MUST truly indicate the type of transaction confirmation display implementation. Typically the "Transaction Confirmation Display" flag will be set to `TRANSACTION_CONFIRMATION_DISPLAY_ANY` (bitwise) or `TRANSACTION_CONFIRMATION_DISPLAY_PRIVILEGED_SOFTWARE`.

3.8 Deregister Request

Delete registered UAF record from the authenticator.

For a Deregister request, the following **`ASMRequest`** member(s) MUST have the following value(s). The remaining **`ASMRequest`** members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `Deregister`
- `ASMRequest.asmVersion` MUST be set to the desired version
- `ASMRequest.authenticatorIndex` MUST be set to the target authenticator index

- ASMRequest.args MUST be set to an object of type DeregisterIn

For a Deregister response, the following **ASMResponse** member(s) MUST have the following value(s). The remaining **ASMResponse** members SHOULD be omitted:

- ASMResponse.statusCode MUST have one of the following values:
  - UAF_ASM_STATUS_OK
  - UAF_ASM_STATUS_ERROR
  - UAF_ASM_STATUS_ACCESS_DENIED
  - UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED

3.8.1 DeregisterIn Object

WebIDL

```
dictionary DeregisterIn {
    required DOMString appID;
    required DOMString keyID;
};
```

*3.8.1.1 Dictionary **DeregisterIn** Members*

appID of type required DOMString
FIDO Server Application Identity

keyID of type required DOMString
Base64url-encoded [RFC4648] key identifier of the authenticator to be de-registered. The keyID can be an empty string. In this case all keyIDs related to this appID MUST be deregistered.

3.8.2 Detailed Description for Processing the Deregister Request

Refer to [UAFAuthnrCommands] for more information about the TAGs and structures mentioned in this paragraph.

1. Locate the authenticator using authenticatorIndex
2. Construct KHAccessToken (see section KHAccessToken for more details).
3. If this is a bound authenticator, then
   - If the value of DeregisterIn.keyID is an empty string, then lookup all pairs of this appID and any keyID mapped to this authenticatorIndex and delete them. Go to step 4.
   - Otherwise, lookup the authenticator related data in the ASM database and delete the record associated with DeregisterIn.appID and DeregisterIn.keyID. Go to step 4.
4. Create the TAG_UAFV1_DEREGISTER_CMD structure, copy KHAccessToken and DeregisterIn.keyID and pass it to the authenticator.

   NOTE

   In the case of roaming authenticators, the keyID passed to the authenticator might be an empty string. The authenticator is supposed to deregister all keys related to this appID in this case.

5. Invoke the command and receive the response. If the authenticator returns an error, handle that error appropriately. If the connection to the authenticator gets lost and cannot be restored, return UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED. If the operation finally fails, map the authenticator error code to

the appropriate ASM error code (see section 3.2.2 Mapping Authenticator Status Codes to ASM Status Codes for details). Return proper ASMResponse.

3.9 GetRegistrations Request

Return all registrations made for the calling FIDO UAF Client.

For a GetRegistrations request, the following **`ASMRequest`** member(s) MUST have the following value(s). The remaining **`ASMRequest`** members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `GetRegistrations`
- `ASMRequest.asmVersion` MUST be set to the desired version
- `ASMRequest.authenticatorIndex` MUST be set to corresponding ID

For a GetRegistrations response, the following **`ASMResponse`** member(s) MUST have the following value(s). The remaining **`ASMResponse`** members SHOULD be omitted:

- `ASMResponse.statusCode` MUST have one of the following values:
  - `UAF_ASM_STATUS_OK`
  - `UAF_ASM_STATUS_ERROR`
  - `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`
- The `ASMResponse.responseData` MUST be an object of type `GetRegistrationsOut`. In the case of an error the values of the fields might be empty (e.g. empty strings).

3.9.1 GetRegistrationsOut Object

WebIDL

```
dictionary GetRegistrationsOut {
    required AppRegistration[] appRegs;
};
```

*3.9.1.1 Dictionary **`GetRegistrationsOut`** Members*

`appRegs` of type array of required AppRegistration
List of registrations associated with an `appID` (see `AppRegistration` below). MAY be an empty list.

3.9.2 AppRegistration Object

WebIDL

```
dictionary AppRegistration {
    required DOMString   appID;
    required DOMString[] keyIDs;
};
```

*3.9.2.1 Dictionary **`AppRegistration`** Members*

`appID` of type required DOMString
FIDO Server Application Identity.

`keyIDs` of type array of required DOMString
List of key identifiers associated with the `appID`

3.9.3 Detailed Description for Processing the GetRegistrations Request

1. Locate the authenticator using `authenticatorIndex`
2. If this is bound authenticator, then
   - Lookup the registrations associated with CallerID and AppID in the ASM database and construct a list of `AppRegistration` objects

     NOTE

     Some ASMs might not store this information inside their own database. Instead it might have been stored inside the authenticator's secure storage area. In this case the ASM must send a proprietary command to obtain the necessary data.

3. If this is *not* a bound authenticator, then set the list to empty.
4. Create `GetRegistrationsOut` object and return

3.10 OpenSettings Request

Display the authenticator-specific settings interface. If the authenticator has its own built-in user interface, then the ASM MUST invoke `TAG_UAFV1_OPEN_SETTINGS_CMD` to display it.

For an OpenSettings request, the following **`ASMRequest`** member(s) MUST have the following value(s). The remaining **`ASMRequest`** members SHOULD be omitted:

- `ASMRequest.requestType` MUST be set to `OpenSettings`
- `ASMRequest.asmVersion` MUST be set to the desired version
- `ASMRequest.authenticatorIndex` MUST be set to the target authenticator index

For an OpenSettings response, the following **`ASMResponse`** member(s) MUST have the following value(s). The remaining **`ASMResponse`** members SHOULD be omitted:

- `ASMResponse.statusCode` MUST have one of the following values:
  - `UAF_ASM_STATUS_OK`

4. Using ASM API

This section is non-normative.

In a typical implementation, the FIDO UAF Client will call `GetInfo` during initialization and obtain information about the authenticators. Once the information is obtained it will typically be used during FIDO UAF message processing to find a match for given FIDO UAF policy. Once a match is found the FIDO UAF Client will send the appropriate request (Register/Authenticate/Deregister...) to this ASM.

The FIDO UAF Client may use the information obtained from a `GetInfo` response to display relevant information about an authenticator to the user.

5. ASM APIs for various platforms

This section is normative.

5.1 Android ASM Intent API

On Android systems FIDO UAF ASMs MAY be implemented as a separate APK-packaged application.

The FIDO UAF Client invokes ASM operations via Android Intents. All interactions between the FIDO UAF Client and an ASM on Android takes place through the following intent identifier:

```
org.fidoalliance.intent.FIDO_OPERATION
```

To carry messages described in this document, an intent MUST also have its `type` attribute set to `application/fido.uaf_asm+json`.

ASMs MUST register that intent in their manifest file and implement a handler for it.

FIDO UAF Clients MUST append an extra, `message`, containing a `String` representation of a **`ASMRequest`**, before invoking the intent.

FIDO UAF Clients MUST invoke ASMs by calling `startActivityForResult()`

FIDO UAF Clients SHOULD assume that ASMs will display an interface to the user in order to handle this intent, e.g. prompting the user to complete the verification ceremony. However, the ASM SHOULD NOT display any user interface when processing a `GetInfo` request.

After processing is complete the ASM will return the response intent as an argument to `onActivityResult()`. The response intent will have an extra, `message`, containing a `String` representation of a **`ASMResponse`**.

5.1.1 Discovering ASMs

FIDO UAF Clients can discover the ASMs available on the system by using `PackageManager.queryIntentActivities(Intent intent, int flags)` with the FIDO Intent described above to see if any activities are available.

A typical FIDO UAF Client will enumerate all ASM applications using this function and will invoke the `GetInfo` operation for each one discovered.

5.1.2 Alternate Android AIDL Service ASM Implementation

The Android Intent API can also be implemented using Android AIDL services as an alternative transport mechanism to Android Intents. Please see Android Intent API section [UAFAppAPIAndTransport] for differences between the Android AIDL service and Android Intent implementation.

This API should be used if the ASM itself doesn't implement any user interface.

NOTE

The advantage of this AIDL Server based API is that it doesn't cause a focus lose on the caller App.

5.2 Java ASM API for Android

NOTE

The Java ASM API is useful for ASMs for KeyStore based authenticators. In this case the platform limits key use-access to the application generating the key. The ASM runs in the process scope of the RP App.

```
public interface IASM {
  enum Event {
    PLUGGED,  /** Indicates that the authenticator was Plugged to system */
    UNPLUGGED /** Indicates that the authenticator was Unplugged from system */
  }

  public interface IEnumeratorListener {
    /**
        This function is called when an authenticator is plugged or
        unplugged.
       @param eventType event type (plugged/unplugged)
       @param serialized AuthenticatorInfo JSON based GetInfoResponse object
    */
    void onNotify(Event eventType, String authenticatorInfo);
  }

  public interface IResponseReceiver {
    /**
        This function is called when ASM's response is ready.

       @param response serialized response JSON based event data
       @param exchangeData for ASM if it needs some
             data back right after calling the callback function.
             onResponse will set the exchangeData to the data to
             be returned to the ASM.
    */
    void onResponse(String response, StringBuilder exchangeData);
  }

  /**
      Initializes the ASM. This is the first function to
      be called.
     @param ctx the Android Application context of the calling application (or null)
     @param enumeratorListener caller provided Enumerator
     @return ASM StatusCode value
  */
  short init(Context ctx, IEnumeratorListener enumeratorListener);

  /**
      Process given JSON request and returns JSON response.
      If the caller wants to execute a function defined in ASM JSON
      schema then this is the function that must be called.
     @param act the calling Android Activity or null
     @param inData input JSON data
     @param ProcessListener event listener for receiving events from ASM
     @return ASM StatusCode value
  */
  short process(Activity act, String inData, IResponseReceiver responseReceiver);

  /**
      Uninitializes (shut's down) the ASM.
     @return ASM StatusCode value
  */
  short uninit();
}
```

5.3 C++ ASM API for iOS

NOTE

The C++ ASM API is useful for ASMs for KeyChain based authenticators. In this case the platform limits key use-access to the application generating the key. The ASM runs in the process scope of the RP App.

```
#include
namespace FIDO_UAF {

class IASM {
 public:

  typedef enum  {
    PLUGGED,  /** Indicates that the authenticator was Plugged to system */
    UNPLUGGED /** Indicates that the authenticator was Unplugged from system */
  } Event;


  class IEnumeratorListener {
    virtual ~IEnumeratorListener() {}
    /**
        This function is called when an authenticator is plugged or
        unplugged.
       @param eventType event type (plugged/unplugged)
       @param serialized AuthenticatorInfo JSON based GetInfoResponse object
    */
    virtual void onNotify(Event eventType, const std::string& authenticatorInfo) {};
  };

  class IResponseReceiver {
    virtual ~IResponseReceiver() {}
    /**
        This function is called when ASM's response is ready.

       @param response serialized JSON based event data
       @param exchangeData for ASM if it needs some
              data back right after calling the callback function.
    */
    virtual void onResponse(const std::string& response, std::string &exchangeData) {};
  };

  /**
      Initializes the ASM. This is the first function to
      be called.
     @param unc the platform UINavigationController or one of the derived classes
       (e.g. UINavigationController) in order to allow smooth UI integration of the ASM.
     @param EnumerationListener caller provided Enumerator
     @return ASM StatusCode value
  */
  virtual short int init(UINavigationController unc, IEnumerator EnumerationListener)=0;

  /**
      Process given JSON request and returns JSON response.
      If the caller wants to execute a function defined in ASM JSON
      schema then this is the function that must be called.
     @param unc the platform UINavigationController or one of the derived classes
       (e.g. UINavigationController) in order to allow smooth UI integration of the ASM
     @param InData input JSON data
     @param ProcessListener event listener for receiving events from ASM
     @return ASM StatusCode value
  */
  virtual short int process(UINavigationController unc, const std::string& InData, ICallback
ProcessListener)=0;

  /**
      Uninitializes (shut's down) the ASM.
     @return ASM StatusCode value
  */
  virtual short int uninit()=0;
};

}
```

5.4 Windows ASM API

On Windows, an ASM is implemented in the form of a Dynamic Link Library (DLL). The following is an example `asmplugin.h` header file defining a Windows ASM API:

EXAMPLE 1

```
/*! @file asm.h
*/

#ifndef __ASMH_
#define __ASMH_
#ifdef _WIN32
#define ASM_API __declspec(dllexport)
#endif

#ifdef _WIN32
#pragma warning ( disable : 4251 )
#endif

#define ASM_FUNC extern "C" ASM_API
#define ASM_NULL 0

/*! \brief Error codes returned by ASM Plugin API.
*  Authenticator specific error codes are returned in JSON form.
*  See JSON schemas for more details.
*/

enum asmResult_t
{
  Success = 0, /**< Success */
  Failure /**< Generic failure */
};

/*! \brief Generic structure containing JSON string in UTF-8
*  format.
*  This structure is used throughout functions to pass and receives
*  JSON data.
*/

struct asmJSONData_t
{
  int length; /**< JSON data length */
  char *pData; /**< JSON data */
};

/*! \brief Enumeration event types for authenticators.
These events will be fired when an authenticator becomes
  available (plugged) or unavailable (unplugged).
*/

enum asmEnumerationType_t
{
  Plugged = 0, /**< Indicates that authenticator Plugged to system */
  Unplugged /**< Indicates that authenticator Unplugged from system */
};

namespace ASM
{
  /*! \brief Callback listener.
  FIDO UAF Client must pass an object implementating this interface to
  Authenticator::Process function. This interface is used to provide
  ASM JSON based response data.*/
  class ICallback
  {
    public
      virtual ~ICallback() {}
      /**
      This function is called when ASM's response is ready.
      *
      @param response JSON based event data
      @param exchangeData must be provided by ASM if it needs some
      data back right after calling the callback function.
      The lifecycle of this parameter must be managed by ASM. ASM must
      allocate enough memory for getting the data back.
      */

      virtual void Callback(const asmJSONData_t &response,
      asmJSONData_t &exchangeData) = 0;
  };

  /*! \brief Authenticator Enumerator.
  FIDO UAF Client must provide an object implementing this
  interface. It will be invoked when a new authenticator is plugged or
  when an authenticator has been unplugged. */

  class IEnumerator
  {
    public
      virtual ~IEnumerator() {}
      /**
        This function is called when an authenticator is plugged or
            unplugged.
      * @param eventType event type (plugged/unplugged)
        @param AuthenticatorInfo JSON based GetInfoResponse object
      */

      virtual void Notify(const asmEnumerationType_t eventType, const
      asmJSONData_t &AuthenticatorInfo) = 0;
  };
}

/**
Initializes ASM plugin. This is the first function to be
            called.
*
@param pEnumerationListener caller provided Enumerator
*/

ASM_FUNC asmResult_t asmInit(ASM::IEnumerator
          *pEnumerationListener);
/**
Process given JSON request and returns JSON response.
*
If the caller wants to execute a function defined in ASM JSON
            schema then this is the function that must be called.
*
@param pInData input JSON data
@param pListener event listener for receiving events from ASM
*/
ASM_FUNC asmResult_t asmProcess(const asmJSONData_t *pInData,
          ASM::ICallback *pListener);
/**
Uninitializes ASM plugin.
*
*/
ASM_FUNC asmResult_t asmUninit();
```

```
    #endif // __ASMPLUGINH_
```

A Windows-based FIDO UAF Client MUST look for ASM DLLs in the following registry paths:

`HKCU\Software\FIDO\UAF\ASM`

`HKLM\Software\FIDO\UAF\ASM`

The FIDO UAF Client iterates over all keys under this path and looks for "path" field:

`[HK**\Software\FIDO\UAF\ASM\<exampleASMName>]`

`"path"="<ABSOLUTE_PATH_TO_ASM>.dll"`

`path` MUST point to the absolute location of the ASM DLL.

6. CTAP2 Interface

This section is normative.

ASMs can (optionally) provide a FIDO CTAP 2 interface in order to allow the authenticator being used as external authenticator from a FIDO2 or Web Authentication enabled platform supporting the CTAP 2 protocol [FIDOCTAP].

In this case the CTAP2 enabled ASM provides the CTAP2 interface upstream through one or more of the transport protocols defined in [FIDOCTAP] (e.g. USB, NFC, BLE). Note that the CTAP2 interface is *the* connection to the FIDO Client / FIDO enabled platform.

In the following section we specify how the ASM needs to map the parameters received via the FIDO CTAP2 interface to FIDO UAF Authenticator Commands [UAFAuthnrCommands].

6.1 authenticatorMakeCredential

This section is normative.

NOTE

This interface has the following input parameters (see [FIDOCTAP]):

1. clientDataHash (required, byte array).
2. rp (required, PublicKeyCredentialEntity). Identity of the relying party.
3. user (required, PublicKeyCredentialUserEntity).
4. pubKeyCredParams (required, CBOR array).
5. excludeList (optional, sequence of PublicKeyCredentialDescriptors).
6. extensions (optional, CBOR map). Parameters to influence authenticator operation.
7. options (optional, sequence of authenticator options, i.e. "rk" and "uv"). Parameters to influence authenticator operation.
8. pinAuth (optional, byte array).
9. pinProtocol (optional, unsigned integer).

The output parameters are (see [FIDOCTAP]):

1. authData (required, sequence of bytes). The authenticator data object.
2. fmt (required, String). The attestation statement format identifier.

3. attStmt (required, sequence of bytes). The attestation statement.

6.1.1 Processing rules for authenticatorMakeCredential

This section is normative.

1. invoke `Register` command for UAF authenticator as described in [UAFAuthnrCommands] section 6.2.4 using the following field mapping instructions:
    - authenticatorIndex set appropriately, e.g. 1.
    - If `webauthn_appid` is present, then
        1. Verify that the effective domain of `AppID` is identical to the effective domain of `rp.id`.
        2. Set `AppID` to the value of extension `webauthn_appid` (see [WebAuthn]).
    - If `webauthn_appid` is not present, then set `AppID` to `rp.id` (see [WebAuthn]).
    - `FinalChallengeHash` set to `clientDataHash`.
    - `Username` set to `user.displayName` (see [WebAuthn]). This string will be displayed to the user in order to select a specific account if the user has multiple accounts at that relying party.
    - `attestationType` set to the attestation supported by that authenticator, e.g. `ATTESTATION_BASIC_FULL` or `ATTESTATION_ECDAA`.
    - `KHAccessToken` set to some persistent identifier used for this authenticator. If the authenticator is bound to the platform this ASM is running on, it needs to be a secret identifier only known to this ASM instance. If the authenticator is a "roaming authenticator", i.e. external to the platform this ASM is running on, the identifier can have value 0.
    - Add the `fido.uaf.userid` extension with value `user.id` to the Register command.
    - Use the `pinAuth` and `pinProtocol` parameters appropriately when communicating with the authenticator (if supported).
2. If this is a bound authenticator and the Authenticator doesn't support the `fido.uaf.userid`, let the ASM remember the `user.id` value related to the generated UAuth key pair.
3. If the command was successful, create the result object as follows
    - set `authData` to a freshly generated authenticator data object, containing the corresponding values taken from the assertion geenrated by the authenticator. That means:
        - set `authData.rpID` to the SHA256 hash of `AppID`.
        - initialize `authData` with 0 and then set set flag `authData.AT` to 1 and set `authData.UP` to 1 if the authenticator is not a silent authenticator. Set flag `authData.uv` to 1 if the authenticator is not a silent authenticator. The flags `authData.UP` and `authData.UV` need to be 0 if it is a silent authenticator. Set `authData.ED` to 1 if the authenticator added extensions to the assertion. In this case add the individual extensions to the CBOR map appropriately.
        - set `authData.signCount` to the `uafAssertion.signCounter`.
        - set `authData.attestationData.AAGUID` to the `AAID` of this authenticator. Setting the remaining bytes to 0.
        - set `authData.attestationData.CredentialID` to `uafAssertion.keyHandle` and set the length L of the Credential ID to the size of the keyHandle.
        - set `authData.attestationData.pubKey` to `uafAssertion.publicKey` with appropriate encoding conversion
    - set `fmt` to the "fido-uaf".
    - set `attStmt` to the `AUTHENTICATOR_ASSERTION` element of the `TAG_UAFV1_REGISTER_CMD_RESPONSE` returned by the authenticator.
4. Return `authData`, `fmt` and `attStmt`.

6.2 authenticatorGetAssertion

This section is normative.

NOTE

This interface has the following input parameters (see [FIDOCTAP]):

1. rpId (required, String). Identity of the relying party.
2. clientDataHash (required, byte array).
3. allowList (optional, sequence of PublicKeyCredentialDescriptors).
4. extensions (optional, CBOR map).
5. options (optional, sequence of authenticator options, i.e. "up" and "uv").

The output parameters are (see [FIDOCTAP]):

1. credential (optional, PublicKeyCredentialDescriptor).
2. authData (required, byte array).
3. signature (required, byte array).
4. user (required, PublicKeyCredentialUserEntity).
5. numberOfCredentials (optional, integer).

6.2.1 Processing rules for authenticatorGetAssertion

This section is normative.

1. invoke `Sign` command for UAF authenticator as described in [UAFAuthnrCommands] section 6.3.4 using the following field mapping instructions
   - authenticatorIndex set appropriately, e.g. 1.
   - If `webauthn_appid` is present, then
     1. Verify that the effective domain of `AppID` is identical to the effective domain of `rpId`.
     2. Set `AppID` to the value of extension `webauthn_appid` (see [WebAuthn]).
   - If `webauthn_appid` is not present, then set `AppID` to `rpId` (see [WebAuthn]).
   - `FinalChallengeHash` set to `clientDataHash`.
   - `TransactionContent` set to value of extension `webauthn_txAuthGeneric` or `webauthn_txAuthsimple` (see [WebAuthn]) depending on which extension is present and supported by this authenticator. If the authenticator doesn't natively support transactionConfirmation, the hash of the value included in either of the webauthn_tx* extensions can be computed by the ASM and passed to the authenticator in `TransactionContentHash`. See [UAFAuthnrCommands] section 6.3.1 for details.
   - `KHAccessToken` set to the persistent identifier used for this authenticator (at authenticatorMakeCredential).
   - If `allowList` is present then add the `.id` field of each element as `KeyHandle` element to the command.
   - Use the `pinAuth` and `pinProtocol` parameters appropriately when communicating with the authenticator (if supported).
2. If the command was successful (with potential ambiguities of RawKeyHandles resolved), create the result object as follows
   - set `credential.id` to the `keyHandle` returned by the authenticator command. Set `credential.type` to "public-key-uaf" and set `credential.transports` to the transport currently being used by this authenticator (e.g. "usb").

    - set `authData` to the `UAFV1_SIGNED_DATA` element included in the `AUTHENTICATOR_ASSERTION` element.
    - set `signature` to the `SIGNATURE` element included in the `AUTHENTICATOR_ASSERTION` element.
    - If the authenticator returned the `fido.uaf.userid` extension, then set `user.id` to the value of the `fido.uaf.userid` extension as returned by the authenticator.
    - If the authenticator did not return the `fido.uaf.userid` extension but the ASM remembered the user ID, then set `user.id` to the value of the user ID remembered by the ASM.
3. Return `credential`, `authData`, `signature`, `user`.

6.3 authenticatorGetNextAssertion

This section is normative.

Not supported. This interface will always return a single assertion.

6.4 authenticatorCancel

This section is normative.

Cancel the existing authenticator command if it is still pending.

6.5 authenticatorReset

This section is normative.

Reset the authenticator back to factory default state. In order to prevent accidental trigger of this mechanism, some form of user approval MAY be performed by the authenticator itself.

6.6 authenticatorGetInfo

This section is normative.

This interface has no input parameters.

NOTE

Output parameters are (see [FIDOCTAP]):

1. versions (required, sequence of strings). List of FIDO protocol versions supported by the authenticator.
2. extensions (optional, sequence of strings). List of extensions supported by the authenticator.
3. aaguid (optional, string). The AAGUID claimed by the authenticator.
4. options (optional, map). Map of "plat", "rk", "clientPin", "up", "uv"
5. maxMsgSize (optional, unsignd integer). The maximum message size accepted by the authenticator.
6. pinProtocols (optional, array of unsigned integers).

6.6.1 Processing rules for authenticatorGetInfo

This section is normative.

This interface is expected to report a single authenticator only.

1. Invoke the `GetInfo` command [UAFAuthnrCommands] for the connected authenticator.

    - authenticatorIndex set appropriately, e.g. 1.
2. If the command was successful, create the result object as follows
    - set `versions` to "FIDO_2_0" as this is the only version supported by CTAP2 at this time.
    - set `extensions` to the list of extensions returned by the authenticator (one entry per field SupportedExtensionID).
    - set `aaguid` to the AAID returned by the authenticator, setting all remaining bytes to 0.
    - set `options` appropriately.
    - set `maxMsgSize` to the maximum message size supported by the authenticator - if known
    - set `pinProtocols` to the list of supported pin protocols (if any).
3. Return `versions`, `extensions`, `aaguid`, `options`, `mxMsgSize` (if known) and `pinProtocols` (if any).

7. Security and Privacy Guidelines

This section is normative.

ASM developers must carefully protect the FIDO UAF data they are working with. ASMs must follow these security guidelines:

- ASMs MUST implement a mechanism for isolating UAF credentials registered by two different FIDO UAF Clients from one another. One FIDO UAF Client MUST NOT have access to FIDO UAF credentials that have been registered via a different FIDO UAF Client. This prevents malware from exercising credentials associated with a legitimate FIDO Client.

  NOTE

  ASMs must properly protect their sensitive data against malware using platform-provided isolation capabilities in order to follow the assumptions made in [FIDOSecRef]. Malware with root access to the system or direct physical attack on the device are out of scope for this requirement.

  NOTE

  The following are examples for achieving this:

    - If an ASM is bundled with a FIDO UAF Client, this isolation mechanism is already built-in.
    - If the ASM and FIDO UAF Client are implemented by the same vendor, the vendor may implement proprietary mechanisms to bind its ASM exclusively to its own FIDO UAF Client.
    - On some platforms ASMs and the FIDO UAF Clients may be assigned with a special privilege or permissions which regular applications don't have. ASMs built for such platforms may avoid supporting isolation of UAF credentials per FIDO UAF Clients since all FIDO UAF Clients will be considered equally trusted.

- An ASM designed specifically for bound authenticators MUST ensure that FIDO UAF credentials registered with one ASM cannot be accessed by another ASM. This is to prevent an application pretending to be an ASM from exercising legitimate UAF credentials.

    - Using a KHAccessToken offers such a mechanism.

- An ASM MUST implement platform-provided security best practices for protecting UAF-related stored data.

- ASMs MUST NOT store any sensitive FIDO UAF data in its local storage, except the following:
    - `CallerID`, `ASMToken`, `PersonaID`, `KeyID`, `KeyHandle`, `AppID`

  NOTE

  An ASM, for example, must never store a username provided by a FIDO Server in its local storage in a form other than being decryptable exclusively by the authenticator.

- ASMs SHOULD ensure that applications cannot use silent authenticators for tracking purposes. ASMs implementing support for a silent authenticator MUST show, during every registration, a user interface which explains what a silent authenticator is, asking for the users consent for the registration. Also, it is RECOMMENDED that ASMs designed to support roaming silent authenticators either
    - Run with a special permission/privilege on the system, or
    - Have a built-in binding with the authenticator which ensures that other applications cannot directly communicate with the authenticator by bypassing this ASM.

7.1 KHAccessToken

`KHAccessToken` is an access control mechanism for protecting an authenticator's FIDO UAF credentials from unauthorized use. It is created by the ASM by mixing various sources of information together. Typically, a `KHAccessToken` contains the following four data items in it: `AppID`, `PersonaID`, `ASMToken` and `CallerID`.

`AppID` is provided by the FIDO Server and is contained in every FIDO UAF message.

`PersonaID` is obtained by the ASM from the operational environment. Typically a different `PersonaID` is assigned to every operating system user account.

`ASMToken` is a randomly generated secret which is maintained and protected by the ASM.

NOTE

In a typical implementation an ASM will randomly generate an ASMToken when it is launched the first time and will maintain this secret until the ASM is uninstalled.

`CallerID` is the ID the platform has assigned to the calling FIDO UAF Client (e.g. "bundle ID" for iOS). On different platforms the *CallerID* can be obtained differently.

NOTE

For example on Android platform ASM can use the hash of the caller's `apk-signing-cert`.

The ASM uses the `KHAccessToken` to establish a link between the ASM and the key handle that is created by authenticator on behalf of this ASM.

The ASM provides the `KHAccessToken` to the authenticator with every command which works with key handles.

NOTE

The following example describes how the ASM constructs and uses `KHAccessToken`.

- During a `Register` request
  - Set `KHAccessToken` to a secret value only known to the ASM. This value will always be the same for this ASM.
  - Append `AppID`
    - `KHAccessToken = AppID`
  - If a bound authenticator, append `ASMToken`, `PersonaID` and `CallerID`
    - `KHAccessToken |= ASMToken | PersonaID | CallerID`
  - Hash `KHAccessToken`
    - Hash `KHAccessToken` using the authenticator's hashing algorithm. The reason of using authenticator specific hash function is to make sure of interoperability between ASMs. If interoperability is not required, an ASM can use any other secure hash function it wants.
    - `KHAccessToken=hash(KHAccessToken)`
  - Provide `KHAccessToken` to the authenticator
  - The authenticator puts the `KHAccessToken` into `RawKeyHandle` (see [UAFAuthnrCommands] for more details)
- During other commands which require `KHAccessToken` as input argument
  - The ASM computes `KHAccessToken` the same way as during the `Register` request and provides it to the authenticator along with other arguments.
  - The authenticator unwraps the provided key handle(s) and proceeds with the command only if `RawKeyHandle.KHAccessToken` is equal to the provided `KHAccessToken`.

Bound authenticators MUST support a mechanism for binding generated key handles to ASMs. The binding mechanism MUST have at least the same security characteristics as mechanism for protcting `KHAccessToken` described above. As a consequence it is RECOMMENDED to securely derive `KHAccessToken` from `AppID`, `ASMToken`, `PersonaID` and the `CallerID`.

Alternative methods for binding key handles to ASMs can be used if their security level is equal or better.

From a security perspective, the KHAccessToken method relies on the OS/platform to:

1. allow the ASM keeping the ASMToken secret
2. and let the ASM determine the CalledID correctly
3. and let the FIDO Client verify the AppID/FacetID correctly

NOTE

It is recommended for roaming authenticators that the `KHAccessToken` contains only the `AppID` since otherwise users won't be able to use them on different machines (`PersonaID`, `ASMToken` and `CallerID` are platform specific). If the authenticator vendor decides to do that in order to address a specific use case, however, it is allowed.

Including `PersonaID` in the `KHAccessToken` is optional for all types of authenticators. However an authenticator designed for multi-user systems will likely have to support it.

If an ASM for roaming authenticators doesn't use a `KHAccessToken` which is different for each `AppID`, the ASM MUST include the `AppID` in the command for a `deregister` request containing an empty `KeyID`.

7.2 Access Control for ASM APIs

The following table summarizes the access control requirements for each API call.

ASMs MUST implement the access control requirements defined below. ASM vendors MAY implement additional security mechanisms.

Terms used in the table:

- `NoAuth` -- no access control
- `CallerID` -- FIDO UAF Client's platform-assigned ID is verified
- `UserVerify` -- user must be explicitly verified
- `KeyIDList` -- must be known to the caller

Commands	First-factor bound authenticator	Second-factor bound authenticator	First-factor roaming authenticator	Second-factor roaming authenticator
GetInfo	NoAuth	NoAuth	NoAuth	NoAuth
OpenSettings	NoAuth	NoAuth	NoAuth	NoAuth
Register	UserVerify	UserVerify	UserVerify	UserVerify
Authenticate	UserVerify AppID CallerID PersonaID	UserVerify AppID KeyIDList CallerID PersonaID	UserVerify AppID	UserVerify AppiD KeyIDList
GetRegistrations*	CallerID PersonaID	CallerID PersonaID	X	X
Deregister	AppID KeyID PersonaID CallerID	AppID KeyID PersonaID CallerID	AppID KeyID	AppID KeyID

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FIDO UAF Authenticator Commands

FIDO Alliance Proposed Standard 20 October 2020

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Abstract

UAF Authenticators may take different forms. Implementations may range from a secure application running inside tamper-resistant hardware to software-only solutions on consumer devices.

This document defines normative aspects of UAF Authenticators and offers security and implementation guidelines for authenticator implementors.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

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This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in "", e.g. "UAF-TLV".

In formulas we use "|" to denote byte wise concatenation operations.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

Unless otherwise specified all data described in this document MUST be encoded in **little-endian** format.

All TLV structures can be parsed using a "recursive-descent" parsing approach. In some cases multiple occurrences of a single tag MAY be allowed within a structure, in which case all values MUST be preserved.

All fields in TLV structures are *mandatory*, unless explicitly mentioned as otherwise.

1.1 Conformance

As well as sections marked as non-normative, all authoring guidelines, diagrams, examples, and notes in this specification are non-normative. Everything else in this specification is normative.

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

2. Overview

This section is non-normative.

This document specifies low-level functionality which UAF Authenticators should implement in order to support the UAF protocol. It has the following goals:

- Define normative aspects of UAF Authenticator implementations
- Define a set of commands implementing UAF functionality that may be implemented by different types of authenticators
- Define `UAFV1TLV` assertion scheme-specific structures which will be parsed by a FIDO Server

NOTE

The UAF Protocol supports various assertion schemes. Commands and structures defined in this document assume that an authenticator supports the `UAFV1TLV` assertion scheme. Authenticators implementing a different assertion scheme do not have to follow requirements specified in this document.

The overall architecture of the UAF protocol and its various operations is described in [UAFProtocol]. The following simplified architecture diagram illustrates the interactions and actors this document is concerned with:

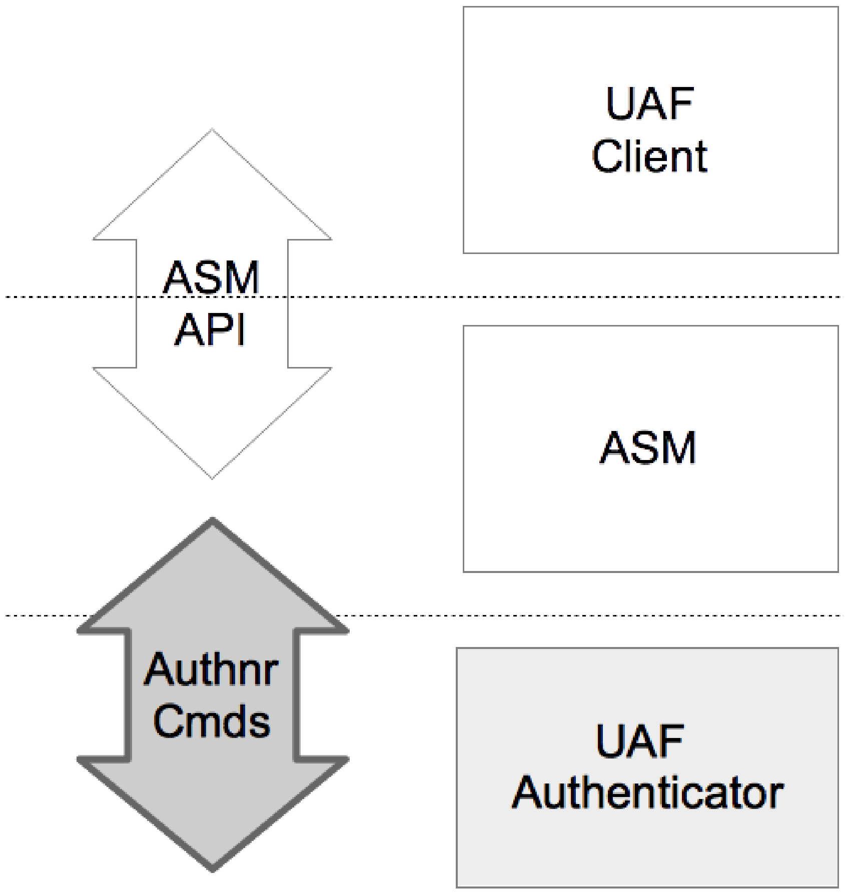

Fig. 1 UAF Authenticator Commands

3. UAF Authenticator

This section is non-normative.

The UAF Authenticator is an authentication component that meets the UAF protocol requirements as described in [UAFProtocol]. The main functions to be provided by UAF Authenticators are:

1. [Mandatory] Verifying the user or the user's presence with the verification mechanism built into the authenticator. The verification technology can vary, from biometric verification to simply verifying physical presence, or no user verification at all (the so-called *Silent Authenticator*).
2. [Mandatory] Performing the cryptographic operations defined in [UAFProtocol]
3. [Mandatory] Creating data structures that can be parsed by FIDO Server.
4. [Mandatory] Attesting itself to the FIDO Server if there is a built-in support for attestation
5. [Optional] Displaying the transaction content to the user using the transaction confirmation display

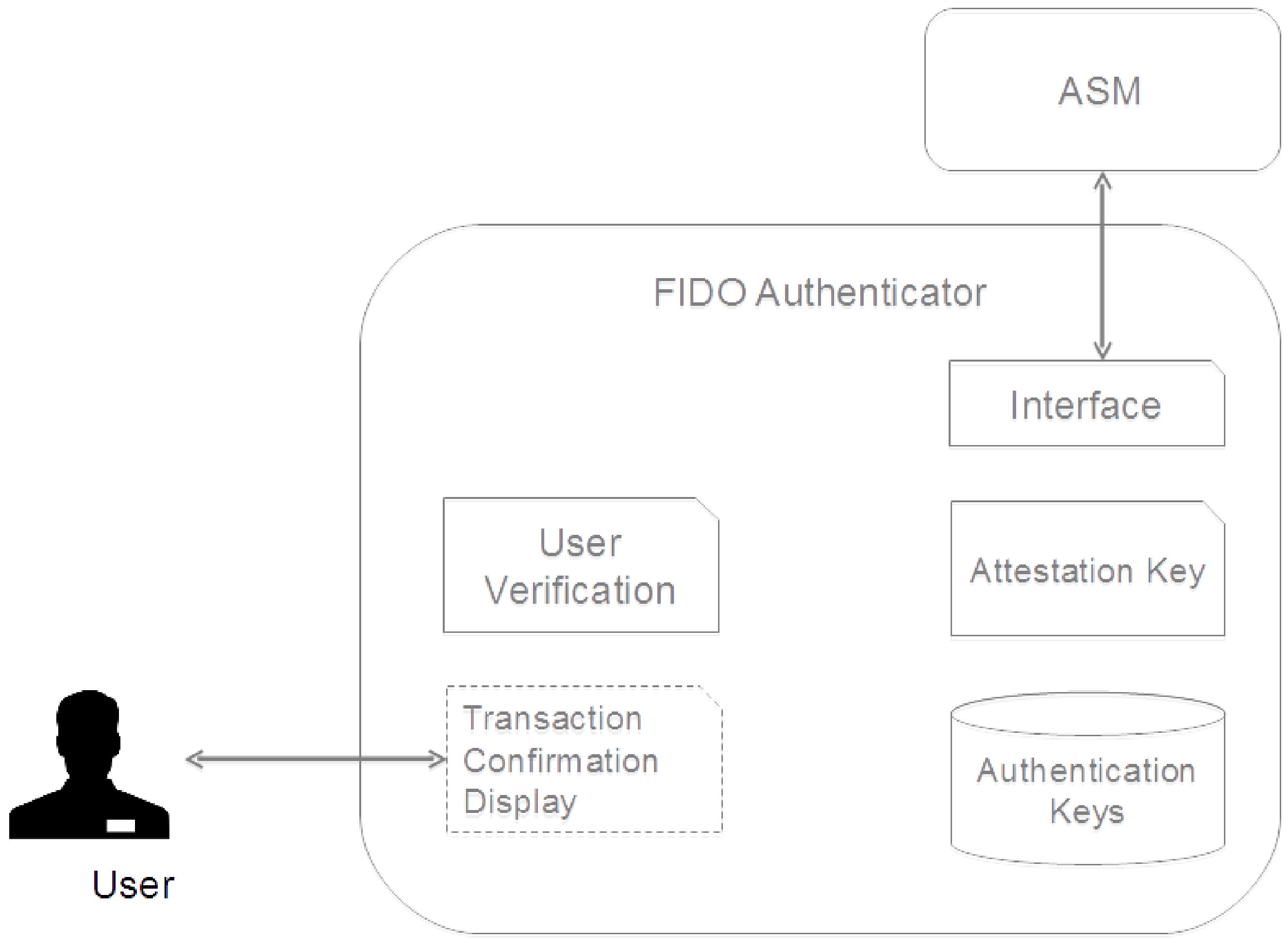

Fig. 2 FIDO Authenticator Logical Sub-Components

Some examples of UAF Authenticators:

- A fingerprint sensor built into a mobile device
- PIN authenticator implemented inside a *secure element*
- A mobile phone acting as an authenticator to a different device
- A USB token with built-in user presence verification
- A voice or face verification technology built into a device

3.1 Types of Authenticators

There are four types of authenticators defined in this document. These definitions are not normative (unless otherwise stated) and are provided merely for simplifying some of the descriptions.

NOTE

The following is the rationale for considering only these 4 types of authenticators:

- Bound authenticators are typically embedded into a user's computing device and thus can utilize the host's storage for their needs. It makes more sense from an economic perspective to utilize the host's storage rather than have embedded storage. Trusted Execution Environments (TEE), Secure Elements and Trusted Platform Modules (TPM) are typically designed in this manner.
- First-factor roaming authenticators must have an internal storage for key handles.
- Second-factor roaming authenticators can store their key handles on an associated server, in order to avoid the need for internal storage.
- Defining such constraints makes the specification simpler and clearer for defining the mainstream use-cases.

Vendors, however, are not limited to these constraints. For example a bound authenticator which has internal storage for storing key handles is possible. Vendors are free to design and implement such authenticators as long as their design follows the normative requirements described in this document.

- **First-factor Bound Authenticator**
  - These authenticators have an internal matcher. The matcher is able to verify an already enrolled user. If there is more than one user enrolled - the matcher can also identify a user.
  - There is a logical binding between this authenticator and the device it is attached to (the binding is expressed through a concept called KeyHandleAccessToken). This authenticator cannot be bound with more than one device.
  - These authenticators do not store key handles in their own internal storage. They always return the key handle to the ASM and the latter stores it in its local database.
  - Authenticators of this type may also work as a second factor.
  - Examples
    - A fingerprint sensor built into a laptop, phone or tablet
    - Embedded secure element in a mobile device
    - Voice verification built into a device

- **Second-factor (2ndF) Bound Authenticator**
  - This type of authenticator is similar to first-factor bound authenticators, except that it can operate only as the second-factor in a multi-factor authentication
  - Examples
    - USB dongle with a built-in capacitive touch device for verifying user presence
    - A "Trustlet" application running on the trusted execution environment of a mobile phone, and leveraging a secure keyboard to verify user presence

- **First Factor (1stF) Roaming Authenticator**
  - These authenticators are not bound to any device. User can use them with any number of devices.
  - It is assumed that these authenticators have an internal matcher. The matcher is able to verify an already enrolled user. If there is more than one user enrolled - the matcher can also identify a user.
  - It is assumed that these authenticators are designed to store key handles in their own internal secure storage and not expose externally.
  - These authenticators may also work as a second factor.
  - Examples
    - A Bluetooth LE based hardware token with built-in fingerprint sensor
    - PIN protected USB hardware token
    - A first-factor bound authenticator acting as a roaming authenticator for a different device on the user's behalf

- **Second-factor Roaming Authenticator**
  - These authenticators are not bound to any device. A user may use them with any number of devices.

- These authenticators may have an internal matcher. The matcher is able to verify an already enrolled user. If there is more than one user enrolled then the matcher can also identify a particular specific user.
- It is assumed that these authenticators do not store key handles in their own internal storage. Instead they push key handles to the FIDO Server and receive them back during the authentication operation.
- These authenticators can only work as second factors.
- Examples
    - USB dongle with a built-in capacitive touch device for verifying user presence
    - A "Trustlet" application running on the trusted execution environment of a mobile phone, and leveraging a secure keyboard to verify user presence

Throughout the document there will be special conditions applying to these types of authenticators.

NORMATIVE

In some deployments, the combination of ASM and a bound authenticator can act as a roaming authenticator (for example when an ASM with an embedded authenticator on a mobile device acts as a roaming authenticator for another device). When this happens such an authenticator MUST follow the requirements applying to bound authenticators within the boundary of the system the authenticator is bound to, and follow the requirements that apply to roaming authenticators in any other system it connects to externally.

Conforming authenticators MUST implement at least one attestation type defined in [UAFRegistry], as well as one authentication algorithm and one key format listed in [FIDORegistry].

NOTE

As stated above, the bound authenticator does not store key handles and roaming authenticators do store them. In the example above the ASM would store the key handles of the bound authenticator and hence meets these assumptions.

4. Tags

This section is normative.

In this document UAF Authenticators use "Tag-Length-Value" (TLV) format to communicate with the outside world. All requests and response data MUST be encoded as TLVs.

Commands and existing predefined TLV tags can be extended by appending other TLV tags (custom or predefined).

Refer to [UAFRegistry] for information about predefined TLV tags.

TLV formatted data has the following simple structure:

2 bytes	2 bytes	Length bytes
Tag	Length in bytes	Data

All lengths are in bytes. e.g. a UINT32[4] will have length 16.

Although 2 bytes are allotted for the tag, only the first 14 bits (values up to 0x3FFF) should be used to accommodate the limitations of some hardware platforms.

Arrays are implicit. The description of some structures indicates where multiple values are permitted, and in these cases, if same tag appears more than once, all values are signifanct and should be treated as an array.

For convenience in decoding TLV-formatted messages, all composite tags - those with values that must be parsed by recursive descent - have the 13th bit (0x1000) set.

A tag that has the 14th bit (0x2000) set indicates that it is critical and a receiver MUST abort processing the entire message if it cannot process that tag.

Since UAF Authenticators may have extremely constrained processing environments, an ASM MUST follow a normative ordering of structures when sending commands.

It is assumed that ASM and Server have sufficient resources to handle parsing tags in any order so structures send from authenticator MAY use tags in any order.

4.1 Command Tags

Name	Value	Description
TAG_UAFV1_GETINFO_CMD	0x3401	Tag for GetInfo command.
TAG_UAFV1_GETINFO_CMD_RESPONSE	0x3601	Tag for GetInfo command response.
TAG_UAFV1_REGISTER_CMD	0x3402	Tag for Register command.
TAG_UAFV1_REGISTER_CMD_RESPONSE	0x3602	Tag for Register command response.
TAG_UAFV1_SIGN_CMD	0x3403	Tag for Sign command.
TAG_UAFV1_SIGN_CMD_RESPONSE	0x3603	Tag for Sign command response.
TAG_UAFV1_DEREGISTER_CMD	0x3404	Tag for Deregister command.
TAG_UAFV1_DEREGISTER_CMD_RESPONSE	0x3604	Tag for Deregister command response.
TAG_UAFV1_OPEN_SETTINGS_CMD	0x3406	Tag for OpenSettings command.
TAG_UAFV1_OPEN_SETTINGS_CMD_RESPONSE	0x3606	Tag for OpenSettings command response.

Table 4.1.1: UAF Authenticator Command TLV tags (0x3400 - 0x34FF, 0x3600-0x36FF)

4.2 Tags used only in Authenticator Commands

Name	Value	Description
TAG_KEYHANDLE	0x2801	Represents key handle. Refer to [FIDOGlossary] for more information about key handle.
TAG_USERNAME_AND_KEYHANDLE	0x3802	Represents an associated Username and key handle. This is a composite tag that contains a TAG_USERNAME and TAG_KEYHANDLE that identify a registration valid oin the authenticator. Refer to [FIDOGlossary] for more information about username.
TAG_USERVERIFY_TOKEN	0x2803	Represents a User Verification Token. Refer to [FIDOGlossary] for more information about user verification tokens.
		A full AppID as a UINT8[] encoding of a UTF-8 string.

TAG_APPID	0x2804	Refer to [FIDOGlossary] for more information about AppID.
TAG_KEYHANDLE_ACCESS_TOKEN	0x2805	Represents a key handle Access Token.
TAG_USERNAME	0x2806	A Username as a UINT8[] encoding of a UTF-8 string.
TAG_ATTESTATION_TYPE	0x2807	Represents an Attestation Type.
TAG_STATUS_CODE	0x2808	Represents a Status Code.
TAG_AUTHENTICATOR_METADATA	0x2809	Represents a more detailed set of authenticator information.
TAG_ASSERTION_SCHEME	0x280A	A UINT8[] containing the UTF8-encoded Assertion Scheme as defined in [UAFRegistry]. ("UAFV1TLV")
TAG_TC_DISPLAY_PNG_CHARACTERISTICS	0x280B	If an authenticator contains a PNG-capable transaction confirmation display that is not implemented by a higher-level layer, this tag is describing this display. See [FIDOMetadataStatement] for additional information on the format of this field.
TAG_TC_DISPLAY_CONTENT_TYPE	0x280C	A UINT8[] containing the UTF-8-encoded transaction display content type as defined in [FIDOMetadataStatement]. ("image/png")
TAG_AUTHENTICATOR_INDEX	0x280D	Authenticator Index
TAG_API_VERSION	0x280E	API Version
TAG_AUTHENTICATOR_ASSERTION	0x280F	The content of this TLV tag is an assertion generated by the authenticator. Since authenticators may generate assertions in different formats - the content format may vary from authenticator to authenticator.
TAG_TRANSACTION_CONTENT	0x2810	Represents transaction content sent to the authenticator.
TAG_AUTHENTICATOR_INFO	0x3811	Includes detailed information about authenticator's capabilities.
TAG_SUPPORTED_EXTENSION_ID	0x2812	Represents extension ID supported by authenticator.
TAG_TRANSACTIONCONFIRMATION_TOKEN	0x2813	Represents a token for transaction confirmation. It might be returned by the authenticator to the ASM and given back to the authenticator at a later stage. The meaning of it is similar to TAG_USERVERIFY_TOKEN, except that it is used for the user's approval of a displayed transaction text.

Table 4.2.1: Non-Command Tags (0x2800 - 0x28FF, 0x3800 - 0x38FF)

4.3 Tags used in UAF Protocol

Name	Value	Description
TAG_UAFV1_REG_ASSERTION	0x3E01	Authenticator response to Register command.
TAG_UAFV1_AUTH_ASSERTION	0x3E02	Authenticator response to Sign command.
TAG_UAFV1_KRD	0x3E03	Key Registration Data
TAG_UAFV1_SIGNED_DATA	0x3E04	Data signed by authenticator with the UAuth.priv key

TAG_ATTESTATION_CERT	0x2E05	Each entry contains a single X.509 DER-encoded [ITU-X690-2008] certificate. Multiple occurrences are allowed and form the attestation certificate chain. Multiple occurrences must be ordered. The attestation certificate itself MUST occur first. Each subsequent occurrence (if exists) MUST be the issuing certificate of the previous occurrence.
TAG_SIGNATURE	0x2E06	A cryptographic signature
ATTESTATION_BASIC_FULL	0x3E07	Full Basic Attestation as defined in [UAFProtocol]
ATTESTATION_BASIC_SURROGATE	0x3E08	Surrogate Basic Attestation as defined in [UAFProtocol]
ATTESTATION_ECDAA	0x3E09	Elliptic curve based direct anonymous attestation as defined in [UAFProtocol]. In this case the signature in TAG_SIGNATURE is a ECDAA signature as specified in [FIDOEcdaaAlgorithm].
TAG_KEYID	0x2E09	Represents a KeyID.
TAG_FINAL_CHALLENGE_HASH	0x2E0A	Represents a Hash of the Final Challenge. Refer to [UAFASM] for more information about the Final Challenge Hash.
TAG_AAID	0x2E0B	Represents an authenticator Attestation ID. Refer to [UAFProtocol] for more information about the AAID.
TAG_PUB_KEY	0x2E0C	Represents a Public Key.
TAG_COUNTERS	0x2E0D	Represents a use counters for the authenticator.
TAG_ASSERTION_INFO	0x2E0E	Represents assertion information necessary for message processing.
TAG_AUTHENTICATOR_NONCE	0x2E0F	Represents a nonce value generated by the authenticator. The Authenticator Nonce allows the authenticator to enforce the to-be-signed object being different each time it is generated - even under attack scenarios in which the caller (e.g. ASM) sends similar data. Side channels attacks are more difficult to perform if the data to-be-signed is different each time.
TAG_TRANSACTION_CONTENT_HASH	0x2E10	Represents a hash of transaction content.
TAG_EXTENSION	0x3E11, 0x3E12	This is a composite tag indicating that the content is an extension. If the tag is 0x3E11 - it's a critical extension and if the recipient does not understand the contents of this tag, it MUST abort processing of the entire message. This tag has two embedded tags - TAG_EXTENSION_ID and TAG_EXTENSION_DATA. For more information about UAF extensions refer to [UAFProtocol] NOTE This tag can be appended to any command and response.

		Using tag 0x3E11 (as opposed to tag 0x3E12) has the same meaning as the flag `fail_if_unknown` in [UAFProtocol].
TAG_EXTENSION_ID	0x2E13	Represents extension ID. Content of this tag is a UINT8[] encoding of a UTF-8 string.
TAG_EXTENSION_DATA	0x2E14	Represents extension data. Content of this tag is a UINT8[] byte array.

Table 4.3.1: Tags used in the UAF Protocol (0x2E00 - 0x2EFF, 0x3E00 - 0x3EFF). Normatively defined in [UAFRegistry]

4.4 Status Codes

Name	Value	Description
UAF_CMD_STATUS_OK	0x00	Success.
UAF_CMD_STATUS_ERR_UNKNOWN	0x01	An unknown error.
UAF_CMD_STATUS_ACCESS_DENIED	0x02	Access to this operation is denied.
UAF_CMD_STATUS_USER_NOT_ENROLLED	0x03	User is not enrolled with the authenticator and the authenticator cannot automatically trigger enrollment.
UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT	0x04	Transaction content cannot be rendered.
UAF_CMD_STATUS_USER_CANCELLED	0x05	User has cancelled the operation. No retry should be performed.
UAF_CMD_STATUS_CMD_NOT_SUPPORTED	0x06	Command not supported.
UAF_CMD_STATUS_ATTESTATION_NOT_SUPPORTED	0x07	Required attestation not supported.
UAF_CMD_STATUS_PARAMS_INVALID	0x08	The parameters for the command received by the authenticator are malformed/invalid.
UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY	0x09	The UAuth key which is relevant for this command disappeared from the authenticator and cannot be restored. On some authenticators this error occurs when the user verification reference data set was modified (e.g. new fingerprint template added).
UAF_CMD_STATUS_TIMEOUT	0x0a	The operation in the authenticator took longer than expected (due to technical issues) and it was finally aborted.
UAF_CMD_STATUS_USER_NOT_RESPONSIVE	0x0e	The user took too long to follow an instruction, e.g. didn't swipe the finger within the accepted time.
UAF_CMD_STATUS_INSUFFICIENT_RESOURCES	0x0f	Insufficient resources in the authenticator to perform the requested task.

UAF_CMD_STATUS_USER_LOCKOUT	0x10	The operation failed because the user is locked out and the authenticator cannot automatically trigger an action to change that. Typically the user would have to enter an alternative password (formally: undergo some other alternative user verification method) to re-enable the use of the main user verification method. NOTE Any method the user can use to (re-) enable the main user verification method is considered an alternative user verification method and must be properly declared as such. For example, if the user can enter an alternative password to re-enable the use of fingerprints or to add additional fingers, the authenticator obviously supports fingerprint *or* password based user verification.
UAF_CMD_STATUS_SYSTEM_INTERRUPTED	0x12	The system interrupted the operation. Retry might make sense.

Table 4.4.1: UAF Authenticator Status Codes (0x00 - 0xFF)

5. Structures

This section is normative.

5.1 RawKeyHandle

RawKeyHandle is a structure generated and parsed by the authenticator. Authenticators MAY define RawKeyHandle in different ways and the internal structure is relevant only to the specific authenticator implementation.

RawKeyHandle for a typical **first-factor bound authenticator** has the following structure.

Depends on hashing algorithm (e.g. 32 bytes)	Depends on key type. (e.g. 32 bytes)	Username Size (1 byte)	Max 128 bytes
KHAccessToken	UAuth.priv	Size	Username

Table 5.1: RawKeyHandle Structure

First Factor authenticators MUST store Usernames in the authenticator and they MUST link the Username to the related key. This MAY be achieved by storing the Username inside the RawKeyHandle. Second Factor authenticators MUST NOT store the Username.

The ability to support Usernames is a key difference between first-, and second-factor authenticators.

The RawKeyHandle MUST be cryptographically wrapped before leaving the authenticator boundary since it typically contains sensitive information, e.g. the user authentication private key (UAuth.priv).

5.2 Structures to be parsed by FIDO Server

The structures defined in this section are created by UAF Authenticators and parsed by FIDO Servers.

Authenticators MUST generate these structures if they implement "UAFV1TLV" assertion scheme.

NOTE

"UAFV1TLV" assertion scheme assumes that the authenticator has exclusive control over all data included inside TAG_UAFV1_KRD and TAG_UAFV1_SIGNED_DATA.

The nesting structure MUST be preserved, but the order of tags within a composite tag is not normative. FIDO Servers MUST be prepared to handle tags appearing in any order.

5.2.1 TAG_UAFV1_REG_ASSERTION

The following TLV structure is generated by the authenticator during processing of a Register command. It is then delivered to FIDO Server intact, and parsed by the server. The structure embeds a TAG_UAFV1_KRD tag which among other data contains the newly generated UAuth.pub.

If the authenticator wants to append custom data to TAG_UAFV1_KRD structure (and thus sign with Attestation Key) - this data MUST be included as TAG_EXTENSION_DATA in a TAG_EXTENSION object inside TAG_UAFV1_KRD.

If the authenticator wants to send additional data to FIDO Server without signing it - this data MUST be included as TAG_EXTENSION_DATA in a TAG_EXTENSION object inside TAG_UAFV1_REG_ASSERTION and not inside TAG_UAFV1_KRD.

Currently this document only specifies ATTESTATION_BASIC_FULL, ATTESTATION_BASIC_SURROGATE and ATTESTATION_ECDAA. In case if the authenticator is required to perform "Some_Other_Attestation" on TAG_UAFV1_KRD - it MUST use the TLV tag and content defined for "Some_Other_Attestation" (defined in [FIDORegistry]).

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_REG_ASSERTION
1.1	UINT16 Length	Length of the structure
1.2	UINT16 Tag	TAG_UAFV1_KRD
1.2.1	UINT16 Length	Length of the structure
1.2.2	UINT16 Tag	TAG_AAID
1.2.2.1	UINT16 Length	Length of AAID
1.2.2.2	UINT8[] AAID	Authenticator Attestation ID
1.2.3	UINT16 Tag	TAG_ASSERTION_INFO
1.2.3.1	UINT16 Length	Length of Assertion Information
1.2.3.2	UINT16 AuthenticatorVersion	Vendor assigned authenticator version
1.2.3.3	UINT8 AuthenticationMode	For Registration this must be 0x01 indicating that the user has explicitly verified the action.
1.2.3.4	UINT16	Signature Algorithm and Encoding of the attestation signature.

	SignatureAlgAndEncoding	Refer to [FIDORegistry] for information on supported algorithms and their values.
1.2.3.5	UINT16 PublicKeyAlgAndEncoding	Public Key algorithm and encoding of the newly generated `UAuth.pub` key. Refer to [FIDORegistry] for information on supported algorithms and their values.
1.2.4	UINT16 Tag	TAG_FINAL_CHALLENGE_HASH
1.2.4.1	UINT16 Length	Final Challenge Hash length
1.2.4.2	UINT8[] FinalChallengeHash	(binary value of) Final Challenge Hash provided in the Command
1.2.5	UINT16 Tag	TAG_KEYID
1.2.5.1	UINT16 Length	Length of KeyID
1.2.5.2	UINT8[] KeyID	(binary value of) KeyID for the key generated by the Authenticator
1.2.6	UINT16 Tag	TAG_COUNTERS
1.2.6.1	UINT16 Length	Length of Counters
1.2.6.2	UINT32 SignCounter	Signature Counter. Indicates how many times this authenticator has performed signatures in the past.
1.2.6.3	UINT32 RegCounter	Registration Counter. Indicates how many times this authenticator has performed registrations in the past.
1.2.7	UINT16 Tag	TAG_PUB_KEY
1.2.7.1	UINT16 Length	Length of UAuth.pub
1.2.7.2	UINT8[] PublicKey	User authentication public key (UAuth.pub) newly generated by authenticator
1.3 **(choice 1)**	UINT16 Tag	ATTESTATION_BASIC_FULL
1.3.1	UINT16 Length	Length of structure
1.3.2	UINT16 Tag	TAG_SIGNATURE
1.3.2.1	UINT16 Length	Length of signature
1.3.2.2	UINT8[] Signature	Signature calculated with Basic Attestation Private Key over TAG_UAFV1_KRD content. The entire TAG_UAFV1_KRD content, including the tag and it's length field, MUST be included during signature computation.
1.3.3	UINT16 Tag	TAG_ATTESTATION_CERT (multiple occurrences possible) Multiple occurrences must be ordered. The attestation certificate MUST occur first. Each subsequent occurrence (if exists) MUST be the issuing certificate of the

		previous occurrence. The last occurence MUST be chained to one of the certificates included in field `attestationRootCertificate` in the related Metadata Statement [FIDOMetadataStatement].
1.3.3.1	UINT16 Length	Length of Attestation Cert
1.3.3.2	UINT8[] Certificate	Single X.509 DER-encoded [ITU-X690-2008] Attestation Certificate or a single certificate from the attestation certificate chain (see description above).
1.3 **(choice 2)**	UINT16 Tag	ATTESTATION_BASIC_SURROGATE
1.3.1	UINT16 Length	Length of structure
1.3.2	UINT16 Tag	TAG_SIGNATURE
1.3.2.1	UINT16 Length	Length of signature
1.3.2.2	UINT8[] Signature	Signature calculated with newly generated UAuth.priv key over TAG_UAFV1_KRD content. The entire TAG_UAFV1_KRD content, including the tag and it's length field, MUST be included during signature computation.
1.3 **(choice 3)**	UINT16 Tag	ATTESTATION_ECDAA
1.3.1	UINT16 Length	Length of structure
1.3.2	UINT16 Tag	TAG_SIGNATURE
1.3.2.1	UINT16 Length	Length of signature
1.3.2.2	UINT8[] Signature	The binary ECDAA signature as specified in [FIDOEcdaaAlgorithm].

5.2.2 TAG_UAFV1_AUTH_ASSERTION

The following TLV structure is generated by an authenticator during processing of a Sign command. It is then delivered to FIDO Server intact and parsed by the server. The structure embeds a TAG_UAFV1_SIGNED_DATA tag.

If the authenticator wants to append custom data to TAG_UAFV1_SIGNED_DATA structure (and thus sign with Attestation Key) - this data MUST be included as an additional tag inside TAG_UAFV1_SIGNED_DATA.

If the authenticator wants to send additional data to FIDO Server without signing it - this data MUST be included as an additional tag inside TAG_UAFV1_AUTH_ASSERTION and not inside TAG_UAFV1_SIGNED_DATA.

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_AUTH_ASSERTION
1.1	UINT16 Length	Length of the structure.
1.2	UINT16 Tag	TAG_UAFV1_SIGNED_DATA
1.2.1	UINT16 Length	Length of the structure.
1.2.2	UINT16 Tag	TAG_AAID

1.2.2.1	UINT16 Length	Length of AAID
1.2.2.2	UINT8[] AAID	Authenticator Attestation ID
1.2.3	UINT16 Tag	TAG_ASSERTION_INFO
1.2.3.1	UINT16 Length	Length of Assertion Information
1.2.3.2	UINT16 AuthenticatorVersion	Vendor assigned authenticator version.
1.2.3.3	UINT8 AuthenticationMode	Authentication Mode indicating whether user explicitly verified or not and indicating if there is a transaction content or not. • 0x01 means that user has been explicitly verified • 0x02 means that transaction content has been shown on the display and user confirmed it by explicitly verifying with authenticator
1.2.3.4	UINT16 SignatureAlgAndEncoding	Signature algorithm and encoding format. Refer to [FIDORegistry] for information on supported algorithms and their values.
1.2.4	UINT16 Tag	TAG_AUTHENTICATOR_NONCE
1.2.4.1	UINT16 Length	Length of authenticator Nonce - MUST be at least 8 bytes, and NOT longer than 64 bytes.
1.2.4.2	UINT8[] AuthnrNonce	(binary value of) A nonce randomly generated by Authenticator
1.2.5	UINT16 Tag	TAG_FINAL_CHALLENGE_HASH
1.2.5.1	UINT16 Length	Length of Final Challenge Hash
1.2.5.2	UINT8[] FinalChallengeHash	(binary value of) Final Challenge Hash provided in the Command
1.2.6	UINT16 Tag	TAG_TRANSACTION_CONTENT_HASH
1.2.6.1	UINT16 Length	Length of Transaction Content Hash. This length is 0 if AuthenticationMode == 0x01, i.e. authentication, not transaction confirmation.
1.2.6.2	UINT8[] TCHash	(binary value of) Transaction Content Hash
1.2.7	UINT16 Tag	TAG_KEYID
1.2.7.1	UINT16 Length	Length of KeyID
1.2.7.2	UINT8[] KeyID	(binary value of) KeyID
1.2.8	UINT16 Tag	TAG_COUNTERS
1.2.8.1	UINT16 Length	Length of Counters
1.2.8.2	UINT32 SignCounter	Signature Counter. Indicates how many times this authenticator has performed signatures in the past.
1.3	UINT16 Tag	TAG_SIGNATURE
1.3.1	UINT16 Length	Length of Signature

1.3.2	UINT8[] Signature	Signature calculated using UAuth.priv over TAG_UAFV1_SIGNED_DATA structure. The entire TAG_UAFV1_SIGNED_DATA content, including the tag and it's length field, MUST be included during signature computation.

5.3 UserVerificationToken

This specification doesn't specify how exactly user verification must be performed inside the authenticator. Verification is considered to be an authenticator, and vendor, specific operation.

This document provides an example on how the "vendor_specific_UserVerify" command (a command which verifies the user using Authenticator's built-in technology) could be securely bound to UAF Register and Sign commands. This binding is done through a concept called `UserVerificationToken`. Such a binding allows decoupling "vendor_specific_UserVerify" and "UAF Register/Sign" commands from each other.

Here is how it is defined:

- The ASM invokes the "vendor_specific_UserVerify" command. The authenticator verifies the user and returns a `UserVerificationToken` back.
- The ASM invokes UAF.Register/Sign command and passes `UserVerificationToken` to it. The authenticator verifies the validity of `UserVerificationToken` and performs the FIDO operation if it is valid.

The concept of UserVerificationToken is non-normative. An authenticator might decide to implement this binding in a very different way. For example an authenticator vendor may decide to append a UAF Register request directly to their "vendor_specific_UserVerify" command and process both as a single command.

If `UserVerificationToken` binding is implemented, it should either meet one of the following criteria or implement a mechanism providing similar, or better security:

- `UserVerificationToken` must allow performing only a single UAF Register or UAF Sign operation.
- `UserVerificationToken` must be time bound, and allow performing multiple UAF operations within the specified time.

6. Commands

This section is non-normative.

NORMATIVE

UAF Authenticators which are designed to be interoperable with ASMs from different vendors MUST implement the command interface defined in this section. Examples of such authenticators:

- Bound Authenticators in which the core authenticator functionality is developed by one vendor, and the ASM is developed by another vendor
- Roaming Authenticators

NORMATIVE

UAF Authenticators which are tightly integrated with a custom ASM (typically bound authenticators) MAY implement a ***different command interface***.

NOTE

Examples of such different command interface include native key store or key chain APIs. It is important to declare whether the Uauth keys are restricted to sign valid FIDO UAF assertions only. See [FIDOMetadataStatement] entry "isKeyRestricted".

All UAF Authenticator commands and responses are semantically similar - they are all represented as TLV-encoded blobs. The first 2 bytes of each command is the command code. After receiving a command, the authenticator must parse the first TLV tag and figure out which command is being issued.

6.1 GetInfo Command

6.1.1 Command Description

This command returns information about the connected authenticators. It may return 0 or more authenticators. Each authenticator has an assigned `authenticatorIndex` which is used in other commands as an authenticator reference.

6.1.2 Command Structure

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_GETINFO_CMD
1.1	UINT16 Length	Entire Command Length - must be 0 for this command

6.1.3 Command Response

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_GETINFO_CMD_RESPONSE
1.1	UINT16 Length	Response length
1.2	UINT16 Tag	TAG_STATUS_CODE
1.2.1	UINT16 Length	Status Code Length
1.2.2	UINT16 Value	Status Code returned by Authenticator
1.3	UINT16 Tag	TAG_API_VERSION
1.3.1	UINT16 Length	Length of API Version (must be 0x0001)
1.3.2	UINT8 Version	Authenticator API Version (must be 0x01). This version indicates the types of commands, and formatting associated with them, that are supported by the authenticator.
1.4	UINT16 Tag	TAG_AUTHENTICATOR_INFO (multiple occurrences possible)
1.4.1	UINT16 Length	Length of Authenticator Info
1.4.2	UINT16 Tag	TAG_AUTHENTICATOR_INDEX
1.4.2.1	UINT16 Length	Length of AuthenticatorIndex (must be 0x0001)
1.4.2.2	UINT8 AuthenticatorIndex	Authenticator Index
1.4.3	UINT16 Tag	TAG_AAID
1.4.3.1	UINT16 Length	Length of AAID
1.4.3.2	UINT8[] AAID	Vendor assigned AAID
1.4.4	UINT16 Tag	TAG_AUTHENTICATOR_METADATA

1.4.4.1	UINT16 Length	Length of Authenticator Metadata
1.4.4.2	UINT16 AuthenticatorType	Indicates whether the authenticator is bound or roaming, and whether it is first-, or second-factor only. The ASM must use this information to understand how to work with the authenticator. Predefined values: • 0x0001 - Indicates second-factor authenticator (first-factor when the flag is not set) • 0x0002 - Indicates roaming authenticator (bound authenticator when the flag is not set) • 0x0004 - Key handles will be stored inside authenticator and won't be returned to ASM • 0x0008 - Authenticator has a built-in UI for enrollment and verification. ASM should not show its custom UI • 0x0010 - Authenticator has a built-in UI for settings, and supports OpenSettings command. • 0x0020 - Authenticator expects TAG_APPID to be passed as an argument to commands where it is defined as an optional argument • 0x0040 - At least one user is enrolled in the authenticator. Authenticators which don't support the concept of user enrollment (e.g. USER_VERIFY_NONE, USER_VERIFY_PRESENCE) must always have this bit set. • 0x0080 - Authenticator supports user verification tokens (UVTs) as described in this document. See section 5.3 UserVerificationToken. • 0x0100 - Authenticator only accepts TAG_TRANSACTION_TEXT_HASH in Sign command. This flag MAY ONLY be set if TransactionConfirmationDisplay is set to 0x0003 (see section 6.3 Sign Command).
1.4.4.3	UINT8 MaxKeyHandles	Indicates maximum number of key handles this authenticator can receive and process in a single command. This information will be used by the ASM when invoking SIGN command with multiple key handles.
1.4.4.4	UINT32 UserVerification	User Verification method (as defined in [FIDORegistry])
1.4.4.5	UINT16 KeyProtection	Key Protection type (as defined in [FIDORegistry]).
1.4.4.6	UINT16 MatcherProtection	Matcher Protection type (as defined in [FIDORegistry]).
1.4.4.7	UINT16 TransactionConfirmationDisplay	Transaction Confirmation type (as defined in [FIDORegistry]). NOTE If Authenticator doesn't support Transaction Confirmation - this value must be set to 0.
1.4.4.8	UINT16 AuthenticationAlg	Authentication Algorithm (as defined in [FIDORegistry]).
1.4.5	UINT16 Tag	TAG_TC_DISPLAY_CONTENT_TYPE (optional)
1.4.5.1	UINT16 Length	Length of content type.
1.4.5.2	UINT8[] ContentType	Transaction Confirmation Display Content Type. See [FIDOMetadataStatement] for additional information on the format of this field.

1.4.6	UINT16 Tag	TAG_TC_DISPLAY_PNG_CHARACTERISTICS (optional,multiple occurrences permitted)
1.4.6.1	UINT16 Length	Length of display characteristics information.
1.4.6.2	UINT32 Width	See [FIDOMetadataStatement] for additional information.
1.4.6.3	UINT32 Height	See [FIDOMetadataStatement] for additional information.
1.4.6.4	UINT8 BitDepth	See [FIDOMetadataStatement] for additional information.
1.4.6.5	UINT8 ColorType	See [FIDOMetadataStatement] for additional information.
1.4.6.6	UINT8 Compression	See [FIDOMetadataStatement] for additional information.
1.4.6.7	UINT8 Filter	See [FIDOMetadataStatement] for additional information.
1.4.6.8	UINT8 Interlace	See [FIDOMetadataStatement] for additional information.
1.4.6.9	UINT8[] PLTE	A PLTE packet descriptor, defined by 3 byte word.

Offset	Length	Mnemonic	Description
0	1	R	Red channel value
1	1	G	Green channel value
2	1	B	Blue channel value

See [FIDOMetadataStatement] for additional information.

1.4.7	UINT16 Tag	TAG_ASSERTION_SCHEME
1.4.7.1	UINT16 Length	Length of Assertion Scheme
1.4.7.2	UINT8[] AssertionScheme	Assertion Scheme (as defined in [UAFRegistry])
1.4.8	UINT16 Tag	TAG_ATTESTATION_TYPE (multiple occurrences possible)
1.4.8.1	UINT16 Length	Length of AttestationType
1.4.8.2	UINT16 AttestationType	Attestation Type values are defined in [UAFRegistry] by the constants with the prefix `TAG_ATTESTATION`.
1.4.9	UINT16 Tag	TAG_SUPPORTED_EXTENSION_ID (optional, multiple occurrences possible)
1.4.9.1	UINT16 Length	Length of SupportedExtensionID
1.4.9.2	UINT8[] SupportedExtensionID	SupportedExtensionID as a UINT8[] encoding of a UTF-8 string

6.1.4 Status Codes

- `UAF_CMD_STATUS_OK`
- `UAF_CMD_STATUS_ERR_UNKNOWN`
- `UAF_CMD_STATUS_PARAMS_INVALID`

6.2 Register Command

This command generates a UAF registration assertion. This assertion can be used to register the authenticator with a FIDO Server.

6.2.1 Command Structure

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_REGISTER_CMD
1.1	UINT16 Length	Command Length
1.2	UINT16 Tag	TAG_AUTHENTICATOR_INDEX
1.2.1	UINT16 Length	Length of AuthenticatorIndex (must be 0x0001)
1.2.2	UINT8 AuthenticatorIndex	Authenticator Index
1.3	UINT16 Tag	TAG_APPID (optional)
1.3.1	UINT16 Length	Length of AppID
1.3.2	UINT8[] AppID	AppID (max 512 bytes)
1.4	UINT16 Tag	TAG_FINAL_CHALLENGE_HASH
1.4.1	UINT16 Length	Final Challenge Hash Length
1.4.2	UINT8[] FinalChallengeHash	Final Challenge Hash provided by ASM (max 32 bytes)
1.5	UINT16 Tag	TAG_USERNAME
1.5.1	UINT16 Length	Length of Username
1.5.2	UINT8[] Username	Username provided by ASM (max 128 bytes)
1.6	UINT16 Tag	TAG_ATTESTATION_TYPE
1.6.1	UINT16 Length	Length of AttestationType
1.6.2	UINT16 AttestationType	Attestation Type to be used
1.7	UINT16 Tag	TAG_KEYHANDLE_ACCESS_TOKEN
1.7.1	UINT16 Length	Length of KHAccessToken
1.7.2	UINT8[] KHAccessToken	KHAccessToken provided by ASM (max 32 bytes)
1.8	UINT16 Tag	TAG_USERVERIFY_TOKEN (optional)
1.8.1	UINT16 Length	Length of VerificationToken
1.8.2	UINT8[] VerificationToken	User verification token

6.2.2 Command Response

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_REGISTER_CMD_RESPONSE
1.1	UINT16 Length	Command Length
1.2	UINT16 Tag	TAG_STATUS_CODE
1.2.1	UINT16 Length	Status Code Length

1.2.2	UINT16 Value	Status code returned by Authenticator
1.3	UINT16 Tag	TAG_AUTHENTICATOR_ASSERTION
1.3.1	UINT16 Length	Length of Assertion
1.3.2	UINT8[] Assertion	Registration Assertion (see section TAG_UAFV1_REG_ASSERTION).
1.4	UINT16 Tag	TAG_KEYHANDLE (optional)
1.4.1	UINT16 Length	Length of key handle
1.4.2	UINT8[] Value	(binary value of) key handle

6.2.3 Status Codes

- `UAF_CMD_STATUS_OK`
- `UAF_CMD_STATUS_ERR_UNKNOWN`
- `UAF_CMD_STATUS_ACCESS_DENIED`
- `UAF_CMD_STATUS_USER_NOT_ENROLLED`
- `UAF_CMD_STATUS_USER_CANCELLED`
- `UAF_CMD_STATUS_ATTESTATION_NOT_SUPPORTED`
- `UAF_CMD_STATUS_PARAMS_INVALID`
- `UAF_CMD_STATUS_TIMEOUT`
- `UAF_CMD_STATUS_USER_NOT_RESPONSIVE`
- `UAF_CMD_STATUS_INSUFFICIENT_RESOURCES`
- `UAF_CMD_STATUS_USER_LOCKOUT`

6.2.4 Command Description

The authenticator must perform the following steps (see below table for command structure):

If the command structure is invalid (e.g. cannot be parsed correctly), return `UAF_CMD_STATUS_PARAMS_INVALID`.

1. If this authenticator has a transaction confirmation display and is able to display AppID, then make sure `Command.TAG_APPID` is provided, and show its content on the display when verifying the user. Return `UAF_CMD_STATUS_PARAMS_INVALID` if `Command.TAG_APPID` is not provided in such case. Update `Command.KHAccessToken` with `TAG_APPID`:
    - Update Command.KHAccessToken by mixing it with Command.TAG_APPID. An example of such mixing function is a cryptographic hash function.

      NOTE

      This method allows us to avoid storing the AppID separately in the RawKeyHandle.

        - For example: Command.KHAccessToken=hash(Command.KHAccessToken | Command.TAG_APPID)
2. If the user is already enrolled with this authenticator (via biometric enrollment, PIN setup or similar mechanism) - verify the user. If the verification has been already done in a previous command - make sure that Command.TAG_USERVERIFY_TOKEN is a valid token.

   If the user is locked out (e.g. too many failed attempts to get verified) and the authenticator cannot automatically trigger unblocking, return `UAF_CMD_STATUS_USER_LOCKOUT`.

    1. If the user doesn't respond to the request to get verified - return `UAF_CMD_STATUS_USER_NOT_RESPONSIVE`

    2. If verification fails - return `UAF_CMD_STATUS_ACCESS_DENIED`
    3. If user explicitly cancels the operation - return `UAF_CMD_STATUS_USER_CANCELLED`
3. If the user is not enrolled with the authenticator then take the user through the enrollment process. If the enrollment process cannot be triggered by the authenticator, return `UAF_CMD_STATUS_USER_NOT_ENROLLED`.
    1. If the authenticator can trigger enrollment, but the user doesn't respond to the request to enroll - return `UAF_CMD_STATUS_USER_NOT_RESPONSIVE`
    2. If the authenticator can trigger enrollment, but enrollment fails - return `UAF_CMD_STATUS_ACCESS_DENIED`
    3. If the authenticator can trigger enrollment, but the user explicitly cancels the enrollment operation - return `UAF_CMD_STATUS_USER_CANCELLED`
4. Make sure that Command.TAG_ATTESTATION_TYPE is supported. If not - return `UAF_CMD_STATUS_ATTESTATION_NOT_SUPPORTED`
5. Generate a new key pair (UAuth.pub/UAuth.priv) If the process takes longer than accepted - return `UAF_CMD_STATUS_TIMEOUT`
6. Create a RawKeyHandle, for example as follows
    1. Add UAuth.priv to RawKeyHandle
    2. Add Command.KHAccessToken to RawKeyHandle
    3. If a first-factor authenticator, then add Command.Username to RawKeyHandle

   If there are not enough resources in the authenticator to perform this task - return `UAF_CMD_STATUS_INSUFFICIENT_RESOURCES`.
7. Wrap RawKeyHandle with Wrap.sym key
8. Create TAG_UAFV1_KRD structure
    1. If this is a second-factor roaming authenticator - place key handle inside TAG_KEYID. Otherwise generate a KeyID and place it inside TAG_KEYID.
    2. Copy all the mandatory fields (see section TAG_UAFV1_REG_ASSERTION)
9. Perform attestation on TAG_UAFV1_KRD based on provided Command.AttestationType.
10. Create TAG_AUTHENTICATOR_ASSERTION
    1. Create TAG_UAFV1_REG_ASSERTION
        1. Copy all the mandatory fields (see section TAG_UAFV1_REG_ASSERTION)
        2. If this is a first-factor roaming authenticator - add KeyID and key handle into internal storage
        3. If this is a bound authenticator - return key handle inside TAG_KEYHANDLE
    2. Put the entire TLV structure for TAG_UAFV1_REG_ASSERTION as the value of TAG_AUTHENTICATOR_ASSERTION
11. Return TAG_UAFV1_REGISTER_CMD_RESPONSE
    1. Use `UAF_CMD_STATUS_OK` as status code
    2. Add TAG_AUTHENTICATOR_ASSERTION
    3. Add TAG_KEY_HANDLE if the key handle must be stored outside the Authenticator

NORMATIVE

The authenticator MUST NOT process a `Register` command without verifying the user (or enrolling the user, if this is the first time the user has used the authenticator).

The authenticator MUST generate a unique UAuth key pair each time the Register command is called.

The authenticator SHOULD either store key handle in its internal secure storage or cryptographically wrap it and export it to the ASM.

For silent authenticators, the key handle MUST never be stored on a FIDO Server, otherwise this would enable tracking of users without providing the ability for users to clear key handles from the local device.

If KeyID is not the key handle itself (e.g. such as in case of a second-factor roaming authenticator) - it MUST be a unique and unguessable byte array with a maximum length of 32 bytes. It MUST be unique within the scope of the AAID.

In the case of bound authenticators implementing a different command interface, the ASM could generate a temporary KeyID and provide it as input to the authenticator in a Register command and change it to the final KeyID (e.g. derived from the public key) when the authenticator has completed the Register command execution.

NOTE

If the KeyID is generated randomly (instead of, for example, being derived from a key handle or the public key) - it should be stored inside RawKeyHandle so that it can be accessed by the authenticator while processing the Sign command.

If the authenticator doesn't support `SignCounter` or `RegCounter` it MUST set these to 0 in TAG_UAFV1_KRD. The `RegCounter` MUST be set to 0 when a factory reset for the authenticator is performed. The `SignCounter` MUST be set to 0 when a factory reset for the authenticator is performed.

6.3 Sign Command

This command generates a UAF assertion. This assertion can be further verified by a FIDO Server which has a prior registration with this authenticator.

6.3.1 Command Structure

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_SIGN_CMD
1.1	UINT16 Length	Length of Command
1.2	UINT16 Tag	TAG_AUTHENTICATOR_INDEX
1.2.1	UINT16 Length	Length of AuthenticatorIndex (must be 0x0001)
1.2.2	UINT8 AuthenticatorIndex	Authenticator Index
1.3	UINT16 Tag	TAG_APPID (optional)
1.3.1	UINT16 Length	Length of AppID
1.3.2	UINT8[] AppID	AppID (max 512 bytes)
1.4	UINT16 Tag	TAG_FINAL_CHALLENGE_HASH
1.4.1	UINT16 Length	Length of Final Challenge Hash
1.4.2	UINT8[] FinalChallengeHash	(binary value of) Final Challenge Hash provided by ASM (max 32 bytes)
1.5	UINT16 Tag	TAG_TRANSACTION_CONTENT (optional)
1.5.1	UINT16 Length	Length of Transaction Content
1.5.2	UINT8[] TransactionContent	(binary value of) Transaction Content provided by the ASM
1.5	UINT16 Tag	TAG_TRANSACTION_CONTENT_HASH (optional and mutually exclusive with TAG_TRANSACTION_CONTENT). This TAG is only allowed for authenticators not able to display the transaction text, i.e. authenticator with `tcDisplay=0x0003` (i.e. flags `TRANSACTION_CONFIRMATION_DISPLAY_ANY` and `TRANSACTION_CONFIRMATION_DISPLAY_PRIVILEGED_SOFTWARE` are set).

1.5.1	UINT16 Length	Length of Transaction Content Hash
1.5.2	UINT8[] TransactionContentHash	(binary value of) Transaction Content Hash provided by the ASM
1.6	UINT16 Tag	TAG_KEYHANDLE_ACCESS_TOKEN
1.6.1	UINT16 Length	Length of KHAccessToken
1.6.2	UINT8[] KHAccessToken	(binary value of) KHAccessToken provided by ASM (max 32 bytes)
1.7	UINT16 Tag	TAG_USERVERIFY_TOKEN (optional)
1.7.1	UINT16 Length	Length of the User Verification Token
1.7.2	UINT8[] VerificationToken	User Verification Token
1.8	UINT16 Tag	TAG_KEYHANDLE (optional, multiple occurrences permitted)
1.8.1	UINT16 Length	Length of KeyHandle
1.8.2	UINT8[] KeyHandle	(binary value of) key handle

6.3.2 Command Response

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_SIGN_CMD_RESPONSE
1.1	UINT16 Length	Entire Length of Command Response
1.2	UINT16 Tag	TAG_STATUS_CODE
1.2.1	UINT16 Length	Status Code Length
1.2.2	UINT16 Value	Status code returned by authenticator
1.3 **(choice 1)**	UINT16 Tag	TAG_USERNAME_AND_KEYHANDLE (optional, multiple occurances) This TLV tag can be used to convey multiple (>=1) {Username, Keyhandle} entries. Each occurance of TAG_USERNAME_AND_KEYHANDLE contains one pair. If this tag is present, TAG_AUTHENTICATOR_ASSERTION must not be present
1.3.1	UINT16 Length	Length of the structure
1.3.2	UINT16 Tag	TAG_USERNAME
1.3.2.1	UINT16 Length	Length of Username

1.3.2.2	UINT8[] Username	Username
1.3.3	UINT16 Tag	TAG_KEYHANDLE
1.3.3.1	UINT16 Length	Length of `KeyHandle`
1.3.3.2	UINT8[] KeyHandle	(binary value of) key handle
1.3 **(choice 2)**	UINT16 Tag	TAG_AUTHENTICATOR_ASSERTION (optional) If this tag is present, TAG_USERNAME_AND_KEYHANDLE must not be present
1.3.1	UINT16 Length	Assertion Length
1.3.2	UINT8[] Assertion	Authentication assertion generated by the authenticator (see section TAG_UAFV1_AUTH_ASSERTION).

6.3.3 Status Codes

- `UAF_CMD_STATUS_OK`
- `UAF_CMD_STATUS_ERR_UNKNOWN`
- `UAF_CMD_STATUS_ACCESS_DENIED`
- `UAF_CMD_STATUS_USER_NOT_ENROLLED`
- `UAF_CMD_STATUS_USER_CANCELLED`
- `UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT`
- `UAF_CMD_STATUS_PARAMS_INVALID`
- `UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY`
- `UAF_CMD_STATUS_TIMEOUT`
- `UAF_CMD_STATUS_USER_NOT_RESPONSIVE`
- `UAF_CMD_STATUS_USER_LOCKOUT`

6.3.4 Command Description

NOTE

First-factor authenticators should implement this command in two stages.

1. The first stage will be executed only if the authenticator finds out that there are multiple key handles after filtering with the KHAccessToken. In this stage, the authenticator must return a list of usernames along with corresponding key handles
2. In the second stage, after the user selects a username, this command will be called with a single key handle and will return a UAF assertion based on this key handle

If a second-factor authenticator is presented with more than one valid key handles, it must exercise only the first one and ignore the rest.

The command is implemented in two stages to ensure that only one assertion can be generated for each command invocation.

Authenticators must take the following steps:

If the command structure is invalid (e.g. cannot be parsed correctly), return `UAF_CMD_STATUS_PARAMS_INVALID`.

1. If this authenticator has a transaction confirmation display, and is able to display the AppID - make sure Command.TAG_APPID is provided, and show it on the display when verifying the user. Return `UAF_CMD_STATUS_PARAMS_INVALID` if `Command.TAG_APPID` is not provided in such case.
    - Update Command.KHAccessToken by mixing it with Command.TAG_APPID. An example of such a mixing function is a cryptographic hash function.
        - Command.KHAccessToken=hash(Command.KHAccessToken | Command.TAG_APPID)
2. If `TransactionContent` is not empty
    - If this is a silent authenticator, then return `UAF_CMD_STATUS_ACCESS_DENIED`
    - If the authenticator doesn't support transaction confirmation (it has set `TransactionConfirmationDisplay` to 0 in the response to a `GetInfo` Command), then return `UAF_CMD_STATUS_ACCESS_DENIED`
    - If the authenticator has a built-in transaction confirmation display and the Authenticator implements displaying transaction text before user verification, then show `Command.TransactionContent` and `Command.TAG_APPID` (optional) on display and wait for the user to confirm it by passing user verification (see step below):
        - Return `UAF_CMD_STATUS_USER_NOT_RESPONSIVE` if the user doesn't respond.
        - Return `UAF_CMD_STATUS_USER_CANCELLED` if the user cancels the transaction.
        - Return `UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT` if the provided transaction content cannot be rendered.
        - Compute hash of TransactionContent
            - TAG_UAFV1_SIGNED_DATA.TAG_TRANSACTION_CONTENT_HASH = hash(Command.TransactionContent)
            - Set TAG_UAFV1_SIGNED_DATA.AuthenticationMode to 0x02
3. If the user is already enrolled with the authenticator (such as biometric enrollment, PIN setup, etc.) then verify the user. If the verification has already been done in one of the previous commands, make sure that `Command.TAG_USERVERIFY_TOKEN` is a valid token.

    If the user is locked out (e.g. too many failed attempts to get verified) and the authenticator cannot automatically trigger unblocking, return `UAF_CMD_STATUS_USER_LOCKOUT`.

    1. If the user doesn't respond to the request to get verified - return `UAF_CMD_STATUS_USER_NOT_RESPONSIVE`
    2. If verification fails - return `UAF_CMD_STATUS_ACCESS_DENIED`
    3. If the user explicitly cancels the operation - return `UAF_CMD_STATUS_USER_CANCELLED`
4. If the user is not enrolled then return `UAF_CMD_STATUS_USER_NOT_ENROLLED`

    NOTE

    This should not occur as the Uauth key must be protected by the authenticator's user verification method. If the authenticator supports alternative user verification methods (e.g. alternative password and finger print verification and the alternative password must be provided before enrolling a finger and *only* the finger print is verified as part of the *Register* or *Sign* operation, then the authenticator should automatically and implicitly ask the user to enroll the modality required in the operation (instead of just returning an error).

5. Unwrap all provided key handles from Command.TAG_KEYHANDLE values using Wrap.sym
    1. If this is a first-factor roaming authenticator:
        - If Command.TAG_KEYHANDLE are provided, then the items in this list are KeyIDs. Use these KeyIDs to locate key handles stored in internal storage
        - If no Command.TAG_KEYHANDLE are provided - unwrap all key handles stored in internal storage

    If no RawKeyHandles are found - return `UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY`.

6. Filter RawKeyHandles with Command.KHAccessToken (RawKeyHandle.KHAccessToken == Command.KHAccessToken)
7. If the number of remaining RawKeyHandles is 0, then fail with `UAF_CMD_STATUS_ACCESS_DENIED`
8. If number of remaining RawKeyHandles is > 1
    1. If this authenticator has a user interface and wants to use it for this purpose: Ask the user which of the usernames he wants to use for this operation. Select the related RawKeyHandle and jump to step #8.
    2. If this is a second-factor authenticator, then choose the first RawKeyHandle only and jump to step #8.
    3. Copy {Command.KeyHandle, RawKeyHandle.username} for all remaining RawKeyHandles into TAG_USERNAME_AND_KEYHANDLE tag.
        - If this is a first-factor roaming authenticator, then the returned TAG_USERNAME_AND_KEYHANDLEs must be ordered by the key handle registration date (the latest-registered key handle must come the latest).

          NOTE

          If two or more key handles with the same username are found, a first-factor roaming authenticator may only keep the one that is registered most recently and delete the rest. This avoids having unusable (old) private key in the authenticator which (surprisingly) might become active after deregistering the newly generated one.
    4. Copy TAG_USERNAME_AND_KEYHANDLE into TAG_UAFV1_SIGN_CMD_RESPONSE and return
9. If number of remaining RawKeyHandles is 1
    1. If the Uauth key related to the RawKeyHandle cannot be used or disappeared and cannot be restored - return `UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY`.
    2. Create TAG_UAFV1_SIGNED_DATA and set TAG_UAFV1_SIGNED_DATA.AuthenticationMode to 0x01
    3. If `TransactionContent` is not empty
        - If the authenticator has a built-in transaction confirmation display and the authenticator implements displaying transaction text after user verification, then show `Command.TransactionContent` and `Command.TAG_APPID` (optional) on display and wait for the user to confirm it:
            - Return `UAF_CMD_STATUS_USER_NOT_RESPONSIVE` if the user doesn't respond.
            - Return `UAF_CMD_STATUS_USER_CANCELLED` if the user cancels the transaction.
            - Return `UAF_CMD_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT` if the provided transaction content cannot be rendered.
            - Compute hash of TransactionContent
                - TAG_UAFV1_SIGNED_DATA.TAG_TRANSACTION_CONTENT_HASH = hash(Command.TransactionContent)
                - Set TAG_UAFV1_SIGNED_DATA.AuthenticationMode to 0x02
    4. If `TransactionContent` is not set, but `TransactionContentHash` is not empty
        - If this is a silent authenticator, then return `UAF_CMD_STATUS_ACCESS_DENIED`
        - If the conditions for receiving TransactionContentHash are not satisfied (if the authenticator's `TransactionConfirmationDisplay` is NOT set to 0x0003 in the response to a `GetInfo` Command), then return `UAF_CMD_STATUS_PARAMS_INVALID`
        - Perform the following steps
            - TAG_UAFV1_SIGNED_DATA.TAG_TRANSACTION_CONTENT_HASH = Command.TransactionContentHash
            - Set TAG_UAFV1_SIGNED_DATA.AuthenticationMode to 0x02
    5. Create TAG_UAFV1_AUTH_ASSERTION
        - Fill in the rest of TAG_UAFV1_SIGNED_DATA fields
        - Perform the following steps
            - Increment SignCounter and put into TAG_UAFV1_SIGNED_DATA
            - Copy all the mandatory fields (see section TAG_UAFV1_AUTH_ASSERTION)

        - If TAG_UAFV1_SIGNED_DATA.AuthenticationMode == 0x01 - set TAG_UAFV1_SIGNED_DATA.TAG_TRANSACTION_CONTENT_HASH.Length to 0
    - Sign TAG_UAFV1_SIGNED_DATA with UAuth.priv

    If these steps take longer than expected by the authenticator - return `UAF_CMD_STATUS_TIMEOUT`.
6. Put the entire TLV structure for TAG_UAFV1_AUTH_ASSERTION as the value of TAG_AUTHENTICATOR_ASSERTION
7. Copy TAG_AUTHENTICATOR_ASSERTION into TAG_UAFV1_SIGN_CMD_RESPONSE and return

NORMATIVE

Authenticator MUST NOT process Sign command without verifying the user first.

Authenticator MUST NOT reveal Username without verifying the user first.

Bound authenticators MUST NOT process Sign command without validating KHAccessToken first.

Bound authenticators implementing a different command interface, MAY implement a different method for binding keys to a specific AppID, if such method provides at least the same security level (i.e. relying the OS/platform to determine the calling App). See [UAFASM] section "KHAccessToken" for more details.

UAuth.priv keys MUST never leave Authenticator's security boundary in plaintext form. UAuth.priv protection boundary is specified in `Metadata.keyProtection` field in Metadata [FIDOMetadataStatement]).

If Authenticator's Metadata indicates that it does support Transaction Confirmation Display - it MUST display provided transaction content in this display and include the hash of content inside TAG_UAFV1_SIGNED_DATA structure.

Authenticators supporting Transaction Confirmation Display SHALL either display the transaction text before user verification (see step #2) or after it (see step 9.3). Displaying the transaction text *before* user verification is preferred.

Silent Authenticators MUST NOT operate in first-factor mode in order to follow the assumptions made in [FIDOSecRef]. However, a native App or web page could "cache" the keyHandle or a Cookie and hence would be considered a first-factor that could be combined with a Silent Authenticator (when doing do).

If Authenticator doesn't support `SignCounter`, then it MUST set it to 0 in TAG_UAFV1_SIGNED_DATA. The `SignCounter` MUST be set to 0 when a factory reset for the Authenticator is performed, in order to follow the assumptions made in [FIDOSecRef].

Some Authenticators might support Transaction Confirmation display functionality not inside the Authenticator but within the boundaries of ASM. Typically these are software based Transaction Confirmation displays. When processing the Sign command with a given transaction such Authenticators should assume that they do have a builtin Transaction Confirmation display and should include the hash of transaction content in the final assertion without displaying anything to the user. Also, such Authenticator's Metadata file MUST clearly indicate the type of Transaction Confirmation display. Typically the flag of Transaction Confirmation display will be TRANSACTION_CONFIRMATION_DISPLAY_ANY or TRANSACTION_CONFIRMATION_DISPLAY_PRIVILEGED_SOFTWARE. See [FIDORegistry] for flags describing Transaction Confirmation Display type.

6.4 Deregister Command

This command deletes a registered UAF credential from Authenticator.

6.4.1 Command Structure

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_DEREGISTER_CMD
1.1	UINT16 Length	Entire Command Length
1.2	UINT16 Tag	TAG_AUTHENTICATOR_INDEX

1.2.1	UINT16 Length	Length of AuthenticatorIndex (must be 0x0001)
1.2.2	UINT8 AuthenticatorIndex	Authenticator Index
1.3	UINT16 Tag	TAG_APPID (optional)
1.3.1	UINT16 Length	Length of AppID
1.3.2	UINT8[] AppID	AppID (max 512 bytes)
1.4	UINT16 Tag	TAG_KEYID
1.4.1	UINT16 Length	Length of KeyID
1.4.2	UINT8[] KeyID	(binary value of) KeyID provided by ASM
1.5	UINT16 Tag	TAG_KEYHANDLE_ACCESS_TOKEN
1.5.1	UINT16 Length	Length of KeyHandle Access Token
1.5.2	UINT8[] KHAccessToken	(binary value of) KeyHandle Access Token provided by ASM (max 32 bytes)

6.4.2 Command Response

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_DEREGISTER_CMD_RESPONSE
1.1	UINT16 Length	Entire Length of Command Response
1.2	UINT16 Tag	TAG_STATUS_CODE
1.2.1	UINT16 Length	Status Code Length
1.2.2	UINT16 StatusCode	StatusCode returned by Authenticator

6.4.3 Status Codes

- `UAF_CMD_STATUS_OK`
- `UAF_CMD_STATUS_ERR_UNKNOWN`
- `UAF_CMD_STATUS_ACCESS_DENIED`
- `UAF_CMD_STATUS_CMD_NOT_SUPPORTED`
- `UAF_CMD_STATUS_PARAMS_INVALID`

6.4.4 Command Description

Authenticator must take the following steps:

If the command structure is invalid (e.g. cannot be parsed correctly), return `UAF_CMD_STATUS_PARAMS_INVALID`.

1. If this authenticator has a Transaction Confirmation display and is able to display AppID, then make sure Command.TAG_APPID is provided. Return `UAF_CMD_STATUS_PARAMS_INVALID` if `Command.TAG_APPID` is not provided in such case.
    - Update Command.KHAccessToken by mixing it with Command.TAG_APPID. An example of such mixing function is a cryptographic hash function.
        - Command.KHAccessToken=hash(Command.KHAccessToken | Command.TAG_APPID)
2. If this Authenticator doesn't store key handles internally, then return `UAF_CMD_STATUS_CMD_NOT_SUPPORTED`

3. If the length of `TAG_KEYID` is zero (i.e., 0000 Hex), then
    - if `TAG_APPID` is provided, then
        - for each KeyHandle that maps to `TAG_APPID` do
            1. if RawKeyHandle.KHAccessToken == Command.KHAccessToken, then delete KeyHandle from internal storage, otherwise, note an error occured
        - if an error occured, then return UAF_CMD_STATUS_ACCESS_DENIED
    - if `TAG_APPID` is not provided, then delete all KeyHandles from internal storage where RawKeyHandle.KHAccessToken == Command.KHAccessToken
    - Go to step 5
4. If the length of `TAG_KEYID` is NOT zero, then
    - Find KeyHandle that matches Command.KeyID
    - Ensure that RawKeyHandle.KHAccessToken == Command.KHAccessToken
        - If not, then return `UAF_CMD_STATUS_ACCESS_DENIED`
    - Delete this KeyHandle from internal storage
5. Return `UAF_CMD_STATUS_OK`

NOTE

The authenticator must unwrap the relevant KeyHandles using Wrap.sym as needed.

NORMATIVE

Bound authenticators MUST NOT process Deregister command without validating KHAccessToken first.

Bound authenticators implementing a different command interface, MAY implement a different method for binding keys to a specific AppID, if such method provides at least the same security level (i.e. relying the OS/platform to determine the calling App). See [UAFASM] section "KHAccessToken" for more details.

Deregister command SHOULD NOT explicitly reveal whether the provided keyID was registered or not.

NOTE
This command *never* returns `UAF_CMD_STATUS_KEY_DISAPPEARED_PERMANENTLY` as this could reveal the keyID registration status.

6.5 OpenSettings Command

This command instructs the Authenticator to open its built-in settings UI (e.g. change PIN, enroll new fingerprint, etc).

The Authenticator must return `UAF_CMD_STATUS_CMD_NOT_SUPPORTED` if it doesn't support such functionality.

If the command structure is invalid (e.g. cannot be parsed correctly), the authenticator must return `UAF_CMD_STATUS_PARAMS_INVALID`.

6.5.1 Command Structure

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_OPEN_SETTINGS_CMD
1.1	UINT16 Length	Entire Command Length
1.2	UINT16 Tag	TAG_AUTHENTICATOR_INDEX

1.2.1	UINT16 Length	Length of AuthenticatorIndex (must be 0x0001)
1.2.2	UINT8 AuthenticatorIndex	Authenticator Index

6.5.2 Command Response

TLV Structure		Description
1	UINT16 Tag	TAG_UAFV1_OPEN_SETTINGS_CMD_RESPONSE
1.1	UINT16 Length	Entire Length of Command Response
1.2	UINT16 Tag	TAG_STATUS_CODE
1.2.1	UINT16 Length	Status Code Length
1.2.2	UINT16 StatusCode	StatusCode returned by Authenticator

6.5.3 Status Codes

- `UAF_CMD_STATUS_OK`
- `UAF_CMD_STATUS_ERR_UNKNOWN`
- `UAF_CMD_STATUS_CMD_NOT_SUPPORTED`
- `UAF_CMD_STATUS_PARAMS_INVALID`

7. KeyIDs and key handles

This section is non-normative.

There are 4 types of Authenticators defined in this document and due to their specifics they behave differently while processing commands. One of the main differences between them is how they store and process key handles. This section tries to clarify it by describing the behavior of every type of Authenticator during the processing of relevant command.

7.1 first-factor Bound Authenticator

Register Command	Authenticator doesn't store key handles. Instead KeyHandle is always returned to ASM and stored in ASM database. KeyID is a randomly generated 32 bytes number (or simply the hash of the KeyHandle or the public key).
Sign Command	When there is no user session (no cookies, a clear machine) the Server doesn't provide any KeyID (since it doesn't know which KeyIDs to provide). In this scenario the ASM selects all key handles and passes them to Authenticator. During step-up authentication (when there is a user session) Server provides relevant KeyIDs. ASM selects key handles that correspond to provided KeyIDs and pass to Authenticator.
Deregister Command	Since Authenticator doesn't store key handles, then there is nothing to delete inside Authenticator. ASM finds the KeyHandle corresponding to provided KeyID and deletes it.

7.2 2ndF Bound Authenticator

Register Command	Authenticator might not store key handles. Instead the KeyHandle might be returned to the ASM and stored in the ASM database. KeyID is a randomly generated 32 bytes number (or simply the hash of the KeyHandle or the public key).
Sign Command	This Authenticator cannot operate without Server providing KeyIDs. Thus it can't be used when there is no user session (no cookies, a clear machine); unless, for example, the user identifies their account and the server is then able to provide a KeyID. During step-up authentication (when there is a user session) Server provides relevant KeyIDs. ASM selects key handles that correspond to provided KeyIDs and pass to Authenticator.
Deregister Command	If the Authenticator doesn't store key handles, then there is nothing to delete inside it. The ASM finds the KeyHandle corresponding to provided KeyID and deletes it.

7.3 first-factor Roaming Authenticator

Register Command	Authenticator stores key handles inside its internal storage. KeyHandle is never returned back to ASM. KeyID is a randomly generated 32 bytes number (or simply the hash of KeyHandle)
Sign Command	When there is no user session (no cookies, a clear machine) Server doesn't provide any KeyID (since it doesn't know which KeyIDs to provide). In this scenario Authenticator uses all key handles that correspond to the provided AppID. During step-up authentication (when there is a user session) Server provides relevant KeyIDs. Authenticator selects key handles that correspond to provided KeyIDs and uses them.
Deregister Command	Authenticator finds the right KeyHandle and deletes it from its storage.

7.4 2ndF Roaming Authenticator

Register Command	Typically neither the Authenticator nor the ASM store key handles. Instead the KeyHandle is sent to the Server (in place of KeyID) and stored in User's record. From Server's perspective it's a KeyID. In fact the KeyID is identical to the KeyHandle.
Sign Command	This Authenticator cannot operate without Server providing KeyIDs. Thus it can't be used when there is no user session (no cookies, a clear machine). During step-up authentication Server provides KeyIDs which are in fact key handles. Authenticator finds the right KeyHandle and uses it.
Deregister Command	Since Authenticator and ASM don't store key handles, then there is nothing to delete on client side.

8. Access Control for Commands

This section is normative.

FIDO Authenticators MAY implement various mechanisms to guard access to privileged commands.

The following table summarizes the access control requirements for each command.

All UAF Authenticators MUST satisfy the access control requirements defined below.

Authenticator vendors MAY offer additional security mechanisms.

Terms used in the table:

- NoAuth - no access control
- UserVerify - explicit user verification
- KHAccessToken - MUST be known to the caller (or alternative method with similar security level MUST be used)
- KeyHandleList - MUST be known to the caller
- KeyID - MUST be known to the caller

Command	First-factor Bound Authenticator	2ndF Bound Authenticator	First-factor Roaming Authenticator	2ndF Roaming Authenticator
GetInfo	NoAuth	NoAuth	NoAuth	NoAuth
OpenSettings	NoAuth	NoAuth	NoAuth	NoAuth
Register	UserVerify	UserVerify	UserVerify	UserVerify
Sign	UserVerify KHAccessToken KeyHandleList	UserVerify KHAccessToken KeyHandleList	UserVerify KHAccessToken	UserVerify KHAccessToken KeyHandleList
Deregister	KHAccessToken KeyID	KHAccessToken KeyID	KHAccessToken KeyID	KHAccessToken KeyID

Table 1: Access Control for Commands

9. Considerations

This section is non-normative.

9.1 Algorithms and Key Sizes

The proposed algorithms and key sizes are chosen such that compatibility to TPMv2 is possible.

9.2 Indicating the Authenticator Model

Some authenticators (e.g. TPMv2) do not have the ability to include their model identifier (i.e. vendor ID and model name) in attested messages (i.e. the to-be-signed part of the registration assertion). The TPM's endorsement key certificate typically contains that information directly or at least it allows the model to be derived from the endorsement key certificate.

In FIDO, the relying party expects the ability to cryptographically verify the authenticator model (i.e. AAID).

If the authenticator cannot securely include its model (i.e. AAID) in the registration assertion (i.e. in the KRD object), we require the ECDAA-Issuers public key (ipkk) to be dedicated to one single authenticator model (identified by its AAID).

Using this method, the issuer public key is uniquely related to one entry in the Metadata Statement and can be used by the FIDO server to get a cryptographic proof of the Authenticator model.

10. Relationship to other standards

This section is non-normative.

The existing standard specifications most relevant to UAF authenticator are [TPM], [TEE] and [SecureElement].

Hardware modules implementing these standards may be extended to incorporate UAF functionality through their extensibility mechanisms such as by loading secure applications (trustlets, applets, etc) into them. Modules which do not support such extensibility mechanisms cannot be fully leveraged within UAF framework.

10.1 TEE

In order to support UAF inside TEE a special Trustlet (trusted application running inside TEE) may be designed which implements UAF Authenticator functionality specified in this document and also implements some kind of user verification technology (biometric verification, PIN or anything else).

An additional ASM must be created which knows how to work with the Trustlet.

10.2 Secure Elements

In order to support UAF inside Secure Element (SE) a special Applet (trusted application running inside SE) may be designed which implements UAF Authenticator functionality specified in this document and also implements some kind of user verification technology (biometric verification, PIN or similar mechanisms).

An additional ASM must be created which knows how to work the Applet.

10.3 TPM

TPMs typically have a built-in attestation capability however the attestation model supported in TPMs is currently incompatible with UAF's basic attestation model. The future enhancements of UAF may include compatible attestation schemes.

Typically TPMs also have a built-in PIN verification functionality which may be leveraged for UAF. In order to support UAF with an existing TPM module, the vendor should write an ASM which:

- Translates UAF data to TPM data by calling TPM APIs
- Creates assertions using TPMs API
- Reports itself as a valid UAF authenticator to FIDO UAF Client

A special AssertionScheme, designed for TPMs, must be also created (see [FIDOMetadataStatement]) and published by FIDO Alliance. When FIDO Server receives an assertion with this AssertionScheme it will treat the received data as TPM-generated data and will parse/validate it accordingly.

10.4 Unreliable Transports

The command structures described in this document assume a reliable transport and provide no support at the application-layer to detect or correct for issues such as unreliable ordering, duplication, dropping or modification of messages. If the transport layer(s) between the ASM and Authenticator are not reliable, the non-normative private contract between the ASM and Authenticator may need to provide a means to detect and correct such errors.

A. Security Guidelines

This section is non-normative.

Category	Guidelines
AppIDs and KeyIDs	Registered AppIDs and KeyIDs must not be returned by an authenticator in plaintext, without first performing user verification. If an attacker gets physical access to a roaming authenticator, then it should not be easy to read out AppIDs and KeyIDs.

Attestation Private Key	Authenticators must protect the attestation private key as a very sensitive asset. The overall security of the authenticator depends on the protection level of this key. It is highly recommended to store and operate this key inside a tamper-resistant hardware module, e.g. [SecureElement]. It is assumed by registration assertion schemes, that the authenticator has exclusive control over the data being signed with the attestation key. FIDO Authenticators must ensure that the attestation private key: 1. is only used to attest authentication keys generated and protected by the authenticator, using the FIDO-defined data structures, KeyRegistrationData. 2. is never accessible outside the security boundary of the authenticator. Attestation must be implemented in a way such that two different relying parties cannot link registrations, authentications or other transactions (see [UAFProtocol]).
Certifications	Vendors should strive to pass common security standard certifications with authenticators, such as [FIPS140-2], [CommonCriteria] and similar. Passing such certifications will positively impact the UAF implementation of the authenticator.
Cryptographic (Crypto) Kernel	The crypto kernel is a module of the authenticator implementing cryptographic functions (key generation, signing, wrapping, etc) necessary for UAF, and having access to UAuth.priv, Attestation Private Key and Wrap.sym. For optimal security, this module should reside within the same security boundary as the UAuth.priv, Att.priv and Wrap.sym keys. If it resides within a different security boundary, then the implementation must guarantee the same level of security as if they would reside within the same module. It is highly recommended to generate, store and operate this key inside a trusted execution environment [TEE]. In situations where physical attacks and side channel attacks are considered in the threat model, it is highly recommended to use a tamper-resistant hardware module. Software-based authenticators must make sure to use state of the art code protection and obfuscation techniques to protect this module, and whitebox encryption techniques to protect the associated keys. Authenticators need good random number generators using a high quality entropy source, for: 1. generating authentication keys 2. generating signatures 3. computing authenticator-generated challenges The authenticator's random number generator (RNG) should be such that it cannot be disabled or controlled in a way that may cause it to generate predictable outputs. If the authenticator doesn't have sufficient entropy for generating strong random numbers, it should fail safely. See the section of this table regarding random numbers
	It is highly recommended to use authenticated encryption while wrapping key handles with Wrap.sym.

KeyHandle	Algorithms such as AES-GCM and AES-CCM are most suitable for this operation.
Liveness Detection / Presentation Attack Detection	The user verification method should include liveness detection [NSTCBiometrics], i.e. a technique to ensure that the sample submitted is actually from a (live) user. In the case of PIN-based matching, this could be implemented using [TEESecureDisplay] in order to ensure that malware can't emulate PIN entry.
Matcher	By definition, the matcher component is part of the authenticator. This does not impose any restrictions on the authenticator implementation, but implementers need to make sure that there is a proper security boundary binding the matcher and the other parts of the authenticator together. Tampering with the matcher module may have significant security consequences. It is highly recommended for this module to reside within the integrity boundaries of the authenticator, and be capable of detecting tampering. It is highly recommended to run this module inside a trusted execution environment [TEE] or inside a secure element [SecureElement]. Authenticators which have separated matcher and CryptoKernel modules should implement mechanisms which would allow the CryptoKernel to securely receive assertions from the matcher module indicating the user's local verification status. Software based Authenticators (if not in trusted execution environment) must make sure to use state of the art code protection and obfuscation techniques to protect this module. When an Authenticator receives an invalid UserVerificationToken it should treat this as an attack, and invalidate the cached UserVerificationToken. A UserVerificationToken should have a lifetime not exceeding 10 seconds. Authenticators must implement anti-hammering protections for their matchers. Biometrics based authenticators must protect the captured biometrics data (such as fingerprints) as well as the reference data (templates), and make sure that the biometric data never leaves the security boundaries of authenticators. Matchers must only accept verification reference data enrolled by the user, i.e. they must not include any default PINs or default biometric reference data.
Private Keys (UAuth.priv and Attestation Private Key)	This document requires (a) the attestation key to be used for attestation purposes only and (b) the authentication keys to be used for FIDO authentication purposes only. The related to-be-signed objects (i.e. Key Registration Data and SignData) are designed to reduce the likelihood of such attacks: 1. They start with a tag marking them as specific FIDO objects 2. They include an authenticator-generated random value. As a consequence all to-be-signed objects are unique with a very high probability. 3. They have a structure allowing only very few fields containing uncontrolled values, i.e. values which are neither generated nor verified by the authenticator
	The FIDO Authenticator uses its random number generator to generate authentication key pairs, client side challenges, and potentially for creating ECDSA signatures. Weak random numbers will make FIDO vulnerable to certain attacks. It is important for the FIDO Authenticator to work with good random numbers only.

Random Numbers	The (pseudo-)random numbers used by authenticators should successfully pass the randomness test specified in [Coron99] and they should follow the guidelines given in [SP800-90b]. Additionally, authenticators may choose to incorporate entropy provided by the FIDO Server via the `ServerChallenge` sent in requests (see [UAFProtocol]). When mixing multiple entropy sources, a suitable mixing function should be used, such as those described in [RFC4086].
RegCounter	The `RegCounter` provides an anti-fraud signal to the relying parties. Using the `RegCounter`, the relying party can detect authenticators which have been excessively registered. If the `RegCounter` is implemented: ensure that 1. it is increased by any registration operation and 2. it cannot be manipulated/modified otherwise (e.g. via API calls, etc.) A registration counter should be implemented as a global counter, i.e. one covering registrations to all AppIDs. This global counter should be increased by 1 upon any registration operation. Note: The RegCounter value should *not* be decreased by `Deregistration` operations.
SignCounter	When an attacker is able to extract a Uauth.priv key from a registered authenticator, this key can be used independently from the original authenticator. This is considered cloning of an authenticator. Good protection measures of the Uauth private keys is one method to prevent cloning authenticators. In some situations the protection measures might not be sufficient. If the Authenticator maintains a signature counter `SignCounter`, then the FIDO Server would have an additional method to detect cloned authenticators. If the `SignCounter` is implemented: ensure that 1. It is increased by any authentication / transaction confirmation operation and 2. it cannot be manipulated/modified otherwise (e.g. API calls, etc.) Signature counters should be implemented that are dedicated for each private key in order to preserve the user's privacy. A per-key `SignCounter` should be increased by 1, whenever the corresponding UAuth.priv key signs an assertion. A per-key `SignCounter` should be deleted whenever the corresponding UAuth key is deleted. If the authenticator is not able to handle many different signature counters, then a global signature counter covering all private keys should be implemented. A global `SignCounter` should be increased by a random positive integer value whenever any of the UAuth.priv keys is used to sign an assertion. NOTE There are multiple reasons why the `SignCounter` value could be 0 in a registration response. A `SignCounter` value of 0 in an authentication response indicates that the authenticator doesn't support the `SignCounter` concept.
	A transaction confirmation display must ensure that the user is presented with the provided transaction

Transaction Confirmation Display	content, e.g. not overlaid by other display elements and clearly recognizable. See [CLICKJACKING] for some examples of threats and potential counter-measures For more guidelines refer to [TEESecureDisplay].
UAuth.priv	An authenticator must protect all UAuth.priv keys as its **most** sensitive assets. The overall security of the authenticator depends **significantly** on the protection level of these keys. It is highly recommended that this key is generated, stored and operated inside a trusted execution environment. In situations where physical attacks and side channel attacks are considered within the threat model, it is highly recommended to use a tamper-resistant hardware module. FIDO Authenticators must ensure that UAuth.priv keys: 1. are specific to the particular account at one relying party (relying party is identified by an AppID) 2. are generated based on good random numbers with sufficient entropy. The challenge provided by the FIDO Server during registration and authentication operations should be mixed into the entropy pool in order to provide additional entropy. 3. are never directly revealed, i.e. always remain in exclusive control of the FIDO Authenticator 4. are only being used for the defined authentication modes, i.e. 1. authenticating to the application (as identified by the AppID) they have been generated for, or 2. confirming transactions to the application (as identified by AppID) they have been generated for, or 3. are only being used to create the FIDO defined data structures, i.e. KRD, SignData.
Username	A username must not be returned in plaintext in any condition other than the conditions described for the SIGN command. In all other conditions usernames must be stored within a `KeyHandle`.
Verification Reference Data	The verification reference data, such as fingerprint templates or the reference value of a PIN, are by definition part of the authenticator. This does not impose any particular restrictions on the authenticator implementation, but implementers need to make sure that there is a proper security boundary binding all parts of the authenticator together.
Wrap.sym	If the authenticator has a wrapping key (Wrap.sym), then the authenticator must protect this key as its most sensitive asset. The overall security of the authenticator depends on the protection of this key. Wrap.sym key strength must be equal or higher than the strength of secrets stored in a RawKeyHandle. Refer to [SP800-57] and [SP800-38F] publications for more information about choosing the right wrapping algorithm and implementing it correctly. It is highly recommended to generate, store and operate this key inside a trusted execution environment. In situations where physical attacks and side channel attacks are considered in the threat model, it is highly recommended to use a tamper-resistant hardware module. If the authenticator uses Wrap.sym, it must ensure that unwrapping corrupted KeyHandle and unwrapping data which has invalid contents (e.g. KeyHandle from invalid origin) are indistinguishable to the caller.

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FIDO UAF Application API and Transport Binding Specification

FIDO Alliance Proposed Standard 20 October 2020

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The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

Describes APIs and an interoperability profile for client applications to utilize FIDO UAF. This includes methods of communicating with a FIDO UAF Client for both Web platform and Android applications, transport requirements, and an HTTPS interoperability profile for sending FIDO UAF messages to a compatible server.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

The notation base64url refers to "Base 64 Encoding with URL and Filename Safe Alphabet" [RFC4648] *without padding*.

DOM APIs are described using the ECMAScript [ECMA-262] bindings for WebIDL [WebIDL-ED].

Following [WebIDL-ED], dictionary members are optional unless they are explicitly marked as `required`.

WebIDL dictionary members MUST NOT have a value of null.

Unless otherwise specified, if a WebIDL dictionary member is DOMString, it MUST NOT be empty.

Unless otherwise specified, if a WebIDL dictionary member is a List, it MUST NOT be an empty list.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

NOTE

Note: Certain dictionary members need to be present in order to comply with FIDO requirements. Such members are marked in the WebIDL definitions found in this document, as `required`. The keyword `required` has been introduced by [WebIDL-ED], which is a work-in-progress. If you are using a WebIDL parser which implements [WebIDL], then you may remove the keyword `required` from your WebIDL and use other means to ensure those fields are present.

1.1 Key Words

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

2. Overview

This section is non-normative.

The FIDO UAF technology replaces traditional username and password-based authentication solutions for online services, with a stronger and simpler alternative. The core UAF protocol consists of four conceptual conversations between a FIDO UAF Client and FIDO Server: Registration, Authentication, Transaction Confirmation, and Deregistration. As specified in the core protocol, these messages do not have a defined network transport, or describe how application software that a user interfaces with can use UAF. This document describes the API surface that a client application can use to communicate with FIDO UAF Client software, and transport patterns and security requirements for delivering UAF Protocol messages to a remote server.

The reader should also be familiar with the FIDO Glossary of Terms [FIDOGlossary] and the UAF Protocol specification [UAFProtocol].

2.1 Audience

This document is of interest to client-side application authors that wish to utilize FIDO UAF, as well as implementers of web browsers, browser plugins and FIDO clients, in that it describes the API surface they need to expose to application authors.

2.2 Scope

This document describes:

- The local ECMAScript [ECMA-262] API exposed by a FIDO UAF-enabled web browser to client-side web applications.
- The mechanisms and APIs for Android [ANDROID] applications to discover and utilize a shared FIDO UAF Client service.
- The general security requirements for applications initiating and transporting UAF protocol exchanges.
- An interoperability profile for transporting FIDO UAF messages over HTTPS [RFC2818].

The following are out of scope for this document:

- The format and details of the underlying UAF Protocol messages
- APIs for, and any details of interactions between FIDO Server software and the server-side application stack.

NOTE

The goal of describing standard APIs and an interoperability profile for the transport of FIDO UAF messages here is to provide an example of how to develop a FIDO-enabled application and to promote the ease of integrating interoperable layers from different vendors to build a complete FIDO UAF solution. For any given application instance, these particular patterns may not be ideal and are not mandatory. Applications may use alternate transports, bundle UAF Protocol messages with other network data, or discover and utilize alternative APIs as they see fit.

2.3 Architecture

The overall architecture of the UAF protocol and its various operations is described in the FIDO UAF Protocol Specification [UAFProtocol]. The following simplified architecture diagram illustrates the interactions and actors this document is concerned with:

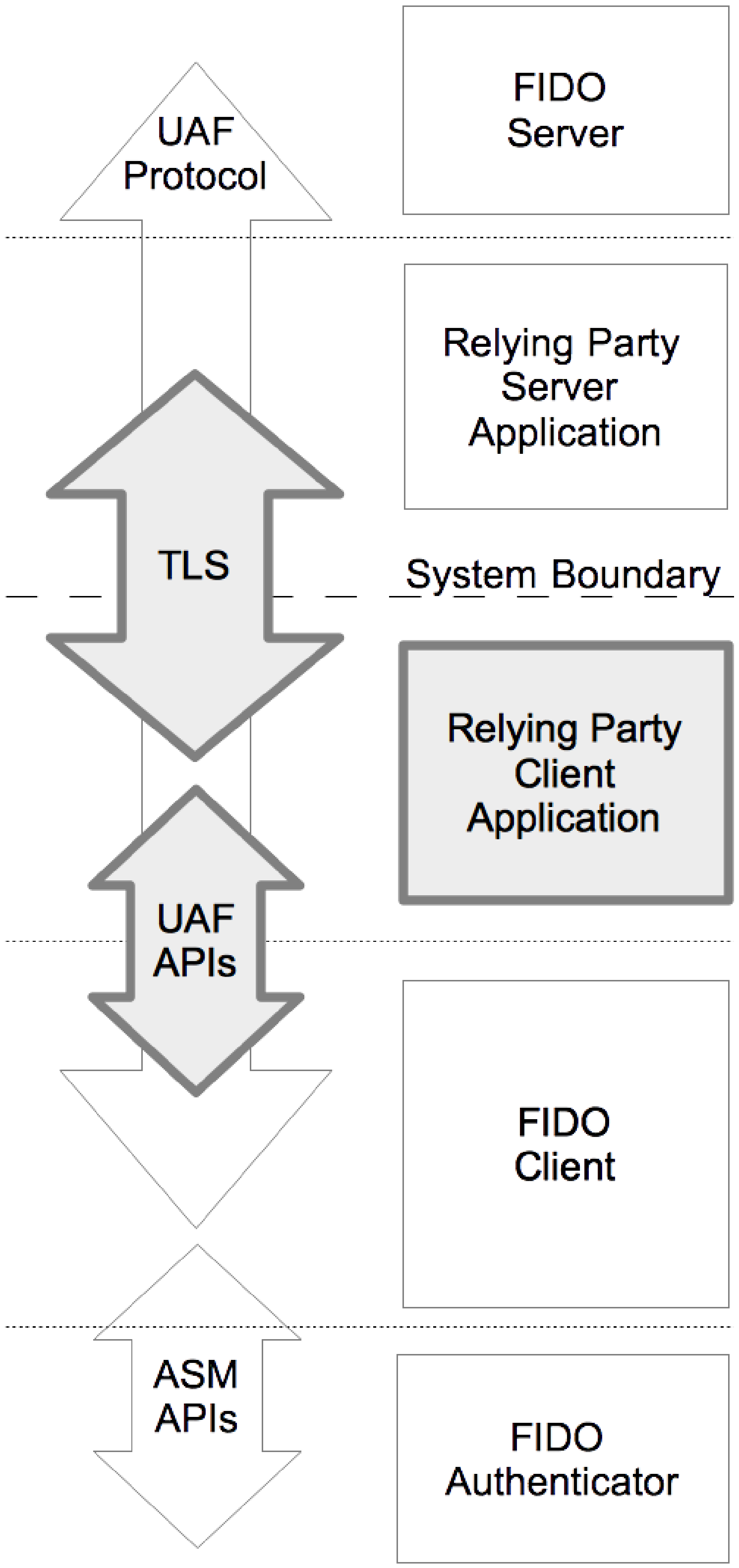

Fig. 1 UAF Application API Architecture and Transport Layers

This document describes the shaded components in Fig 1.

2.3.1 Protocol Conversation

The core UAF protocol consists of five conceptual phases:

- **Discovery** allows the relying party server to determine the availability of FIDO capabilities at the client, including metadata about the available authenticators.

- **Registration** allows the client to generate and associate new key material with an account at the relying party server, subject to policy set by the server and acceptable attestation that the authenticator and registration matches that policy.
- **Authentication** allows a user to provide an account identifier, proof-of-possession of previously registered key material associated with that identifier, and potentially other attested data, to the relying party server.
- **Transaction Confirmation** allows a server to request that a FIDO client and authenticator with the appropriate capabilities display some information to the user, request that the user authenticate locally to their FIDO authenticator to confirm it, and provide proof-of-possession of previously registered key material and an attestation of the confirmation back to the relying party server.
- **Deregistration** allows a relying party server to tell an authenticator to forget selected locally managed key material associated with that relying party in case such keys are no longer considered valid by the relying party.

Discovery does not involve a protocol exchange with the FIDO Server. However, the information available through the discovery APIs might be communicated back to the server in an application-specific manner, such as by obtaining a UAF protocol request message containing an authenticator policy tailored to the specific capabilities of the FIDO user device.

Although the UAF protocol abstractly defines the FIDO server as the initiator of requests, UAF client applications working as described in this document will always transport UAF protocol messages over a client-initiated request/response protocol such as HTTP.

The protocol flow from the point of view of the relying party client application for registration, authentication, and transaction confirmation is as follows:

1. The client application either explicitly contacts the server to obtain a UAF Protocol Request Message, or this message is delivered along with other client application content.
2. The client application invokes the appropriate API to pass the UAF protocol request message asynchronously to the FIDO UAF Client, and receives a set of callbacks.
3. The FIDO UAF Client performs any necessary interactions with the user and authenticator(s) to complete the request and uses a callback to either notify the client application of an error, or to return a UAF response message.
4. The client application delivers the UAF response message to the server over a transport protocol such as HTTP.
5. The server optionally returns an indication of the results of the operation and additional data such as authorization tokens or a redirect.
6. The client application optionally uses the appropriate API to inform the FIDO UAF Client of the results of the operation. This allows the FIDO UAF Client to perform “housekeeping” tasks for a better user experience, e.g. by not attempting to use again later a key that the server refused to register.
7. The client application optionally processes additional data returned to it in an application-specific manner, e.g. processing new authorization tokens, redirecting the user to a new resource or interpreting an error code to determine if and how it should retry a failed operation.

Deregister does not involve a UAF protocol round-trip. If the relying party server instructs the client application to perform a deregistration, the client application simply delivers the UAF protocol Request message to the FIDO UAF Client using the appropriate API. The FIDO UAF Client does not return the results of a deregister operation to the relying party client application or FIDO Server.

UAF protocol Messages are JSON [ECMA-404] structures, but client applications are discouraged from modifying them. These messages may contain embedded cryptographic integrity protections and any modifications might invalidate the messages from the point of view of the FIDO UAF Client or Server.

3. Common Definitions

This section is normative.

These elements are shared by several APIs and layers.

3.1 UAF Status Codes

This table lists UAF protocol status codes.

NOTE
These codes indicate the result of the UAF operation at the FIDO Server. They do not represent the HTTP [RFC7230] layer or other transport layers. These codes are intended for consumption by both the client-side web app and FIDO UAF Client to inform application-specific error reporting, retry and housekeeping behavior.

Code	Meaning
1200	OK. Operation completed
1202	Accepted. Message accepted, but not completed at this time. The RP may need time to process the attestation, run risk scoring, etc. The server SHOULD NOT send an authenticationToken with a 1202 response
1400	Bad Request. The server did not understand the message

1401	Unauthorized. The userid must be authenticated to perform this operation, or this KeyID is not associated with this UserID.
1403	Forbidden. The userid is not allowed to perform this operation. Client SHOULD NOT retry
1404	Not Found.
1408	Request Timeout.
1480	Unknown AAID. The server was unable to locate authoritative metadata for the AAID.
1481	Unknown KeyID. The server was unable to locate a registration for the given UserID and KeyID combination. This error indicates that there is an invalid registration on the user's device. It is recommended that FIDO UAF Client deletes the key from local device when this error is received.
1490	Channel Binding Refused. The server refused to service the request due to a missing or mismatched channel binding(s).
1491	Request Invalid. The server refused to service the request because the request message nonce was unknown, expired or the server has previously serviced a message with the same nonce and user ID.
1492	Unacceptable Authenticator. The authenticator is not acceptable according to the server's policy, for example because the capability registry used by the server reported different capabilities than client-side discovery.
1493	Revoked Authenticator. The authenticator is considered revoked by the server.
1494	Unacceptable Key. The key used is unacceptable. Perhaps it is on a list of known weak keys or uses insecure parameter choices.
1495	Unacceptable Algorithm. The server believes the authenticator to be capable of using a stronger mutually-agreeable algorithm than was presented in the request.
1496	Unacceptable Attestation. The attestation(s) provided were not accepted by the server.
1497	Unacceptable Client Capabilities. The server was unable or unwilling to use required capabilities provided supplementally to the authenticator by the client software.
1498	Unacceptable Content. There was a problem with the contents of the message and the server was unwilling or unable to process it.
1500	Internal Server Error

4. Shared Definitions

This section is normative.

NOTE

This section defines a number of JSON structures, specified with WebIDL [WebIDL-ED]. These structures are shared among APIs for multiple target platforms.

4.1 UAFMessage Dictionary

The UAFMessage dictionary is a wrapper object that contains the raw UAF protocol Message and additional JSON data that may be used to carry application-specific data for use by either the client application or FIDO UAF Client.

WebIDL

```
dictionary UAFMessage {
    required DOMString uafProtocolMessage;
    Object             additionalData;
};
```

4.1.1 Dictionary `UAFMessage` Members

`uafProtocolMessage` of type required DOMString
: This key contains the UAF protocol Message that will be processed by the FIDO UAF Client or Server. Modification by the client application may invalidate the message. A client application MAY examine the contents of a message, for example, to determine if a message is still fresh. Details of the structure of the message can be found in the UAF protocol Specification [UAFProtocol].

`additionalData` of type Object
: This key allows the FIDO Server or client application to attach additional data for use by the FIDO UAF Client as a JSON object, or the FIDO UAF Client or client application to attach additional data for use by the client application.

4.2 Version interface

Describes a version of the UAF protocol or FIDO UAF Client for compatibility checking.

WebIDL

```
interface Version {
    readonly    attribute unsigned short major;
    readonly    attribute unsigned short minor;
};
```

4.2.1 Attributes

`major` of type unsigned short, readonly
Major version number.

`minor` of type unsigned short, readonly
Minor version number.

4.3 Authenticator interface

Used by several phases of UAF, the `Authenticator` interface exposes a subset of both verified metadata [FIDOMetadataStatement] and transient information about the state of an available authenticator.

WebIDL

```
interface Authenticator {
    readonly    attribute DOMString                            title;
    readonly    attribute AAID                                 aaid;
    readonly    attribute DOMString                            description;
    readonly    attribute Version[]                            supportedUAFVersions;
    readonly    attribute DOMString                            assertionScheme;
    readonly    attribute unsigned short                       authenticationAlgorithm;
    readonly    attribute unsigned short[]                     attestationTypes;
    readonly    attribute unsigned long                        userVerification;
    readonly    attribute unsigned short                       keyProtection;
    readonly    attribute unsigned short                       matcherProtection;
    readonly    attribute unsigned long                        attachmentHint;
    readonly    attribute boolean                              isSecondFactorOnly;
    readonly    attribute unsigned short                       tcDisplay;
    readonly    attribute DOMString                            tcDisplayContentType;
    readonly    attribute DisplayPNGCharacteristicsDescriptor[] tcDisplayPNGCharacteristics;
    readonly    attribute DOMString                            icon;
    readonly    attribute DOMString[]                          supportedExtensionIDs;
};
```

4.3.1 Attributes

`title` of type DOMString, readonly
A short, user-friendly name for the authenticator.

> NOTE
>
> This text must be localized for current locale.
>
> If the ASM doesn't return a title in the `AuthenticatorInfo` object [UAFASM], the FIDO UAF Client must generate a title based on the other fields in `AuthenticatorInfo`, because `title` must not be empty (see section 1. Notation).

`aaid` of type AAID, readonly
The *Authenticator Attestation ID*, which identifies the type and batch of the authenticator. See [UAFProtocol] for the definition of the AAID structure.

`description` of type DOMString, readonly
A user-friendly description string for the authenticator.

> NOTE
>
> This text must be localized for current locale.
>
> It is intended to be displayed to the user. It might deviate from the description specified in the authenticator's metadata

statement [FIDOMetadataStatement].

If the ASM doesn't return a description in the `AuthenticatorInfo` object [UAFASM], the FIDO UAF Client must generate a meaningful description to the calling App based on the other fields in `AuthenticatorInfo`, because `description` must not be empty (see section 1. Notation).

`supportedUAFVersions` of type array of *Version*, readonly
Indicates the UAF protocol Versions supported by the authenticator.

`assertionScheme` of type DOMString, readonly

The assertion scheme the authenticator uses for attested data and signatures.

Assertion scheme identifiers are defined in the UAF Registry of Predefined Values. [UAFRegistry]

`authenticationAlgorithm` of type unsigned short, readonly
Supported Authentication Algorithm. The value MUST be related to constants with prefix `ALG_SIGN`.

`attestationTypes` of type array of unsigned short, readonly
A list of supported attestation types. The values are defined in [UAFRegistry] by the constants with the prefix `TAG_ATTESTATION`.

`userVerification` of type unsigned long, readonly
A set of bit flags indicating the user verification methods supported by the authenticator. The algorithm for combining the flags is defined in [UAFProtocol], section 3.1.12.1. The values are defined by the constants with the prefix `USER_VERIFY`.

`keyProtection` of type unsigned short, readonly
A set of bit flags indicating the key protection used by the authenticator. The values are defined by the constants with the prefix `KEY_PROTECTION`.

`matcherProtection` of type unsigned short, readonly
A set of bit flags indicating the matcher protection used by the authenticator. The values are defined by the constants with the prefix `MATCHER_PROTECTION`.

`attachmentHint` of type unsigned long, readonly
A set of bit flags indicating how the authenticator is *currently* connected to the FIDO User Device. The values are defined by the constants with the prefix `ATTACHMENT_HINT`.

NOTE

Because the connection state and topology of an authenticator may be transient, these values are only hints that can be used in applying server-supplied policy to guide the user experience. This can be used to, for example, prefer a device that is connected and ready for authenticating or confirming a low-value transaction, rather than one that is more secure but requires more user effort.

These values are not reflected in authenticator metadata and cannot be relied upon by the relying party, although some models of authenticator may provide attested measurements with similar semantics as part of UAF protocol messages.

`isSecondFactorOnly` of type boolean, readonly
Indicates whether the authenticator can only be used as a second-factor.

`tcDisplay` of type unsigned short, readonly
A set of bit flags indicating the availability and type of transaction confirmation display. The values are defined by the constants with the prefix `TRANSACTION_CONFIRMATION_DISPLAY`.

This value MUST be 0 if transaction confirmation is not supported by the authenticator.

`tcDisplayContentType` of type DOMString, readonly
The MIME content-type [RFC2045] supported by the transaction confirmation display, such as `text/plain` or `image/png`.

This value MUST be non-empty if transaction confirmation is supported (`tcDisplay` is non-zero).

`tcDisplayPNGCharacteristics` of type array of DisplayPNGCharacteristicsDescriptor, readonly
The set of PNG characteristics *currently* supported by the transaction confirmation display (if any).

NOTE

See [FIDOMetadataStatement] for additional information on the format of this field and the definition of the `DisplayPNGCharacteristicsDescriptor` structure.

This list MUST be non-empty if PNG-image based transaction confirmation is supported, i.e. `tcDisplay` is non-zero and `tcDisplayContentType` is `image/png`.

`icon` of type DOMString, readonly
: A PNG [PNG] icon for the authenticator, encoded as a `data:` url [RFC2397].

> NOTE
>
> If the ASM doesn't return an icon in the `AuthenticatorInfo` object [UAFASM], the FIDO UAF Client must set a default icon, because `icon` must not be empty (see section 1. Notation).

`supportedExtensionIDs` of type array of DOMString, readonly
: A list of supported UAF protocol extension identifiers. These MAY be vendor-specific.

4.3.2 Authenticator Interface Constants

A number of constants are defined for use with the bit flag fields `userVerification`, `keyProtection`, `attachmentHint`, and `tcDisplay`. To avoid duplication and inconsistencies, these are defined in the FIDO Registry of Predefined Values [FIDORegistry].

4.4 DiscoveryData dictionary

WebIDL

```
dictionary DiscoveryData {
    required Version[]       supportedUAFVersions;
    required DOMString       clientVendor;
    required Version         clientVersion;
    required Authenticator[] availableAuthenticators;
};
```

4.4.1 Dictionary `DiscoveryData` Members

`supportedUAFVersions` of type array of required Version
: A list of the FIDO UAF protocol versions supported by the client, most-preferred first.

`clientVendor` of type required DOMString
: The vendor of the FIDO UAF Client.

`clientVersion` of type required Version
: The version of the FIDO UAF Client. This is a vendor-specific version for the client software, not a UAF version.

`availableAuthenticators` of type array of required Authenticator
: An array containing Authenticator dictionaries describing the available UAF authenticators. The order is not significant. The list MAY be empty.

4.5 ErrorCode interface

WebIDL

```
interface ErrorCode {
    const short NO_ERROR = 0x0;
    const short WAIT_USER_ACTION = 0x01;
    const short INSECURE_TRANSPORT = 0x02;
    const short USER_CANCELLED = 0x03;
    const short UNSUPPORTED_VERSION = 0x04;
    const short NO_SUITABLE_AUTHENTICATOR = 0x05;
    const short PROTOCOL_ERROR = 0x06;
    const short UNTRUSTED_FACET_ID = 0x07;
    const short KEY_DISAPPEARED_PERMANENTLY = 0x09;
    const short AUTHENTICATOR_ACCESS_DENIED = 0x0c;
    const short INVALID_TRANSACTION_CONTENT = 0x0d;
    const short USER_NOT_RESPONSIVE = 0x0e;
    const short INSUFFICIENT_AUTHENTICATOR_RESOURCES = 0x0f;
    const short USER_LOCKOUT = 0x10;
    const short USER_NOT_ENROLLED = 0x11;
    const short SYSTEM_INTERRUPTED = 0x12;
    const short UNKNOWN = 0xFF;
};
```

4.5.1 Constants

`NO_ERROR` of type short
: The operation completed with no error condition encountered. Upon receipt of this code, an application should no longer expect an associated `UAFResponseCallback` to fire.

`WAIT_USER_ACTION` of type short
: Waiting on user action to proceed. For example, selecting an authenticator in the FIDO client user interface, performing user verification, or completing an enrollment step with an authenticator.

`INSECURE_TRANSPORT` of type short
: `window.location.protocol` is not "https" or the DOM contains insecure mixed content.

`USER_CANCELLED` of type short
: The user declined any necessary part of the interaction to complete the registration.

`UNSUPPORTED_VERSION` of type short
: The `UAFMessage` does not specify a protocol version supported by this FIDO UAF Client.

`NO_SUITABLE_AUTHENTICATOR` of type short
: No authenticator matching the authenticator policy specified in the `UAFMessage` is available to service the request, or the user declined to consent to the use of a suitable authenticator.

`PROTOCOL_ERROR` of type short
: A violation of the UAF protocol occurred. The interaction may have timed out; the origin associated with the message may not match the origin of the calling DOM context, or the protocol message may be malformed or tampered with.

`UNTRUSTED_FACET_ID` of type short
: The client declined to process the operation because the caller's calculated facet identifier was not found in the trusted list for the application identifier specified in the request message.

`KEY_DISAPPEARED_PERMANENTLY` of type short
: The UAuth key disappeared from the authenticator and cannot be restored.

> NOTE
>
> The RP App might want to re-register the authenticator in this case.

`AUTHENTICATOR_ACCESS_DENIED` of type short
: The authenticator denied access to the resulting request.

`INVALID_TRANSACTION_CONTENT` of type short
: Transaction content cannot be rendered, e.g. format doesn't fit authenticator's need.

> NOTE
>
> The transaction content format requirements are specified in the authenticator's metadata statement.

`USER_NOT_RESPONSIVE` of type short
: The user took too long to follow an instruction, e.g. didn't swipe the finger within the accepted time.

`INSUFFICIENT_AUTHENTICATOR_RESOURCES` of type short
: Insufficient resources in the authenticator to perform the requested task.

`USER_LOCKOUT` of type short
: The operation failed because the user is locked out and the authenticator cannot automatically trigger an action to change that. For example, an authenticator could allow the user to enter an alternative password to re-enable the use of fingerprints after too many failed finger verification attempts. This error will be reported if such method either doesn't exist or the ASM / authenticator cannot automatically trigger it.

`USER_NOT_ENROLLED` of type short
: The operation failed because the user is not enrolled to the authenticator and the authenticator cannot automatically trigger user enrollment.

`SYSTEM_INTERRUPTED` of type short
: The system interrupted the operation. Retry might make sense.

`UNKNOWN` of type short

An error condition not described by the above-listed codes.

5. DOM API

This section is normative.

This section describes the API details exposed by a web browser or browser plugin to a client-side web application executing in a `Document` [DOM] context.

5.1 Feature Detection

FIDO's UAF DOM APIs are rooted in a new `fido` object, a property of `window.navigator` code; the existence and properties of which MAY be used for feature detection.

EXAMPLE 1

```
<script>
if(!!window.navigator.fido.uaf) { var useUAF = true; }
</script>
```

5.2 uaf Interface

The `window.navigator.fido.uaf` interface is the primary means of interacting with the FIDO UAF Client. All operations are asynchronous.

WebIDL

```
interface uaf {
    void discover (DiscoveryCallback completionCallback, ErrorCallback errorCallback);
    void checkPolicy (UAFMessage message, ErrorCallback cb);
    void processUAFOperation (UAFMessage message, UAFResponseCallback completionCallback, ErrorCallback errorCallback);
    void notifyUAFResult (int responseCode, UAFMessage uafResponse);
};
```

5.2.1 Methods

`discover`

Discover if the user's client software and devices support UAF and if authenticator capabilities are available that it may be willing to accept for authentication.

Parameter	Type	Nullable	Optional	Description
completionCallback	`DiscoveryCallback`			The callback that receives `DiscoveryData` from the FIDO UAF Client.
errorCallback	`ErrorCallback`			A callback function to receive error and progress events.

Return type: `void`

`checkPolicy`

Ask the browser or browser plugin if it would be able to process the supplied request message without prompting the user.

Unlike other operations using an `ErrorCallback`, this operation MUST always trigger the callback and return `NO_ERROR` if it believes that the message can be processed and a suitable authenticator matching the embedded policy is available, or the appropriate`ErrorCode` value otherwise.

NOTE

Because this call should not prompt the user, it should not incur a potentially disrupting context-switch even if the FIDO UAF Client is implemented out-of-process.

Parameter	Type	Nullable	Optional	Description
message	`UAFMessage`			A `UAFMessage` containing the policy and operation to be tested.
cb	`ErrorCallback`			The callback function which receives the status of the operation.

Return type: `void`

`processUAFOperation`

Invokes the FIDO UAF Client, transferring control to prompt the user as necessary to complete the operation, and returns to the callback a message in one of the supported protocol versions indicated by the UAFMessage.

Parameter	Type	Nullable	Optional	Description
message	`UAFMessage`			The `UAFMessage` to be used by the FIDO client software.
completionCallback	`UAFResponseCallback`			The callback that receives the client response `UAFMessage` from the FIDO UAF Client, to be delivered to the relying party server.
errorCallback	`ErrorCallback`			A callback function to receive error and progress events from the FIDO UAF Client.

Return type: `void`

`notifyUAFResult`

Used to indicate the status code resulting from a FIDO UAF message delivered to the remote server. Applications MUST make this call when they receive a UAF status code from a server. This allows the FIDO UAF Client to perform housekeeping for a better user experience, for example not attempting to use keys that a server refused to register.

NOTE

If, and how, a status code is delivered by the server, is application and transport specific. A non-normative example can be found below in the HTTPS Transport Interoperability Profile.

Parameter	Type	Nullable	Optional	Description
responseCode	`int`			The `uafResult` field of a `ServerResponse`.
uafResponse	`UAFMessage`			The `UAFMessage` to which this `responseCode` applies.

Return type: `void`

5.3 UAFResponseCallback

A `UAFResponseCallback` is used upon successful completion of an asynchronous operation by the FIDO UAF Client to return the protocol response message to the client application for transport to the server.

NOTE

This callback is also called in the case of deregistration completion, even though the response object is empty then.

WebIDL

```
callback UAFResponseCallback = void (UAFMessage uafResponse);
```

5.3.1 Callback `UAFResponseCallback` Parameters

`uafResponse` of type `UAFMessage`

The message and any additional data representing the FIDO UAF Client's response to the server's request message.

5.4 DiscoveryCallback

A `DiscoveryCallback` is used upon successful completion of an asynchronous discover operation by the FIDO UAF Client to return the `DiscoveryData` to the client application.

WebIDL

```
callback DiscoveryCallback = void (DiscoveryData data);
```

5.4.1 Callback `DiscoveryCallback` Parameters

`data` of type `DiscoveryData`

Describes the current state of FIDO UAF client software and authenticators available to the application.

5.5 ErrorCallback

An ErrorCallback is used to return progress and error codes from asynchronous operations performed by the FIDO UAF Client.

WebIDL

```
callback ErrorCallback = void (ErrorCode code);
```

5.5.1 Callback `ErrorCallback` Parameters

`code` of type `ErrorCode`
A value from the `ErrorCode` interface indicating the result of the operation.

For certain operations, an ErrorCallback may be called multiple times, for example with the `WAIT_USER_ACTION` code.

5.6 Privacy Considerations for the DOM API

This section is non-normative.

Differences in the FIDO capabilities on a user device may (among many other characteristics) allow a server to "fingerprint" a remote client and attempt to persistently identify it, even in the absence of any explicit session state maintenance mechanism. Although it may contribute some amount of signal to servers attempting to fingerprint clients, the attributes exposed by the Discovery API are designed to have a large anonymity set size and should present little or no qualitatively new privacy risk. Nonetheless, an unusual configuration of FIDO Authenticators may be sufficient to uniquely identify a user.

It is recommended that user agents expose the Discovery API to all applications without requiring explicit user consent by default, but user agents or FIDO Client implementers should provide users with the means to opt-out of discovery if they wish to do so for privacy reasons.

5.7 Security Considerations for the DOM API

This section is non-normative.

5.7.1 Insecure Mixed Content

When FIDO UAF APIs are called and operations are performed in a `Document` context in a web user agent, such a context MUST NOT contain insecure mixed content. The exact definition insecure mixed content is specific to each user agent, but generally includes any script, plugins and other "active" content, forming part of or with access to the DOM, that was not itself loaded over HTTPS.

The UAF APIs must immediately trigger the `ErrorCallback` with the `INSECURE_TRANSPORT` code and cease any further processing if any APIs defined in this document are invoked by a Document context that was not loaded over a secure transport and/or which contains insecure mixed content.

5.7.2 The Same Origin Policy, HTTP Redirects and Cross-Origin Content

When retrieving or transporting UAF protocol messages over HTTP, it is important to maintain consistency among the web origin of the document context and the origin embedded in the UAF protocol message. Mismatches may cause the protocol to fail or enable attacks against the protocol. Therefore:

FIDO UAF messages should not be transported using methods that opt-out of the Same Origin Policy [SOP], for example, using `<script src="url">` to non-same-origin URLs or by setting the `Access-Control-Allow-Origin` header at the server.

When transporting FIDO UAF messages using XMLHttpRequest [XHR] the client should not follow redirects that are to URLs with a different origin than the requesting document.

FIDO UAF messages should not be exposed in HTTP responses where the entire response body parses as valid ECMAScript. Resources exposed in this manner may be subject to unauthorized interactions by hostile applications hosted at untrusted origins through cross-origin embedding using `<script src="url">`.

Web applications should not share FIDO UAF messages across origins through channels such as `postMessage()` [webmessaging].

5.8 Implementation Notes for Browser/Plugin Authors

This section is non-normative.

Web applications utilizing UAF depend on services from the web browser as a trusted platform. The APIs for web applications do not provide a means to assert an origin as an application identity for the purposes of FIDO operations as this will be provided to the FIDO UAF Client by the browser based on its privileged understanding of the actual origin context.

The browser must enforce that the web origin communicated to the FIDO UAF Client as the application identity is accurate

The browser must also enforce that resource instances containing insecure mixed-content cannot utilize the UAF DOM APIs.

6. Android Intent API

This section is normative.

This section describes how an Android [ANDROID] client application can locate and communicate with a conforming FIDO Client installation operating on the host device.

NOTE

As with web applications, a variety of integration patterns are possible on the Android platform. The API described here allows an app to communicate with a shared FIDO UAF Client on the user device in a loosely-coupled fashion using Android *Intents*.

6.1 Android-specific Definitions

6.1.1 org.fidoalliance.uaf.permissions.FIDO_CLIENT

FIDO UAF Clients running on Android versions prior to Android 5 MUST declare the `org.fidoalliance.uaf.permissions.FIDO_CLIENT` permission and they also MUST declare the related "uses-permission". See the below example of this permission expressed in an Android app manifest file `<permission/>` and `<uses-permission/>` element [AndroidAppManifest].

FIDO UAF Clients running on Android version 5 or later MUST NOT declare this permission and they also MUST NOT declare the related "uses-permission".

EXAMPLE 2

```
<permission
    android:name="org.fidoalliance.uaf.permissions.FIDO_CLIENT"
    android:label="Act as a FIDO Client."
    android:description="This application acts as a FIDO Client. It may
       access authentication devices available on the system, create and
       delete FIDO registrations on behalf of other applications."
    android:protectionLevel="dangerous"
/>
<uses-permission android:name="org.fidoalliance.uaf.permissions.FIDO_CLIENT"/>
```

NOTE

- Since FIDO Clients perform security relevant tasks (e.g. verifying the AppID/FacetID relation and asking for user consent), users should carefully select the FIDO Clients they use. Requiring apps acting as FIDO Clients to declare and use this permission allows them to be identified as such to users.
- There are not any FIDO Client resources needing "protection" based upon the FIDO_CLIENT permission. The reason for having FIDO Client declare the FIDO_CLIENT permission is solely that users should be able to carefully decide which FIDO Clients to install.
- Android version 5 changed the way it handles the case where multiple apps declare the same permission [Android5Changes]; it blocks the installation of all subsequent apps declaring that permission.
- *The best way to flag the fact that an app may act as a FIDO Client needs to be determined for Android version 5.*

6.1.2 org.fidoalliance.uaf.permissions.ACT_AS_WEB_BROWSER

Android applications requesting services from the FIDO UAF Client can do so under their own identity, or they can act as the user's agent by explicitly declaring an RFC6454 [RFC6454] serialization of the remote server's origin when invoking the FIDO UAF Client.

An application that is operating on behalf of a single entity MUST NOT set an explicit origin. Omitting an explicit origin will cause the FIDO UAF Client to determine the caller's identity as `android:apk-key-hash:<hash-of-public-key>`. The FIDO UAF Client will then compare this with the list of authorized application facets for the target AppID and proceed if it is listed as trusted.

NOTE

See the UAF Protocol Specification [UAFProtocol] for more information on application and facet identifiers.

If the application is explicitly intended to operate as the user's agent in the context of an arbitrary number of remote applications (as when implementing a full web browser) it may set its origin to the RFC6454 [RFC6454] Unicode serialization of the remote application's Origin. The application MUST satisfy the necessary conditions described in Transport Security Requirements for authenticating the remote server before setting the origin.

Use of the origin parameter requires the application to declare the `org.fidoalliance.uaf.permissions.ACT_AS_WEB_BROWSER` permission, and the FIDO UAF Client MUST verify that the calling application has this permission before processing the operation.

EXAMPLE 3

```
<permission
   android:name="org.fidoalliance.uaf.permissions.ACT_AS_WEB_BROWSER"
   android:label="Act as a browser for FIDO registrations."
   android:description="This application may act as a web browser,
       creating new and accessing existing FIDO registrations for any domain."
   android:protectionLevel="dangerous"
/>
```

6.1.3 channelBindings

This section is non-normative.

In the DOM API, the browser or browser plugin is responsible for supplying any available channel binding information to the FIDO Client, but an Android application, as the direct owner of the transport channel, must provide this information itself.

The `channelBindings` data structure is:

`Map<String,String>`

with the keys as defined for the `ChannelBinding` structure in the UAF Protocol Specification. [UAFProtocol]

The use of channel bindings for TLS helps assure the server that the channel over which UAF protocol messages are transported is the same channel the legitimate client is using and that messages have not been forwarded through a malicious party.

UAF defines support for the `tls-unique` and `tls-server-end-point` bindings from [RFC5929], as well as server certificate and ChannelID [ChannelID] bindings. The client should supply all channel binding information available to it.

Missing or invalid channel binding information may cause a relying party server to reject a transaction.

6.1.4 UAFIntentType enumeration

This enumeration describes the type of operation for the intent implementing the Android API.

NOTE

UAF uses only a single intent to simplify behavior in the situation even where multiple FIDO clients may be installed. In such a case, the user will be prompted which of the installed FIDO UAF clients should be used to handle an implicit intent.

If the user selected to make different FIDO UAF Clients the default for different intents representing different phases, it could produce inconsistent results or fail to function at all.

If the application workflow requires multiple calls to the client (and it usually does) the application should read the `componentName` from the intent extras it receives from `startActivityForResult()` and pass it to `setComponent()` for subsequent intents to be sure they are explicitly resolved to the same FIDO UAF Client.

WebIDL

```
enum UAFIntentType {
    "DISCOVER",
    "DISCOVER_RESULT",
    "CHECK_POLICY",
    "CHECK_POLICY_RESULT",
    "UAF_OPERATION",
    "UAF_OPERATION_RESULT",
    "UAF_OPERATION_COMPLETION_STATUS"
};
```

Enumeration description	
`DISCOVER`	Discovery
`DISCOVER_RESULT`	Discovery results
`CHECK_POLICY`	Perform a no-op check if a message could be processed.
`CHECK_POLICY_RESULT`	Check Policy results.
`UAF_OPERATION`	Process a Registration, Authentication, Transaction Confirmation or Deregistration message.

`UAF_OPERATION_RESULT`	UAF Operation results.
`UAF_OPERATION_COMPLETION_STATUS`	Inform the FIDO UAF Client of the completion status of a Registration, Authentication, Transaction Confirmation or Deregistration message.

6.2 org.fidoalliance.intent.FIDO_OPERATION Intent

All interactions between a FIDO UAF Client and an application on Android takes place via a single Android intent:

`org.fidoalliance.intent.FIDO_OPERATION`

The specifics of the operation are carried by the MIME media type and various extra data included with the intent.

The operations described in this document are of MIME media type `application/fido.uaf_client+json` and this MUST be set as the `type` attribute of any intent.

NOTE

Client applications can discover if a FIDO UAF Client (or several) is available on the system by using `PackageManager.queryIntentActivities(Intent intent, int flags)` with this intent to see if any activities are available.

Extra	Type	Description
`UAFIntentType`	String	One of the **`UAFIntentType`** enumeration values describing the intent.
`discoveryData`	String	**`DiscoveryData`** JSON dictionary.
`componentName`	String	The component name of the responding FIDO UAF Client. It must be serialized using ComponentName.flattenString()
`errorCode`	short	**`ErrorCode`** value for operation
`message`	String	**`UAFMessage`** request to test or process, depending on **`UAFIntentType`**.
`origin`	String	An RFC6454 Web Origin [RFC6454] string for the request, if the caller has the `org.fidoalliance.permissions.ACT_AS_WEB_BROWSER` permission.
`channelBindings`	String	The JSON dictionary of channel bindings for the operation.
`responseCode`	short	The `uafResult` field of a `ServerResponse`.

The following table shows what intent extras are expected, depending on the value of the `UAFIntentType` extra:

UAFIntentType value	discoveryData	componentName	errorCode	message	origin	channelBindings	responseCode
"DISCOVER"							
"DISCOVER_RESULT"	OPTIONAL	REQUIRED	REQUIRED				
"CHECK_POLICY"				REQUIRED	OPTIONAL		
"CHECK_POLICY_RESULT"		REQUIRED	REQUIRED				
"UAF_OPERATION"				REQUIRED	OPTIONAL	REQUIRED	
"UAF_OPERATION_RESULT"		REQUIRED	REQUIRED	OPTIONAL			
"UAF_OPERATION_COMPLETION_STATUS"				REQUIRED			REQUIRED

6.2.1 UAFIntentType.DISCOVER

This Android intent invokes the FIDO UAF Client to discover the available authenticators and capabilities. The FIDO UAF Client generally will not show a UI associated with the handling of this intent, but immediately return the JSON structure. The calling application cannot depend on this however, as the FIDO UAF Client MAY show a UI for privacy purposes, allowing the user to choose whether and which authenticators to disclose to the calling application.

This intent MUST be invoked with `startActivityForResult()`.

6.2.2 UAFIntentType.DISCOVER_RESULT

An intent with this type is returned by the FIDO UAF Client as an argument to `onActivityResult()` in response to receiving an intent of type `DISCOVER`.

If the `resultCode` passed to `onActivityResult()` is `RESULT_OK`, and the intent extra `errorCode` is `NO_ERROR`, this intent has an extra, `discoveryData`, containing a `String` representation of a **`DiscoveryData`** JSON dictionary with the available authenticators and capabilities.

6.2.3 UAFIntentType.CHECK_POLICY

This intent invokes the FIDO UAF Client to discover if it would be able to process the supplied message without prompting the user. The action handling this intent SHOULD NOT show a UI to the user.

This intent requires the following extras:

- `message`, containing a `String` representation of a **`UAFMessage`** representing the request message to test.
- `origin`, an OPTIONAL extra that allows a caller with the `org.fidoalliance.uaf.permissions.ACT_AS_WEB_BROWSER` permission to supply an RFC6454 Origin [RFC6454] string to be used instead of the application's own identity.

This intent MUST be invoked with `startActivityForResult()`.

6.2.4 UAFIntentType.CHECK_POLICY_RESULT

This Android intent is returned by the FIDO UAF Client as an argument to `onActivityResult()` in response to receiving a `CHECK_POLICY` intent.

In addition to the `resultCode` passed to `onActivityResult()`, this intent has an extra, `errorCode`, containing an **`ErrorCode`** value indicating the specific error condition or `NO_ERROR` if the FIDO UAF Client could process the message.

6.2.5 UAFIntentType.UAF_OPERATION

This Android intent invokes the FIDO UAF Client to process the supplied request message and return a response message ready for delivery to the FIDO UAF Server.

The sender SHOULD assume that the FIDO UAF Client will display a user interface allowing the user to handle this intent, for example, prompting the user to complete their verification ceremony.

This intent requires the following extras:

- `message`, containing a `String` representation of a **`UAFMessage`** representing the request message to process.
- `channelBindings`, containing a `String` representation of a JSON dictionary as defined by the `ChannelBinding` structure in the FIDO UAF Protocol Specification [UAFProtocol].
- `origin`, an OPTIONAL parameter that allows a caller with the `org.fidoalliance.uaf.permissions.ACT_AS_WEB_BROWSER` permission to supply an RFC6454 Origin [RFC6454] string to be used instead of the application's own identity.

This intent MUST be invoked with `startActivityForResult()`.

6.2.6 UAFIntentType.UAF_OPERATION_RESULT

This intent is returned by the FIDO UAF Client as an argument to `onActivityResult()`, in response to receiving a `UAF_OPERATION` intent.

If the `resultCode` passed to `onActivityResult()` is `RESULT_CANCELLED`, this intent will have an extra, `errorCode` parameter, containing an **`ErrorCode`** value indicating the specific error condition.

If the `resultCode` passed to `onActivityResult()` is `RESULT_OK`, and the `errorCode` is `NO_ERROR`, this intent has a `message`, containing a `String` representation of a **`UAFMessage`**, being the UAF protocol response message to be delivered to the FIDO Server.

6.2.7 UAFIntentType.UAF_OPERATION_COMPLETION_STATUS

This intent MUST be delivered to the FIDO UAF Client to indicate the processing status of a FIDO UAF message delivered to the remote server. This is especially important as a new registration may be considered by the client to be in a pending state until it is communicated that the server accepted it.

6.3 Alternate Android AIDL Service UAF Client Implementation

The Android Intent API can also be implemented using Android AIDL services as an alternative transport mechanism to Android Intents. While Android Intents work at the UI layer, Android AIDL services are performed at a lower level. This can ease integration with relying party apps, since UAF requests can be fulfilled without interfering with existing relying party app UI and application lifecycle behavior.

The UAF Android AIDL service needs to be defined in the UAF client manifest. This is done using the `<service>` tag for an Android AIDL service instead of the `<activity>` tag in Android Intents. Just as with Android intents, the manifest definition for the AIDL service uses an intent filter (note `org.fidoalliance.aidl.FIDO_OPERATION` versus `org.fidoalliance.intent.FIDO_OPERATION`) to identify itself as a FIDO UAF client to the relying party app:

EXAMPLE 4

```
<service android:name="foo" >
<intent-filter>
<action android:name="org.fidoalliance.aidl.FIDO_OPERATION" />
<category android:name="android.intent.category.DEFAULT" />
<data android:mimeType="application/fido.uaf_client+json" />
</intent-filter>
</service>
```

Once the relying party app chooses a UAF client from the list discovered by `PackageManager.queryIntentServices()`, the relying party app and the FIDO UAF client share the following AIDL interface to service UAF requests:

EXAMPLE 5

```
package org.fidoalliance.aidl

oneway interface IUAFOperation
{
        void process(in Intent uafRequest, in IUAFResponseListener uafResponseListener);
}
```

NOTE

Android AIDL services use `Binder.getCallingUid()` instead of `Activity.getCallingActivity()` with Android Intents to identify the caller and obtain FacetID information.

For consistency, the Intents for the Android AIDL service are the same as defined in the Android Intent specification in the UAF standard. In `process()`, the `uafRequest` parameter is the Intent that would be passed to `startActivityForResult()`. The `uafResponseListener` parameter is a listener interface that receives the result. The following AIDL defines this interface:

EXAMPLE 6

```
package org.fidoalliance.aidl

interface IUAFResponseListener
{
        void onResult(in Intent uafResponse);
}
```

In the listener, the `uafResponse` parameter is the Intent that would be passed to `onActivityResult`.

6.4 Security Considerations for Android Implementations

This section is non-normative.

Android applications may choose to implement the user-interactive portion of FIDO in at least two ways:

- by authoring an Android Activity using Android-native user interface components, or
- with an HTML-based experience by loading an Android WebView and injecting the UAF DOM APIs with `addJavaScriptInterface()`.

An application that chooses to inject the UAF interface into a WebView MUST follow all appropriate security considerations that apply to usage of the DOM APIs, *and* those that apply to user agent implementers.

In particular, the content of a WebView into which an API will be injected MUST be loaded only from trusted local content or over a secure channel as specified in Transport Security Requirements and must not contain insecure mixed-content.

Applications SHOULD NOT declare the `ACT_AS_WEB_BROWSER` permission unless they need to act as the user's agent for an un-predetermined number of third party applications. Where an Android application has an explicit relationship with a relying party application(s), the preferred method of access control is for those applications to list the Android application's identity as a trusted facet. See the UAF Protocol Specification [UAFProtocol] for more information on application and facet identifiers.

To protect against a malicious application registering itself as a FIDO UAF Client, relying party applications can obtain the identity of the responding application, and utilize it in risk management decisions around the authentication or transaction events.

For example, a relying party might maintain a list of application identities known to belong to malware and refuse to accept operations completed with such clients, or a list of application identities of known-good clients that receive preferred risk-scoring.

Relying party applications running on Android versions prior to Android 5 MUST make sure that a FIDO UAF Client has the "uses-permission" for `org.fidoalliance.uaf.permissions.FIDO_CLIENT`. Relying party applications running on Android 5 SHOULD NOT implement this check.

NOTE

Relying party applications SHOULD implement the check on Android prior to 5 by using the package manager to verify that the FIDO Client indeed declared the `org.fidoalliance.uaf.permissions.FIDO_CLIENT` permission (see example below). Relying party applications SHOULD NOT use a "uses-permission" for `FIDO_CLIENT`.

EXAMPLE 7

```
boolean checkFIDOClientPermission(String packageName)
                                  throws NameNotFoundException {
  for (String requestedPermission :
         getPackageManager().getPackageInfo(packageName,
             PackageManager.GET_PERMISSIONS).requestedPermissions) {
      if (requestedPermission.matches(
           "org.fidoalliance.uaf.permissions.FIDO_CLIENT"))
        return true;
  }
 return false;
}
```

Relying party applications which use the AIDL service implementation of the UAF Client Intent API MUST use an explicit intent to bind to the AIDL service. Failing to do so may result in binding to an unexpected and possibly malicious service, because intent filter resolution depends on application installation order and intent filter priority. Android 5.0 and later will throw a `SecurityException` if an implicit intent is used, but earlier versions do not enforce this behavior.

7. iOS Custom URL API

This section is normative.

This section describes how an iOS relying party application can locate and communicate with a conforming FIDO UAF Client installed on the host device.

NOTE

Because of sandboxing and no true multitasking support, the iOS operating system offers very limited ways to do interprocess communication (IPC).

Any IPC solution for a FIDO UAF Client must be able to:

1. Identify the calling app in order to provide FacetID approval.
2. Allow transition to another app without user intervention

Currently the only IPC method on iOS that satisfies both of these requirements is custom URL handlers.

Custom URL handlers use the iOS operating system to handle URL requests from the sender, launch the receiving app, and then pass the request to the receiving app for processing. By enabling custom URL handlers for two different applications, it is possible to achieve bidirectional IPC between them--one custom URL handler to send data from app A to app B and another custom URL handler to send data from app B to app A.

Because iOS has no true multitasking, there must be an app transition to process each request and response. Too many app transitions can negatively affect the user experience, so relying party applications must carefully choose when it is necessary to query the FIDO UAF Client.

7.1 iOS-specific Definitions

7.1.1 X-Callback-URL Transport

When the relying party application communicates with the FIDO UAF Client, it sends a URL with the standard `x-callback-url` format (see x-callback-url.com):

EXAMPLE 8

```
FidoUAFClient1://x-callback-url/[UAFxRequestType]?x-success=[RelyingPartyURL]://x-callback-url/
        [UAFxResponseType]&
        key=[SecretKey]&
        state=[STATE]&
        json=[Base64URLEncodedJSON]
```

- `FidoUAFClient1` is the iOS custom URL scheme used by FIDO UAF Clients. As specified in the `x-callback-url` standard, version information for the transport layer is encoded in the URL scheme itself (in this case, `FidoUAFClient1`). This is so other applications can check for support for the 1.0 version by using the `canOpenURL` call.
- `[UAFxRequestType]` is the type that should be used for request operations, which are described later in this document.
- `[RelyingPartyURL]` is the URL that the relying party app has registered in order to receive the response. According to the `x-callback-url` standard, this is defined using the `x-success` parameter.
- `[UAFxResponseType]` is the type that should be used for response operations, which are described later in this document.
- `[SecretKey]` is a base64url-encoded, without padding, random key generated for each request by the calling application.

  The response from the FIDO UAF Client will be encrypted with this key in order to prevent rogue applications from obtaining information by spoofing the return URL.

- `[STATE]` is data that can be used to match the request with the response.
- Finally `[Base64URLEncodedJSON]` contains the message to be sent to the FIDO UAF Client.

  Items are stored in JSON format and then base64url-encoded without padding.

For FIDO UAF Clients, the custom URL scheme handler entrypoint is the openURL() function:

Objective-C

EXAMPLE 9

```
(BOOL)application:(UIApplication *)application openURL:(NSURL *)url sourceApplication:(NSString *)sourceApplication
annotation:(id)annotation
```

SWIFT

EXAMPLE 10

```
func application(_ application: UIApplication, open url: URL, sourceApplication: String?, annotation: Any) -> Bool {
    ...
}
```

Here, the URL above is received via the `url` parameter. For security considerations, the `sourceApplication` parameter contains the iOS bundle ID of the relying party application. This bundle ID MUST be used to verify the application `FacetID`.

Conversely, when the FIDO UAF Client responds to the request, it sends the following URL back in standard `x-callback-url` format:

EXAMPLE 11

```
[RelyingPartyURL]://x-callback-url/
      [UAFxResponseType]?
      state=[STATE]&
      json=[Base64URLEncodedJWE]
```

The parameters in the response are similar to those of the request, except that the `[Base64URLEncodedEncryptedJSON]` parameter is encrypted with the public key before being base64url-encoded without padding. `[STATE]` is the same `STATE` as was sent in the request--it is echoed back to the sender to verify the matched response.

In the relying party application's `openURL()` handler, the `url` parameter will be the URL listed above and the `sourceApplication` parameter will be the iOS bundle ID for the FIDO client application.

7.1.2 Secret Key Generation

A new secret encryption key MUST be generated by the calling application every time it sends a request to FIDO UAF Client. The FIDO UAF Client MUST then use this key to encrypt the response message before responding to the caller.

JSON Web Encryption (JWE), JSON Serialization (JWE Section 7.2) format MUST be used to represent the encrypted response message.

The encryption algorithm is that specified in "A128CBC-HS256" where the JWE "Key Management Mode" employed is "Direct Encryption" and the JWE "Content Encryption Key (CEK)" is the secret key generated by the calling application and passed to the FIDO UAF Client in the `key` parameter of the request.

EXAMPLE 12

```
{
    "unprotected": {"alg": "dir", "enc": "A128CBC-HS256"},
    "iv": "...",
    "ciphertext": "...",
    "tag": "..."
}
```

7.1.3 Origin

iOS applications requesting services from the FIDO Client can do so under their own identity, or they can act as the user's agent by explicitly declaring an RFC6454 [RFC6454] serialization of the remote server's origin when invoking the FIDO UAF Client.

An application that is operating on behalf of a single entity MUST NOT set an explicit origin. Omitting an explicit origin will cause the FIDO UAF Client to determine the caller's identity as `"ios:bundle-id"`. The FIDO UAF Client will then compare this with the list of authorized application facets for the target AppID and proceed if it is listed as trusted.

See the UAF Protocol Specification [UAFProtocol] for more information on application and facet identifiers.

If the application is explicitly intended to operate as the user's agent in the context of an arbitrary number of remote applications (as when implementing a full web browser) it may set origin to the RFC6454 [RFC6454] Unicode serialization of the remote application's Origin. The application MUST satisfy the necessary conditions described in Transport Security Requirements for authenticating the remote server before setting origin.

7.1.4 channelBindings

This section is non-normative.

In the DOM API, the browser or browser plugin is responsible for supplying any available channel binding information to the FIDO Client, but an iOS application, as the direct owner of the transport channel, must provide this information itself.

The channelBindings data structure is `Map<String,String>` with the keys as defined for the `ChannelBinding` structure in the FIDO UAF Protocol Specification. [UAFProtocol]

The use of channel bindings for TLS helps assure the server that the channel over which UAF protocol messages are transported is the same channel the legitimate client is using and that messages have not been forwarded through a malicious party. UAF defines support for the `tls-unique` and `tls-server-end-point` bindings from [RFC5929], as well as server certificate and `ChannelID` [ChannelID] bindings. The client should supply all channel binding information available to it.

Missing or invalid channel binding information may cause a relying party server to reject a transaction.

7.1.5 UAFxType

This value describes the type of operation for the `x-callback-url` operations implementing the iOS API.

WebIDL

```
enum UAFxType {
    "DISCOVER",
    "DISCOVER_RESULT",
    "CHECK_POLICY",
    "CHECK_POLICY_RESULT",
    "UAF_OPERATION",
    "UAF_OPERATION_RESULT",
    "UAF_OPERATION_COMPLETION_STATUS"
};
```

Enumeration description	
`DISCOVER`	Discovery
`DISCOVER_RESULT`	Discovery results
`CHECK_POLICY`	Perform a no-op check if a message could be processed.
`CHECK_POLICY_RESULT`	Check Policy results.
`UAF_OPERATION`	The UAF message operation type (for example `Registration`).
`UAF_OPERATION_RESULT`	UAF Operation results.
`UAF_OPERATION_COMPLETION_STATUS`	Inform the FIDO UAF Client of the completion status of a UAF operation (such as `Registration`.

7.2 JSON Values

The specifics of the UAFxType operation are carried by various JSON values encoded in the `json` `x-callback-url` parameter.

JSON value	Type	Description
discoveryData	String	**DiscoveryData** JSON dictionary.
errorCode	short	**ErrorCode** value for operation
message	String	**UAFMessage** request to test or process, depending on **UAFxType**.
origin	String	An RFC6454 Web Origin [RFC6454] string for the request.
channelBindings	String	The channel bindings JSON dictionary for the operation.
responseCode	short	The uafResult field of a ServerResponse.

The following table shows what JSON values are expected, depending on the value of the UAFxType x-callback-url operation:

UAFxType operation	discoveryData	errorCode	message	origin	channelBindings	responseCode
"DISCOVER"						
"DISCOVER_RESULT"	OPTIONAL	REQUIRED				
"CHECK_POLICY"			REQUIRED	OPTIONAL		
"CHECK_POLICY_RESULT"		REQUIRED				
"UAF_OPERATION"			REQUIRED	OPTIONAL	REQUIRED	
"UAF_OPERATION_RESULT"		REQUIRED	OPTIONAL			
"UAF_OPERATION_COMPLETION_STATUS"			REQUIRED			REQUIRED

7.2.1 DISCOVER

This operation invokes the FIDO UAF Client to discover the available authenticators and capabilities. The FIDO UAF Client generally will not show a user interface associated with the handling of this operation, but will simply return the resulting JSON structure.

The calling application cannot depend on this however, as the client MAY show a user interface for privacy purposes, allowing the user to choose whether and which authenticators to disclose to the calling application.

NOTE

iOS custom URL scheme handlers always require an application switch for every request and response, even if no user interface is displayed.

7.2.2 DISCOVER_RESULT

An operation with this type is returned by the FIDO UAF Client in response to receiving an x-callback-url operation of type DISCOVER.

If x-callback-url JSON value errorCode is NO_ERROR, this x-callback-url operation has a JSON value, discoveryData, containing a String representation of a **DiscoveryData** JSON dictionary listing the available authenticators and their capabilities.

7.2.3 CHECK_POLICY

This operation invokes the FIDO UAF Client to discover if the client would be able to process the supplied message, without prompting the user.

The related Action handling this operation SHOULD NOT show an interface to the user.

NOTE

iOS custom URL scheme handlers always require an application switch for every request and response, even if no UI is displayed.

This x-callback-url operation requires the following JSON values:

- message, containing a String representation of a **UAFMessage** representing the request message to test.
- origin, an OPTIONAL JSON value that allows a caller to supply an RFC6454 Origin [RFC6454] string to be used instead of the application's

own identity.

7.2.4 CHECK_POLICY_RESULT

This operation is returned by the FIDO UAF Client in response to receiving a `CHECK_POLICY` x-callback-url operation.

The x-callback-url JSON value `errorCode` containing an **`ErrorCode`** value indicating the specific error condition or `NO_ERROR` if the FIDO Client could process the message.

7.2.5 UAF_OPERATION

This operation invokes the FIDO UAF Client to process the supplied request message and return a result message ready for delivery to the FIDO UAF Server. The sender SHOULD assume that the FIDO UAF Client will display a UI to the user to handle this x-callback-url operation, e.g. prompting the user to complete their verification ceremony.

This x-callback-url operation requires the following JSON values:

- `message`, containing a `String` representation of a **`UAFMessage`** representing the request message to process.
- `channelBindings`, containing a `String` representation of a JSON dictionary as defined by the `ChannelBinding` structure in the UAF Protocol Specification [UAFProtocol].
- `origin`, an OPTIONAL JSON value that allows a caller to supply an RFC6454 Origin [RFC6454] string to be used instead of the application's own identity.

7.2.6 UAF_OPERATION_RESULT

This x-callback-url operation is returned by the FIDO UAF Client in response to receiving a `UAF_OPERATION` x-callback-url operation.

The x-callback-url JSON value `errorCode` containing an **`ErrorCode`**value indicating the specific error condition.

If x-callback-url JSON value `errorCode` is `NO_ERROR`, this x-callback-url operation has a JSON value, `message`, containing a `String` representation of a **`UAFMessage`**, being the UAF protocol response message to be delivered to the FIDO Server.

7.2.7 UAF_OPERATION_COMPLETION_STATUS

This x-callback-url operation MUST be delivered to the FIDO UAF Client to indicate the completion status of a FIDO UAF message delivered to the remote server. This is especially important as, e.g. a new registration may be considered in a pending status until it is known the server accepted it.

7.3 Implementation Guidelines for iOS Implementations

Each iOS Custom URL based request results in a human-noticeable context switch between the App and FIDO UAF Client and vice versa. This will be most noticeable when invoking DISCOVER and CHECK_POLICY requests since typically these requests will be invoked automatically, without user's involvement. Such a context switch impacts the User Experience and therefore it's RECOMMENDED to avoid making these two requests and integrate FIDO without using them.

7.4 Security Considerations for iOS Implementations

This section is non-normative.

A security concern with custom URLs under iOS is that any app can register any custom URL. If multiple applications register the same custom URL, the behavior for handling the URL call in iOS is undefined.

On the FIDO UAF Client side, this issue with custom URL scheme handlers is solved by using the `sourceApplication` parameter which provides the bundle ID of the URL originator. This is effective as long as the device has not been jailbroken and as long as Apple has done due diligence vetting submissions to the app store for malware with faked bundle IDs. The `sourceApplication` parameter can be matched with the FacetID list to ensure that the calling app is approved to use the credentials for the relying party.

On the relying party app side, encryption is used to prevent a rogue app from spoofing the relying party app's response URL. The relying party app generates a random encryption key on every request and sends it to the FIDO client. The FIDO client then encrypts the response to this key. In this manner, only the relying party app can decrypt the response. Even in the event that malware is able to spoof the relying party app's URL and intercept the response, it would not be able to decode it.

To protect against potentially malicious applications registering themselves to handle the FIDO UAF Client custom URL scheme, relying party Applications can obtain the bundle-id of the responding app and utilize it in risk management decisions around the authentication or transaction events. For example, a relying party might maintain a list of bundle-ids known to belong to malware and refuse to accept operations completed with such clients, or a list of bundle-ids of known-good clients that receive preferred risk-scoring.

8. Transport Binding Profile

This section is normative.

This section describes general normative security requirements for how a client application transports FIDO UAF protocol messages, gives specific requirements for Transport Layer Security (TLS), and describes an interoperability profile for using HTTP over TLS [RFC2818] with the FIDO UAF protocol.

8.1 Transport Security Requirements

This section is non-normative.

The UAF protocol contains no inherent means of identifying a relying party server, or for end-to-end protection of UAF protocol messages. To perform a secure UAF protocol exchange, the following abstract requirements apply:

1. The client application must securely authenticate the server endpoint as authorized, from that client's viewpoint, to represent the Web origin [RFC6454] (scheme:host:port tuple) reported to the FIDO UAF Client by the client application. Most typically this will be done by using TLS and verifying the server's certificate is valid, asserts the correct DNS name, and chains up to a root trusted by the client platform. Clients MAY also utilize other means to authenticate a server, such as via a pre-provisioned certificate or key that is distributed with an application, or alternative network authentication protocols such as Kerberos [RFC4120].
2. The transport mechanism for UAF protocol messages must provide confidentiality for the message, to prevent disclosure of their contents to unauthorized third parties. These protections should be cryptographically bound to proof of the server's identity as described above.
3. The transport mechanism for UAF protocol messages must protect the integrity of the message from tampering by unauthorized third parties. These protections should be cryptographically bound to proof of the server's identity in as described above.

8.2 TLS Security Requirements

This section is non-normative.

If using HTTP over TLS ([RFC2246] [RFC4346], [RFC5246] or [TLS13draft02]) to transport an UAF protocol exchange, the following specific requirements apply:

1. If there are any TLS errors, whether "warning" or "fatal" or any other error level with the TLS connection, the HTTP client must terminate the connection without prompting the user. For example, this includes any errors found in certificate validity checking that HTTP clients employ, such as via TLS server identity checking [RFC6125], Certificate Revocation Lists (CRLs) [RFC5280], or via the Online Certificate Status Protocol (OCSP) [RFC2560].
2. Whenever comparisons are made between the presented TLS server identity (as presented during the TLS handshake, typically within the server certificate) and the intended source TLS server identity (e.g., as entered by a user, or embedded in a link), [RFC6125] server identity checking must be employed. The client must terminate the connection without prompting the user upon any error condition.
3. The TLS server certificate must either be provisioned explicitly out-of-band (e.g. packaged with an app as a "pinned certificate") or be trusted by chaining to a root included in the certificate store of the operating system or a major browser by virtue of being currently in compliance with their root store program requirements. The client must terminate the connection without user recourse if there are any error conditions when building the chain of trust.
4. The "anon" and "null" crypto suites are not allowed and insecure cryptographic algorithms in TLS (e.g. MD4, RC4, SHA1) should be avoided (see NIST SP800-131A [SP800-131A]).
5. The client and server should use the latest practicable TLS version.
6. The client should supply, and the server should verify whatever practicable channel binding information is available, including a `ChannelID` [ChannelID] public key, the `tls-unique` and `tls-server-end-point` bindings [RFC5929], and TLS server certificate binding [UAFProtocol]. This information provides protection against certain classes of network attackers and the forwarding of protocol messages, and a server may reject a message that lacks or has channel binding data that does not verify correctly.

8.3 HTTPS Transport Interoperability Profile

This section is normative.

Conforming applications MAY support this profile.

Complex and highly-optimized applications utilizing UAF will often transport UAF protocol messages in-line with other application protocol messages. The profile defined here for transporting UAF protocol messages over HTTPS is intended to:

- Provide an interoperability profile to enable easier composition of client-side application libraries and server-side implementations for FIDO UAF-enabled products from different vendors.
- Provide detailed illustration of specific necessary security properties for the transport layer and HTTP interfaces, especially as they may interact with a browser-hosted application.
- This profile is also utilized in the examples that constitute the appendices of this document. This profile is OPTIONAL to implement. RFC 2119

key words are used in this section to indicate necessary security and other properties for implementations that intend to use this profile to interoperate [RFC2119].

NOTE

Certain FIDO UAF operations, in particular, transaction confirmation, will always require an application-specific implementation. This interoperability profile only provides a skeleton framework suitable for replacing username/password authentication.

8.3.1 Obtaining a UAF Request message

A UAF-enabled web application might typically deliver request messages as part of a response body containing other application content, e.g. in a script block as such:

EXAMPLE 13

```
...

<script type=”application/json”>
{
“initialRequest”: {
// initial request message here
},

“lifetimeMillis”: 60000; // hint: this initial request is valid for 60 seconds
}
</script>

...
```

However, request messages have a limited lifetime, and an installed application cannot be delivered with a request, so client applications generally need the ability to retrieve a fresh request.

When sending a request message over HTTPS with XMLHttpRequest [XHR] or another HTTP API:

1. The URI of the server endpoint, and how it is communicated to the client, is application-specific.
2. The client MUST set the HTTP method to POST. [RFC7231]
3. The client SHOULD set the HTTP “Content-Type” header to `“application/fido+uaf; charset=utf-8”.` [RFC7231]
4. The client SHOULD include `“application/fido+uaf”` as a media type in the HTTP “Accept” header [RFC7231]. Conforming servers MUST accept `“application/fido+uaf”` as media type.
5. The client MAY need to supply additional headers, such as a HTTP Cookie [RFC6265], to demonstrate, in an application-specific manner, their authorization to perform a request.
6. The entire POST body MUST consist entirely of a JSON [ECMA-404] structure described by the `GetUAFRequest` dictionary.
7. The server's response SHOULD set the HTTP “Content-Type” to `“application/fido+uaf; charset=utf-8”`
8. The client SHOULD decode the response byte string as UTF-8 with error handling. [HTML5]
9. The decoded body of the response MUST consist entirely of a JSON structure described by the `ReturnUAFRequest` interface.

8.3.2 Operation enum

Describes the operation type of a FIDO UAF message or request for a message.

WebIDL

```
enum Operation {
    "Reg",
    "Auth",
    "Dereg"
};
```

Enumeration description	
`Reg`	Registration
`Auth`	Authentication or Transaction Confirmation
`Dereg`	Deregistration

8.3.3 GetUAFRequest dictionary

WebIDL

```
dictionary GetUAFRequest {
    Operation op;
    DOMString previousRequest;
    DOMString context;
};
```

8.3.3.1 Dictionary `GetUAFRequest` Members

`op` of type *Operation*
: The type of the UAF request message desired. Allowable string values are defined by the Operation enum. This field is OPTIONAL but MUST be set if the operation is not known to the server through other context, e.g. an operation-specific URL endpoint.

`previousRequest` of type DOMString
: If the application is requesting a new UAF request message because a previous one has expired, this OPTIONAL key can include the previous one to assist the server in locating any state that should be re-associated with a new request message, should one be issued.

`context` of type DOMString
: Any additional contextual information that may be useful or necessary for the server to generate the correct request message. This key is OPTIONAL and the format and nature of this data is application-specific.

8.3.4 ReturnUAFRequest dictionary

WebIDL

```
dictionary ReturnUAFRequest {
    required unsigned long statusCode;
    DOMString              uafRequest;
    Operation              op;
    long                   lifetimeMillis;
};
```

8.3.4.1 Dictionary `ReturnUAFRequest` Members

`statusCode` of type required unsigned long
: The UAF Status Code for the operation (see section 3.1 UAF Status Codes).

`uafRequest` of type DOMString
: The new UAF Request Message, OPTIONAL, if the server decided to issue one.

`op` of type *Operation*
: An OPTIONAL hint to the client of the operation type of the message, useful if the server might return a different type than was requested. For example, a server might return a deregister message if an authentication request referred to a key it no longer considers valid. Allowable string values are defined by the Operation enum.

`lifetimeMillis` of type long
: If the server returned a `uafRequest`, this is an OPTIONAL hint informing the client application of the lifetime of the message in milliseconds.

8.3.5 SendUAFResponse dictionary

WebIDL

```
dictionary SendUAFResponse {
    required DOMString uafResponse;
    DOMString          context;
};
```

8.3.5.1 Dictionary `SendUAFResponse` Members

`uafResponse` of type required DOMString
: The UAF Response Message. It MUST be set to `UAFMessage.uafProtocolMessage` returned by FIDO UAF Client.

`context` of type DOMString
: Any additional contextual information that MAY be useful or necessary for the server to process the response message. This key is OPTIONAL and the format and nature of this data is application-specific.

8.3.6 Delivering a UAF Response

Although it is not the only pattern possible, an asynchronous HTTP request is a useful way of delivering a UAF Response to the remote server for either web applications or standalone applications.

When delivering a response message over HTTPS with XMLHttpRequest [XHR] or another API:

1. The URI of the server endpoint and how it is communicated to the client is application-specific.
2. The client MUST set the HTTP method to POST. [RFC7231]
3. The client MUST set the HTTP "Content-Type" header to `"application/fido+uaf; charset=utf-8"`. [RFC7231]
4. The client SHOULD include `"application/fido+uaf"` as a media type in the HTTP "Accept" header. [RFC7231]
5. The client MAY need to supply additional headers, such as a HTTP Cookie [RFC6265], to demonstrate, in an application-specific manner, their authorization to perform an operation.
6. The entire POST body MUST consist entirely of a JSON [ECMA-404] structure described by the `SendUAFResponse`.
7. The server's response SHOULD set the "Content-Type" to `"application/fido+uaf; charset=utf-8"` and the body of the response MUST consist entirely of a JSON structure described by the `ServerResponse` interface.

8.3.7 ServerResponse Interface

The `ServerResponse` interface represents the completion status and additional application-specific additional data that results from successful processing of a Register, Authenticate, or Transaction Confirmation operation. This message is not formally part of the UAF protocol, but the `statusCode` should be posted to the FIDO UAF Client, for housekeeping, using the `notifyUAFResult()` operation.

WebIDL

```
interface ServerResponse {
    readonly    attribute int       statusCode;
    [Optional]
    readonly    attribute DOMString description;
    [Optional]
    readonly    attribute Token[]   additionalTokens;
    [Optional]
    readonly    attribute DOMString location;
    [Optional]
    readonly    attribute DOMString postData;
    [Optional]
    readonly    attribute DOMString newUAFRequest;
};
```

8.3.7.1 Attributes

`statusCode` of type int, readonly
: The FIDO UAF response status code. Note that this status code describes the result of processing the tunneled UAF operation, not the status code for the outer HTTP transport.

`description` of type DOMString, readonly
: A detailed message describing the status code or providing additional information to the user.

`additionalTokens` of type array of *Token*, readonly
: This key contains new authentication or authorization token(s) for the client that are not natively handled by the HTTP transport. Tokens SHOULD be processed prior to processing of `location`.

`location` of type DOMString, readonly
: If present, indicates to the client web application that it should navigate the Document context to the URI contained on this field after processing any tokens.

`postData` of type DOMString, readonly
: If present in combination with `location`, indicates that the client should POST the contents to the specified location after processing any tokens.

`newUAFRequest` of type DOMString, readonly
: The server may use this to return a new UAF protocol message. This might be used to supply a fresh request to retry an operation in response to a transient failure, to request additional confirmation for a transaction, or to send a deregistration message in response to a permanent failure.

8.3.8 Token interface

NOTE

The UAF Server is not responsible for creating additional tokens returned as part of a UAF response. Such tokens exist to provide a means for the relying party application to update the authentication/authorization state of the client in response to a successful UAF operation. For example, these fields could be used to allow UAF to serve as the initial authentication leg of a federation protocol, but the scope and details of any such federation are outside of the scope of UAF.

WebIDL

```
interface Token {
    readonly    attribute TokenType type;
    readonly    attribute DOMString value;
};
```

8.3.8.1 Attributes

type of type *TokenType*, readonly
The type of the additional authentication / authorization token.

value of type DOMString, readonly
The string value of the additional authentication / authorization token.

8.3.9 TokenType enum

WebIDL

```
enum TokenType {
    "HTTP_COOKIE",
    "OAUTH",
    "OAUTH2",
    "SAML1_1",
    "SAML2",
    "JWT",
    "OPENID_CONNECT"
};
```

Enumeration description	
HTTP_COOKIE	If the user agent is a standard web browser or other HTTP native client with a cookie store, this TokenType SHOULD NOT be used. Cookies should be set directly with the Set-Cookie HTTP header for processing by the user agent. For non-HTTP or non-browser contexts this indicates a token intended to be set as an HTTP cookie. [RFC6265] For example, a native VPN client that authenticates with UAF might use this TokenType to automatically add a cookie to the browser cookie jar.
OAUTH	Indicates that the token is of type OAUTH. [RFC5849].
OAUTH2	Indicates that the token is of type OAUTH2. [RFC6749].
SAML1_1	Indicates that the token is of type SAML 1.1. [SAML11].
SAML2	Indicates that the token is of type SAML 2.0. [SAML2-CORE]
JWT	Indicates that the token is of type JSON Web Token (JWT). [JWT]
OPENID_CONNECT	Indicates that the token is an OpenID Connect “id_token”. [OpenIDConnect]

8.3.10 Security Considerations

This section is non-normative.

It is important that the client set, and the server require, the method be POST and the “Content-Type” HTTP header be the correct values. Because the response body is valid ECMAScript, to protect against unauthorized cross-origin access, a server must not respond to the type of request that can be generated by a script tag, e.g. `<script src=”https://example.com/fido/uaf/getRequest”>`. The request a user agent generates with this kind of embedding cannot set custom headers.

Likewise, by requiring a custom “Content-Type” header, cross-origin requests cannot be made with an XMLHttpRequest [XHR] without triggering a CORS preflight access check. [CORS]

As FIDO UAF messages are only valid when used same-origin, servers should not supply an “Access-Control-Allow-Origin” [CORS] header with responses that would allow them to be read by non-same-origin content.

To protect from some classes of cross-origin, browser-based, distributed denial-of-service attacks, request endpoints should ignore, without performing additional processing, all requests with an “Access-Control-Request-Method” [CORS] HTTP header or an incorrect “Content-Type” HTTP header.

If a server chooses to respond to requests made with the GET method and without the custom “Content-Type” header, it should apply a prefix string such as “`while(1);`” or “`&&&BEGIN_UAF_RESPONSE&&&`” to the body of all replies and so prevent their being read through cross-origin <script>

tag embedding. Legitimate same-origin callers will need to (and alone be able to) strip this prefix string before parsing the JSON content.

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FIDO UAF Architectural Overview

FIDO Alliance Proposed Standard 20 October 2020

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John Kemp, FIDO Alliance
Jeff Hodges, PayPal, Inc.

The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

The FIDO UAF strong authentication framework enables online services and websites, whether on the open Internet or within enterprises, to transparently leverage native security features of end-user computing devices for strong user authentication and to reduce the problems associated with creating and remembering many online credentials. The FIDO UAF Reference Architecture describes the components, protocols, and interfaces that make up the FIDO UAF strong authentication ecosystem.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Introduction

This section is non-normative.

This document describes the FIDO Universal Authentication Framework (UAF) Reference Architecture. The target audience for this document is decision makers and technical architects who need a high-level understanding of the FIDO UAF strong authentication solution and its relationship to other relevant industry standards.

The FIDO UAF specifications are as follows:

- FIDO UAF Protocol
- FIDO UAF Application API and Transport Binding
- FIDO UAF Authenticator Commands
- FIDO UAF Authenticator-Specific Module API
- FIDO UAF Registry of Predefined Values
- FIDO UAF APDU

The following additional FIDO documents provide important information relevant to the UAF specifications:

- FIDO AppID and Facets Specification
- FIDO Metadata Statements
- FIDO Metadata Service
- FIDO Registry of Predefined Values
- FIDO ECDAA Algorithm
- FIDO Security Reference
- FIDO Glossary

These documents may all be found on the FIDO Alliance website at http://fidoalliance.org/specifications/download/

1.1 Background

This section is non-normative.

The FIDO Alliance mission is to change the nature of online strong authentication by:

- Developing technical specifications defining open, scalable, interoperable mechanisms that supplant reliance on passwords to securely

authenticate users of online services.
- Operating industry programs to help ensure successful worldwide adoption of the specifications.
- Submitting mature technical specifications to recognized standards development organization(s) for formal standardization.

The core ideas driving the FIDO Alliance's efforts are 1) ease of use, 2) privacy and security, and 3) standardization. The primary objective is to enable online services and websites, whether on the open Internet or within enterprises, to leverage native security features of end-user computing devices for strong user authentication and to reduce the problems associated with creating and remembering many online credentials.

There are two key protocols included in the FIDO architecture that cater to two basic options for user experience when dealing with Internet services. The two protocols share many of underpinnings but are tuned to the specific intended use cases.

Universal Authentication Framework (UAF) Protocol

The UAF protocol allows online services to offer password-less and multi-factor security. The user registers their device to the online service by selecting a local authentication mechanism such as swiping a finger, looking at the camera, speaking into the mic, entering a PIN, etc. The UAF protocol allows the service to select which mechanisms are presented to the user.

Once registered, the user simply repeats the local authentication action whenever they need to authenticate to the service. The user no longer needs to enter their password when authenticating from that device. UAF also allows experiences that combine multiple authentication mechanisms such as fingerprint + PIN.

This document that you are reading describes the UAF reference architecture.

Universal 2nd Factor (U2F) Protocol

The U2F protocol allows online services to augment the security of their existing password infrastructure by adding a strong second factor to user login. The user logs in with a username and password as before. The service can also prompt the user to present a second factor device at any time it chooses. The strong second factor allows the service to simplify its passwords (e.g. 4-digit PIN) without compromising security.

During registration and authentication, the user presents the second factor by simply pressing a button on a USB device or tapping over NFC. The user can use their FIDO U2F device across all online services that support the protocol leveraging built-in support in web browsers.

Please refer to the FIDO website for an overview and documentation set focused on the U2F protocol.

1.2 FIDO UAF Documentation

This section is non-normative.

To understand the FIDO UAF protocol, it is recommended that new audiences start by reading this architecture overview document and become familiar with the technical terminology used in the specifications (the glossary). Then they should proceed to the individual UAF documents in the recommended order listed below.

- **FIDO UAF Overview**: This document. Provides an introduction to the FIDO UAF architecture, protocols, and specifications.
- **FIDO Technical Glossary**: Defines the technical terms and phrases used in FIDO Alliance specifications and documents.
- **Universal Authentication Framework (UAF)**
  - **UAF Protocol Specification** : Message formats and processing rules for all UAF protocol messages.
  - **UAF Application API and Transport Binding Specification**: APIs and interoperability profile for client applications to utilize FIDO UAF.
  - **UAF Authenticator Commands**: Low-level functionality that UAF Authenticators should implement to support the UAF protocol.
  - **UAF Authenticator-specific Module API**: Authenticator-specific Module API provided by an ASM to the FIDO client.
  - **UAF Registry of Predefined Values**: defines all the strings and constants reserved by UAF protocols.
  - **UAF APDU**: defines a mapping of FIDO UAF Authenticator commands to Application Protocol Data Units (APDUs).
- **FIDO AppID and Facet Specification** : Scope of user credentials and how a trusted computing base which supports application isolation may make access control decisions about which keys can be used by which applications and web origins.
- **FIDO Metadata Statements**: Information describing form factors, characteristics, and capabilities of FIDO Authenticators used to inform interactions with and make policy decisions about the authenticators.
- **FIDO Metadata Service** : Baseline method for relying parties to access the latest Metadata statements.
- **FIDO ECDAA Algorithm** : Defines the direct anonymous attestation algorithm for FIDO Authenticators.
- **FIDO Registry of Predefined Values**: defines all the strings and constants reserved by FIDO protocols with relevance to multiple FIDO protocol families.
- **FIDO Security Reference**: Provides an analysis of FIDO security based on detailed analysis of security threats pertinent to the FIDO protocols based on its goals, assumptions, and inherent security measures.

The remainder of this Overview section of the reference architecture document introduces the key drivers, goals, and principles which inform the design of FIDO UAF.

Following the Overview, this document describes:

- A high-level look at the components, protocols, and APIs defined by the architecture
- The main FIDO UAF use cases and the protocol message flows required to implement them.
- The relationship of the FIDO protocols to other relevant industry standards.

1.3 FIDO UAF Goals

This section is non-normative.

In order to address today's strong authentication issues and develop a smoothly-functioning low-friction ecosystem, a comprehensive, open, multi-vendor solution architecture is needed that encompasses:

- User devices, whether personally acquired, enterprise-issued, or enterprise BYOD, and the device's potential operating environment, e.g. home, office, in the field, etc.
- Authenticators[1]
- Relying party applications and their deployment environments
- Meeting the needs of both end users and Relying Parties
- Strong focus on both browser- and native-app-based end-user experience

This solution architecture must feature:

- FIDO UAF Authenticator discovery, attestation, and provisioning
- Cross-platform strong authentication protocols leveraging FIDO UAF Authenticators
- A uniform cross-platform authenticator API
- Simple mechanisms for Relying Party integration

The FIDO Alliance envisions an open, multi-vendor, cross-platform reference architecture with these goals:

- **Support strong, multi-factor authentication**: Protect Relying Parties against unauthorized access by supporting end user authentication using two or more strong authentication factors ("something you know", "something you have", "something you are").
- **Build on, but not require, existing device capabilities**: Facilitate user authentication using built-in platform authenticators or capabilities (fingerprint sensors, cameras, microphones, embedded TPM hardware), but do not preclude the use of discrete additional authenticators.
- **Enable selection of the authentication mechanism**: Facilitate Relying Party and user choice amongst supported authentication mechanisms in order to mitigate risks for their particular use cases.
- **Simplify integration of new authentication capabilities**: Enable organizations to expand their use of strong authentication to address new use cases, leverage new device's capabilities, and address new risks with a single authentication approach.
- **Incorporate extensibility for future refinements and innovations**: Design extensible protocols and APIs in order to support the future emergence of additional types of authenticators, authentication methods, and authentication protocols, while maintaining reasonable backwards compatibility.
- **Leverage existing open standards where possible, openly innovate and extend where not**: An open, standardized, royalty-free specification suite will enable the establishment of a virtuous-circle ecosystem, and decrease the risk, complexity, and costs associated with deploying strong authentication. Existing gaps -- notably uniform authenticator provisioning and attestation, a uniform cross-platform authenticator API, as well as a flexible strong authentication challenge-response protocol leveraging the user's authenticators will be addressed.
- **Complement existing single sign-on, federation initiatives**: While industry initiatives (such as OpenID, OAuth, SAML, and others) have created mechanisms to reduce the reliance on passwords through single sign-on or federation technologies, they do not directly address the need for an initial strong authentication interaction between end users and Relying Parties.
- **Preserve the privacy of the end user**: Provide the user control over the sharing of device capability information with Relying Parties, and mitigate the potential for collusion amongst Relying Parties.
- **Unify end-User Experience**: Create easy, fun, and unified end-user experiences across all platforms and across similar Authenticators.

2. FIDO UAF High-Level Architecture

This section is non-normative.

The FIDO UAF Architecture is designed to meet the FIDO goals and yield the desired ecosystem benefits. It accomplishes this by filling in the status-quo's gaps using standardized protocols and APIs.

The following diagram summarizes the reference architecture and how its components relate to typical user devices and Relying Parties.

The FIDO-specific components of the reference architecture are described below.

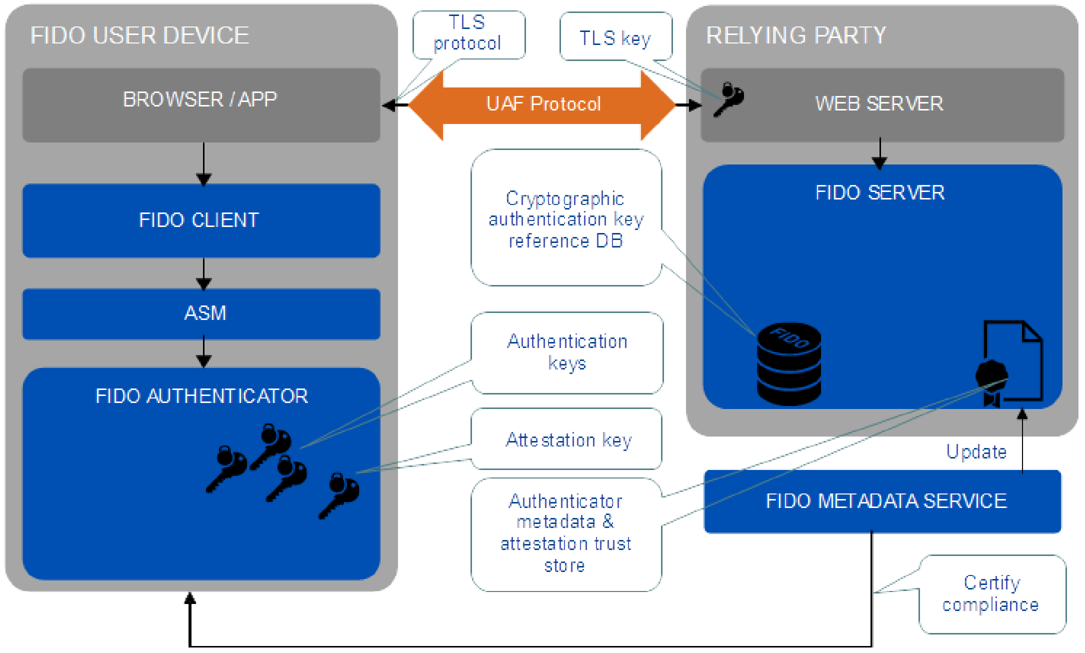

Fig. 1 FIDO UAF High-Level Architecture

2.1 FIDO UAF Client

A FIDO UAF Client implements the client side of the FIDO UAF protocols, and is responsible for:

- Interacting with specific FIDO UAF Authenticators using the FIDO UAF Authenticator Abstraction layer via the FIDO UAF Authenticator API.
- Interacting with a user agent on the device (e.g. a mobile app, browser) using user agent-specific interfaces to communicate with the FIDO UAF Server. For example, a FIDO-specific browser plugin would use existing browser plugin interfaces or a mobile app may use a FIDO-specific SDK. The user agent is then responsible for communicating FIDO UAF messages to a FIDO UAF Server at a Relying Party.

The FIDO UAF architecture ensures that FIDO client software can be implemented across a range of system types, operating systems, and Web browsers. While FIDO client software is typically platform-specific, the interactions between the components should ensure a consistent user experience from platform to platform.

2.2 FIDO UAF Server

A FIDO UAF server implements the server side of the FIDO UAF protocols and is responsible for:

- Interacting with the Relying Party web server to communicate FIDO UAF protocol messages to a FIDO UAF Client via a device user agent.
- Validating FIDO UAF authenticator attestations against the configured authenticator metadata to ensure only trusted authenticators are registered for use.
- Manage the association of registered FIDO UAF Authenticators to user accounts at the Relying Party.
- Evaluating user authentication and transaction confirmation responses to determine their validity.

The FIDO UAF server is conceived as being deployable as an on-premise server by Relying Parties or as being outsourced to a FIDO-enabled third-party service provider.

2.3 FIDO UAF Protocols

The FIDO UAF protocols carry FIDO UAF messages between user devices and Relying Parties. There are protocol messages addressing:

- Authenticator Registration: The FIDO UAF registration protocol enables Relying Parties to:
    - Discover the FIDO UAF Authenticators available on a user's system or device. Discovery will convey FIDO UAF Authenticator attributes to the Relying Party thus enabling policy decisions and enforcement to take place.
    - Verify attestation assertions made by the FIDO UAF Authenticators to ensure the authenticator is authentic and trusted. Verification occurs using the attestation public key certificates distributed via authenticator metadata.
    - Register the authenticator and associate it with the user's account at the Relying Party. Once an authenticator attestation has been validated, the Relying Party can provide a unique secure identifier that is specific to the Relying Party and the FIDO UAF Authenticator. This identifier can be used in future interactions between the pair {RP, Authenticator} and is not known to any other devices.
- User Authentication: Authentication is typically based on cryptographic challenge-response authentication protocols and will facilitate user choice regarding which FIDO UAF Authenticators are employed in an authentication event.
- Secure Transaction Confirmation: If the user authenticator includes the capability to do so, a Relying Party can present the user with a

secure message for confirmation. The message content is determined by the Relying Party and could be used in a variety of contexts such as confirming a financial transaction, a user agreement ,or releasing patient records.

- Authenticator Deregistration: Deregistration is typically required when the user account is removed at the Relying Party. The Relying Party can trigger the deregistration by requesting the Authenticator to delete the associated UAF credential with the user account.

2.4 FIDO UAF Authenticator Abstraction Layer

The FIDO UAF Authenticator Abstraction Layer provides a uniform API to FIDO Clients enabling the use of authenticator-based cryptographic services for FIDO-supported operations. It provides a uniform lower-layer "authenticator plugin" API facilitating the deployment of multi-vendor FIDO UAF Authenticators and their requisite drivers.

2.5 FIDO UAF Authenticator

A FIDO UAF Authenticator is a secure entity, connected to or housed within FIDO user devices, that can create key material associated to a Relying Party. The key can then be used to participate in FIDO UAF strong authentication protocols. For example, the FIDO UAF Authenticator can provide a response to a cryptographic challenge using the key material thus authenticating itself to the Relying Party.

In order to meet the goal of simplifying integration of trusted authentication capabilities, a FIDO UAF Authenticator will be able to attest to its particular type (e.g., biometric) and capabilities (e.g., supported crypto algorithms), as well as to its provenance. This provides a Relying Party with a high degree of confidence that the user being authenticated is indeed the user that originally registered with the site.

2.6 FIDO UAF Authenticator Metadata Validation

In the FIDO UAF context, attestation is how Authenticators make claims to a Relying Party during registration that the keys they generate, and/or certain measurements they report, originate from genuine devices with certified characteristics. An attestation signature, carried in a FIDO UAF registration protocol message is validated by the FIDO UAF Server. FIDO UAF Authenticators are created with attestation private keys used to create the signatures and the FIDO UAF Server validates the signature using that authenticator's attestation public key certificate located in the authenticator metadata. The metadata holding attestation certificates is shared with FIDO UAF Servers out of band.

3. FIDO UAF Usage Scenarios and Protocol Message Flows

This section is non-normative.

The FIDO UAF ecosystem supports the use cases briefly described in this section.

3.1 FIDO UAF Authenticator Acquisition and User Enrollment

It is expected that users will acquire FIDO UAF Authenticators in various ways: they purchase a new system that comes with embedded FIDO UAF Authenticator capability; they purchase a device with an embedded FIDO UAF Authenticator, or they are given a FIDO Authenticator by their employer or some other institution such as their bank.

After receiving a FIDO UAF Authenticator, the user must go through an authenticator-specific enrollment process, which is outside the scope of the FIDO UAF protocols. For example, in the case of a fingerprint sensing authenticator, the user must register their fingerprint(s) with the authenticator. Once enrollment is complete, the FIDO UAF Authenticator is ready for registration with FIDO UAF enabled online services and websites.

3.2 Authenticator Registration

Given the FIDO UAF architecture, a Relying Party is able to transparently detect when a user begins interacting with them while possessing an initialized FIDO UAF Authenticator. In this initial introduction phase, the website will prompt the user regarding any detected FIDO UAF Authenticator(s), giving the user options regarding registering it with the website or not.

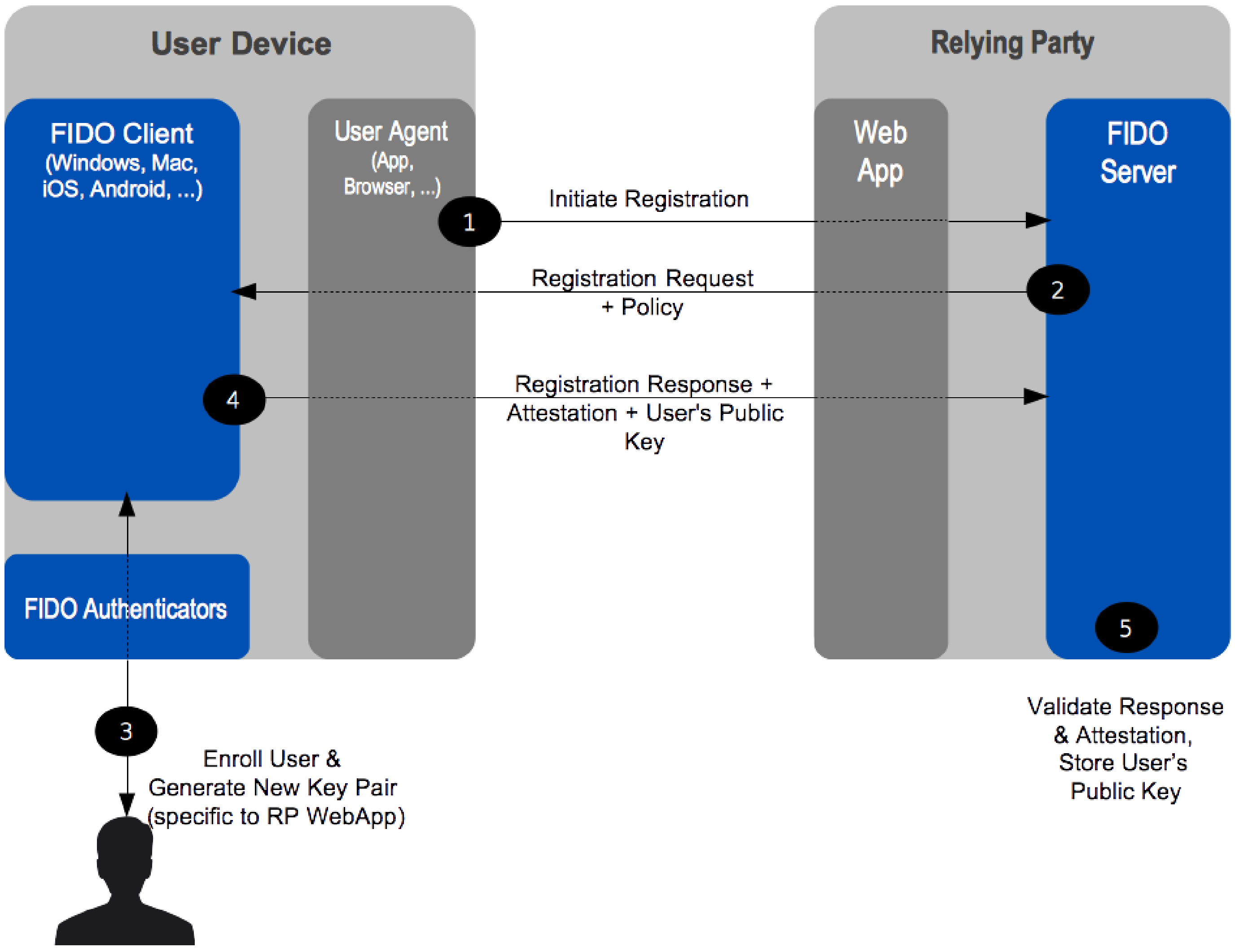
User Device
FIDO Client
(Windows, Mac, iOS, Android, ...)
User Agent
(App, Browser, ...)
Relying Party
Web App
FIDO Server
1
Initiate Registration
Registration Request + Policy
2
4
Registration Response + Attestation + User's Public Key
FIDO Authenticators
5
3
Enroll User & Generate New Key Pair (specific to RP WebApp)
Validate Response & Attestation, Store User's Public Key

Fig. 2 Registration Message Flow

3.3 Authentication

Following registration, the FIDO UAF Authenticator will be subsequently employed whenever the user authenticates with the website (and the authenticator is present). The website can implement various fallback strategies for those occasions when the FIDO Authenticator is not present. These might range from allowing conventional login with diminished privileges to disallowing login.

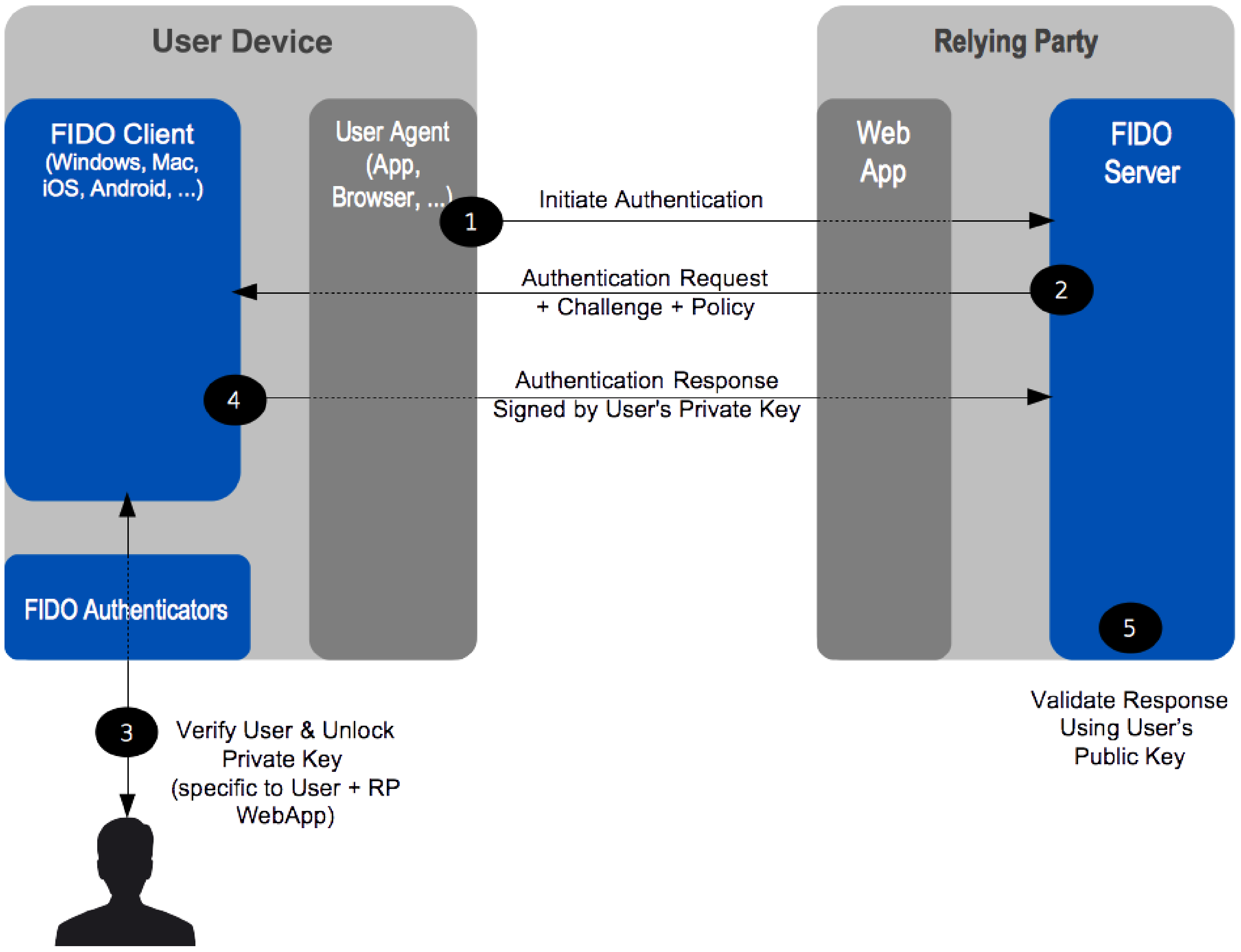
User Device
FIDO Client (Windows, Mac, iOS, Android, ...)
User Agent (App, Browser, ...)
FIDO Authenticators
Relying Party
Web App
FIDO Server
1
Initiate Authentication
2
Authentication Request + Challenge + Policy
3
Verify User & Unlock Private Key (specific to User + RP WebApp)
4
Authentication Response Signed by User's Private Key
5
Validate Response Using User's Public Key

Fig. 3 Authentication Message Flow

This overall scenario will vary slightly depending upon the type of FIDO UAF Authenticator being employed. Some authenticators may sample biometric data such as a face image, fingerprint, or voice print. Others will require a PIN or local authenticator-specific passphrase entry. Still others may simply be a hardware bearer authenticator. Note that it is permissible for a FIDO Client to interact with external services as part of the authentication of the user to the authenticator as long as the FIDO Privacy Principles are adhered to.

3.4 Step-up Authentication

Step-up authentication is an embellishment to the basic website login use case. Often, online services and websites allow unauthenticated, and/or only nominally authenticated use -- for informational browsing, for example. However, once users request more valuable interactions, such as entering a members-only area, the website may request further higher-assurance authentication. This could proceed in several steps if the user then wishes to purchase something, with higher-assurance steps with increasing transaction value.

FIDO UAF will smoothly facilitate this interaction style since the website will be able to discover which FIDO UAF Authenticators are available on FIDO-wielding users' systems, and select incorporation of the appropriate one(s) in any particular authentication interaction. Thus online services and websites will be able to dynamically tailor initial, as well as step-up authentication interactions according to what the user is able to wield and the needed inputs to website's risk analysis engine given the interaction the user has requested.

3.5 Transaction Confirmation

There are various innovative use cases possible given FIDO UAF-enabled Relying Parties with end-users wielding FIDO UAF Authenticators. Website login and step-up authentication are relatively simple examples. A somewhat more advanced use case is secure transaction processing.

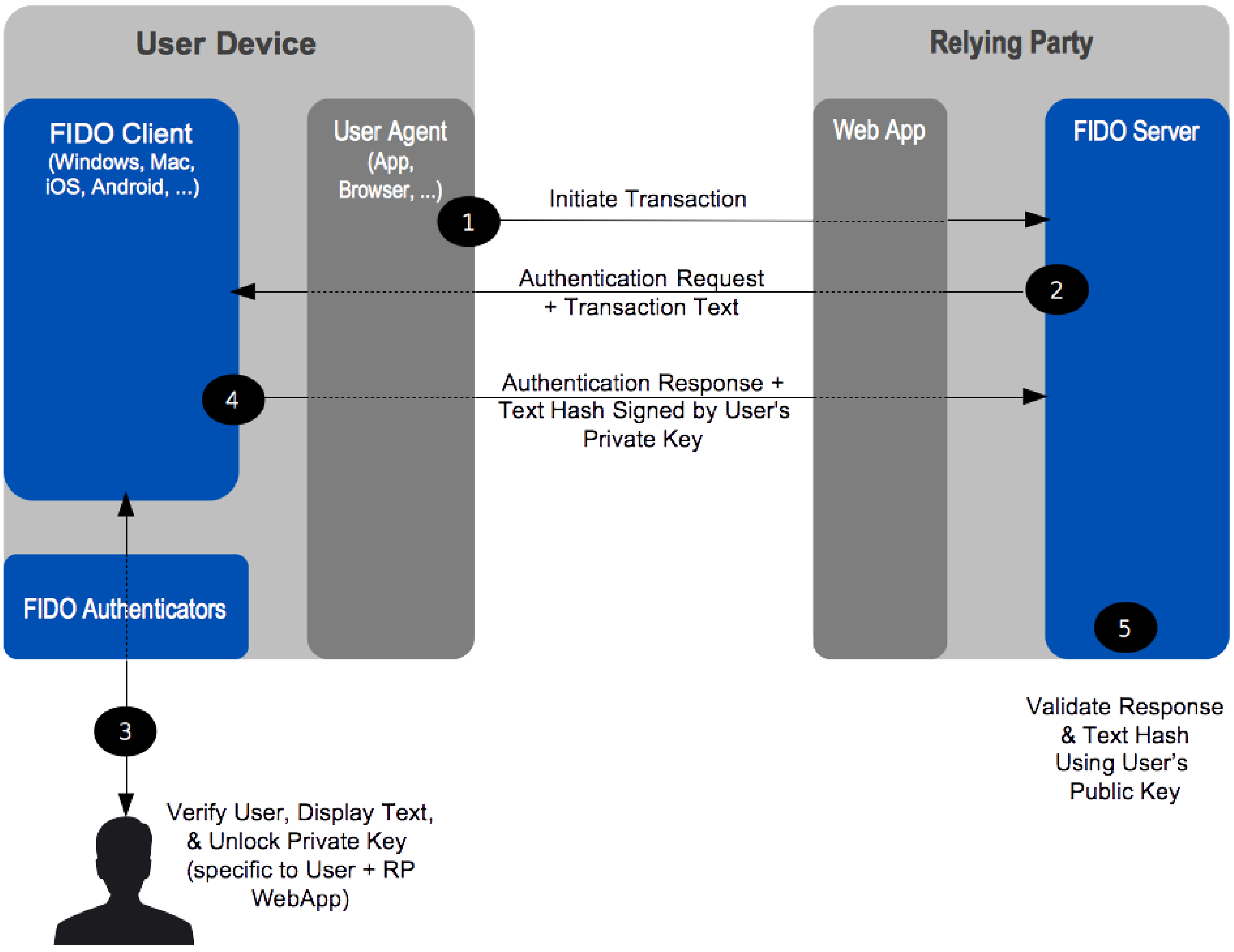
User Device
FIDO Client
(Windows, Mac, iOS, Android, ...)
User Agent
(App, Browser, ...)
Relying Party
Web App
FIDO Server
1
Initiate Transaction
2
Authentication Request + Transaction Text
4
Authentication Response + Text Hash Signed by User's Private Key
FIDO Authenticators
5
3
Verify User, Display Text, & Unlock Private Key (specific to User + RP WebApp)
Validate Response & Text Hash Using User's Public Key

Fig. 4 Confirmation Message Flow

Imagine a situation in which a Relying Party wants the end-user to confirm a transaction (e.g. financial operation, privileged operation, etc) so that any tampering of a transaction message during its route to the end device display and back can be detected. FIDO architecture has a concept of "secure transaction" which provides this capability. Basically if a FIDO UAF Authenticator has a transaction confirmation display capability, FIDO UAF architecture makes sure that the system supports What You See is What You Sign mode (WYSIWYS). A number of different use cases can derive from this capability -- mainly related to authorization of transactions (send money, perform a context specific privileged action, confirmation of email/address, etc).

3.6 Authenticator Deregistration

There are some situations where a Relying Party may need to remove the UAF credentials associated with a specific user account in FIDO Authenticator. For example, the user's account is cancelled or deleted, the user's FIDO Authenticator is lost or stolen, etc. In these situations, the RP may request the FIDO Authenticator to delete authentication keys that are bound to user account.

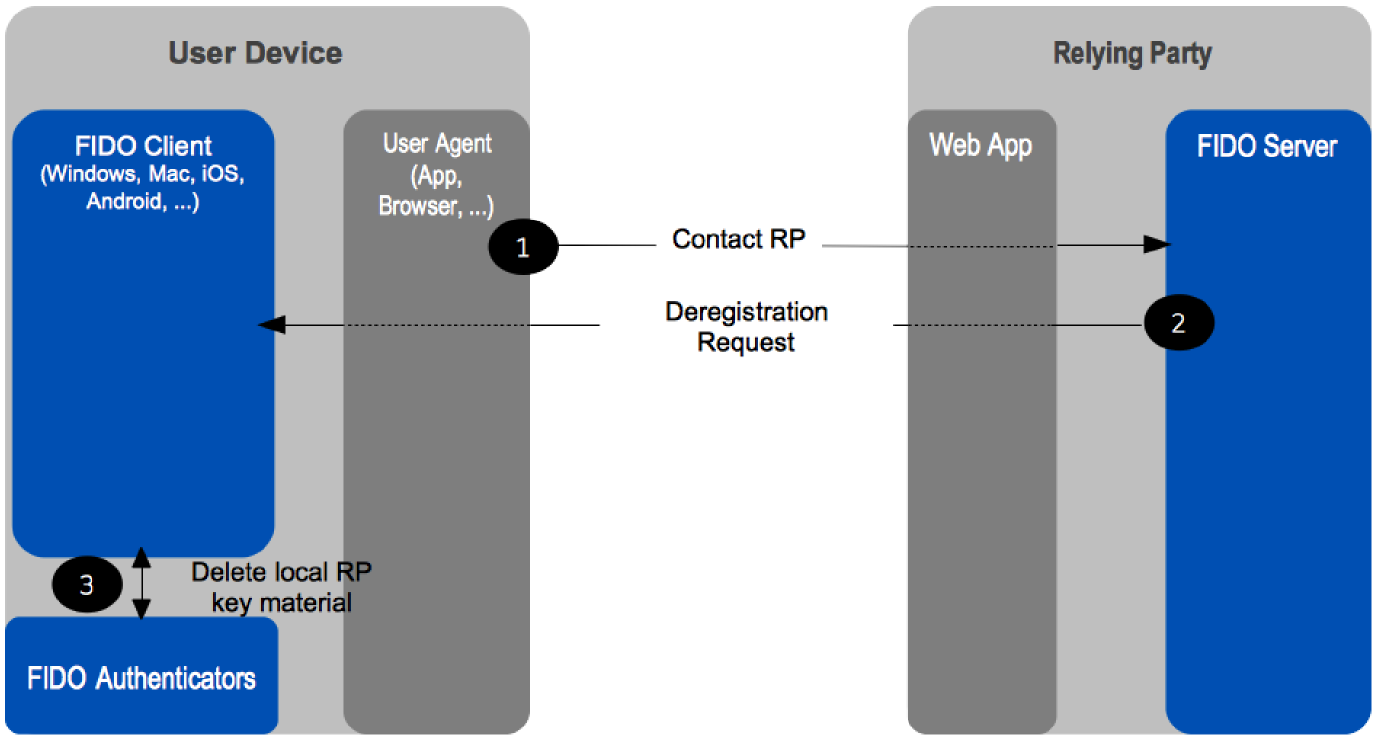
User Device
FIDO Client (Windows, Mac, iOS, Android, ...)
User Agent (App, Browser, ...)
FIDO Authenticators
Relying Party
Web App
FIDO Server
1
Contact RP
2
Deregistration Request
3
Delete local RP key material

Fig. 5 Deregistration Message Flow

3.7 Adoption of New Types of FIDO UAF Authenticators

Authenticators will evolve and new types are expected to appear in the future. Their adoption on the part of both users and Relying Parties is facilitated by the FIDO architecture. In order to support a new FIDO UAF Authenticator type, Relying Parties need only to add a new entry to their configuration describing the new authenticator, along with its FIDO Attestation Certificate. Afterwards, end users will be able to use the new FIDO UAF Authenticator type with those Relying Parties.

4. Privacy Considerations

This section is non-normative.

User privacy is fundamental to FIDO and is supported in UAF by design. Some of the key privacy-aware design elements are summarized here:

- A UAF device does not have a global identifier visible across relying parties and does not have a global identifier within a particular relying party. If for example, a person looses their UAF device, someone finding it cannot “point it at a relying party” and discover if the original user had any accounts with that relying party. Similarly, if two users share a UAF device and each has registered their account with the same relying party with this device, the relying party will not be able to discern that the two accounts share a device, based on the UAF protocol alone.
- The UAF protocol generates unique asymmetric cryptographic key pairs on a per-device, per-user account, and per-relying party basis. Cryptographic keys used with different relying parties will not allow any one party to link all the actions to the same user, hence the unlinkability property of UAF.
- The UAF protocol operations require minimal personal data collection: at most they incorporate a user's relying party username. This personal data is only used for FIDO purposes, for example to perform user registration, user verification, or authorization. This personal data does not leave the user’s computing environment and is only persisted locally when necessary.
- In UAF, user verification is performed locally. The UAF protocol does not convey biometric data to relying parties, nor does it require the storage of such data at relying parties.
- Users explicitly approve the use of a UAF device with a specific relying party. Unique cryptographic keys are generated and bound to a relying party during registration only after the user’s consent.
- UAF authenticators can only be identified by their attestation certificates on a production batch-level or on manufacturer- and device model-level. They cannot be identified individually. The UAF specifications require implementers to ship UAF authenticators with the same attestation certificate and private key in batches of 100,000 or more in order to provide unlinkability.

5. Relationship to Other Technologies

This section is non-normative.

OpenID, SAML, and OAuth

FIDO protocols (both UAF and U2F) complement Federated Identity Management (FIM) frameworks, such as OpenID and SAML, as well as web authorization protocols, such as OAuth. FIM Relying Parties can leverage an initial authentication event at an identity provider (IdP). However, OpenID and SAML do not define specific mechanisms for direct user authentication at the IdP.

When an IdP is integrated with a FIDO-enabled authentication service, it can subsequently leverage the attributes of the strong authentication with its Relying Parties. The following diagram illustrates this relationship. FIDO-based authentication (1) would logically occur first, and the FIM protocols would then leverage that authentication event into single sign-on events between the identity provider and its federated Relying Parties (2).[2]

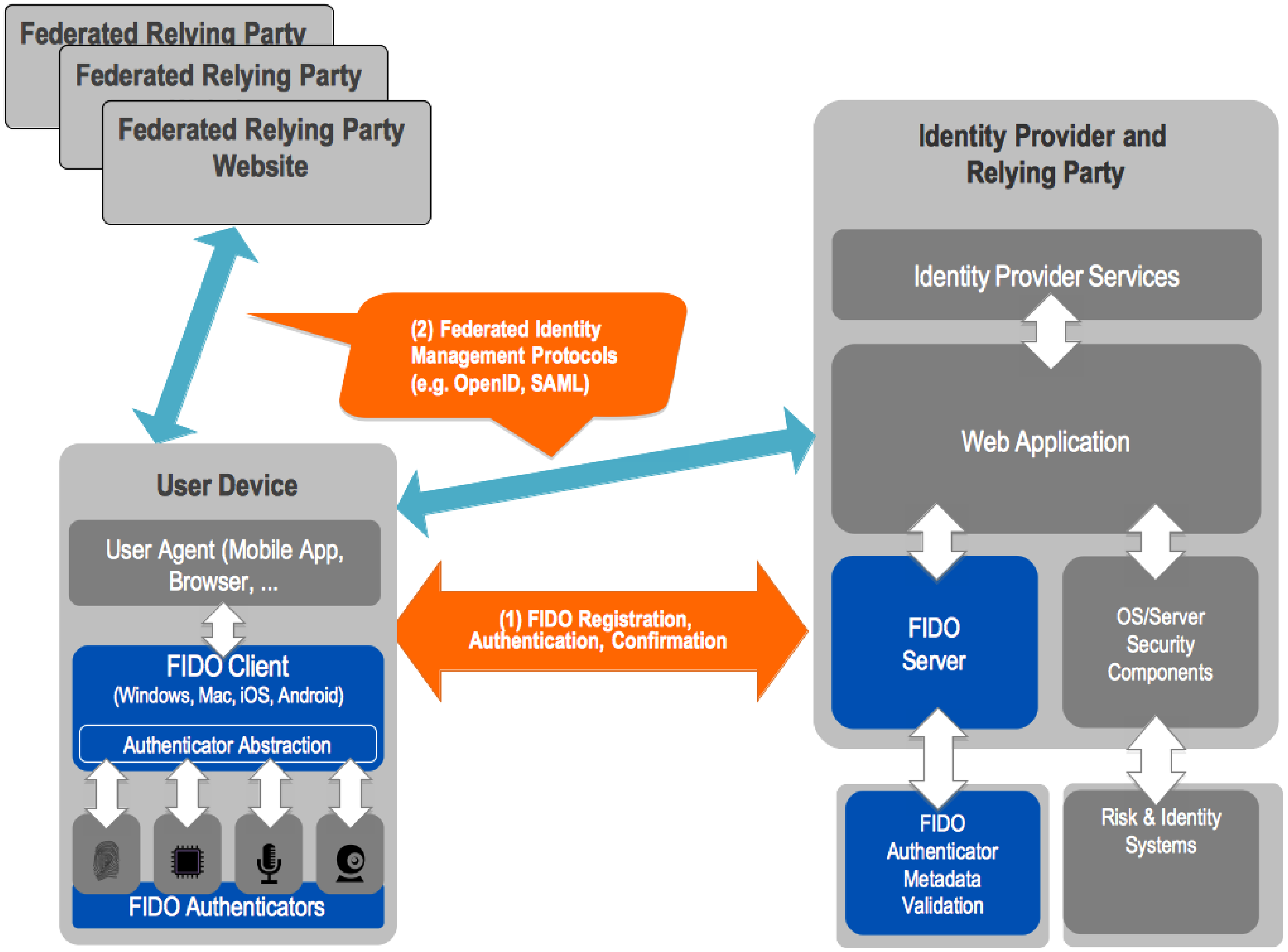
Federated Relying Party
Federated Relying Party
Federated Relying Party Website
(2) Federated Identity Management Protocols (e.g. OpenID, SAML)
Identity Provider and Relying Party
Identity Provider Services
Web Application
User Device
User Agent (Mobile App, Browser, ...
FIDO Client (Windows, Mac, iOS, Android)
Authenticator Abstraction
FIDO Authenticators
(1) FIDO Registration, Authentication, Confirmation
FIDO Server
OS/Server Security Components
FIDO Authenticator Metadata Validation
Risk & Identity Systems

Fig. 6 FIDO UAF & Federated Identity Frameworks

6. OATH, TCG, PKCS#11, and ISO 24727

These are either initiatives (OATH, Trusted Computing Group (TCG)), or industry standards (PKCS#11, ISO 24727). They all share an underlying focus on hardware authenticators.

PKCS#11 and ISO 24727 define smart-card-based authenticator abstractions.

TCG produces specifications for the Trusted Platform Module, as well as networked trusted computing.

OATH, the "Initiative for Open AuTHentication", focuses on defining symmetric key provisioning protocols and authentication algorithms for hardware One-Time Password (OTP) authenticators.

The FIDO framework shares several core notions with the foregoing efforts, such as an authentication abstraction interface, authenticator attestation, key provisioning, and authentication algorithms. FIDO's work will leverage and extend some of these specifications.

Specifically, FIDO will complement them by addressing:

- Authenticator discovery
- User experience
- Harmonization of various authenticator types, such as biometric, OTP, simple presence, smart card, TPM, etc.

7. Table of Figures

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1. Also known as: Authentication Tokens, Security Tokens, etc.↩

2. FIM protocols typically convey IdP <-> RP interactions through the browser via HTTP redirects and POSTs.↩

FIDO UAF Protocol Specification

FIDO Alliance Proposed Standard 20 October 2020

This version:
https://fidoalliance.org/specs/fido-uaf-v1.2-ps-20201020/fido-uaf-protocol-v1.2-ps-20201020.html
Previous version:
https://fidoalliance.org/specs/fido-uaf-v1.2-id-20180220/fido-uaf-protocol-v1.2-id-20180220.html
Editors:
Dr. Rolf Lindemann, Nok Nok Labs, Inc.
Eric Tiffany, FIDO Alliance
Contributors:
Davit Baghdasaryan, Nok Nok Labs, Inc.
Dirk Balfanz, Google, Inc.
Brad Hill, PayPal, Inc.
Jeff Hodges, PayPal, Inc.
Ka Yang, Nok Nok Labs, Inc.

The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

The goal of the Universal Authentication Framework is to provide a unified and extensible authentication mechanism that supplants passwords while avoiding the shortcomings of current alternative authentication approaches.

This approach is designed to allow the relying party to choose the best available authentication mechanism for a particular end user or interaction, while preserving the option to leverage emerging device security capabilities in the future without requiring additional integration effort.

This document describes the FIDO architecture in detail, it defines the flow and content of all UAF protocol messages and presents the rationale behind the design choices.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

The notation base64url refers to "Base 64 Encoding with URL and Filename Safe Alphabet" [RFC4648] *without padding*.

Following [WebIDL-ED], dictionary members are optional unless they are explicitly marked as `required`.

WebIDL dictionary members MUST NOT have a value of null — i.e., there are no declarations of nullable dictionary members in this specification.

Unless otherwise specified, if a WebIDL dictionary member is DOMString, it MUST NOT be empty.

Unless otherwise specified, if a WebIDL dictionary member is a List, it MUST NOT be an empty list.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

NOTE

Note: Certain dictionary members need to be present in order to comply with FIDO requirements. Such members are marked in the WebIDL definitions found in this document, as `required`. The keyword `required` has been introduced by [WebIDL-ED], which is a work-in-progress. If you are using a WebIDL parser which implements [WebIDL], then you may remove the keyword `required` from your WebIDL and use other means to ensure those fields are present.

1.1 Key Words

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

2. Overview

This section is non-normative.

The goal of this Universal Authentication Framework is to provide a unified and extensible authentication mechanism that supplants passwords while avoiding the shortcomings of current alternative authentication approaches.

The design goal of the protocol is to enable Relying Parties to leverage the diverse and heterogeneous set of security capabilities available on end users' devices via a single, unified protocol.

This approach is designed to allow the FIDO Relying Parties to choose the best available authentication mechanism for a particular end user or interaction, while preserving the option for a relying party to leverage emerging device security capabilities in the future, without requiring additional integration effort.

2.1 Scope

This document describes FIDO architecture in detail and defines the UAF protocol as a network protocol. It defines the flow and content of all UAF messages and presents the rationale behind the design choices.

Particular application-level bindings are outside the scope of this document. This document is not intended to answer questions such as:

- What does an HTTP binding look like for UAF?
- How can a web application communicate to FIDO UAF Client?
- How can FIDO UAF Client communicate to FIDO enabled Authenticators?

The answers to these questions can be found in other UAF specifications, e.g. [UAFAppAPIAndTransport] [UAFASM] [UAFAuthnrCommands].

2.2 Architecture

The following diagram depicts the entities involved in UAF protocol.

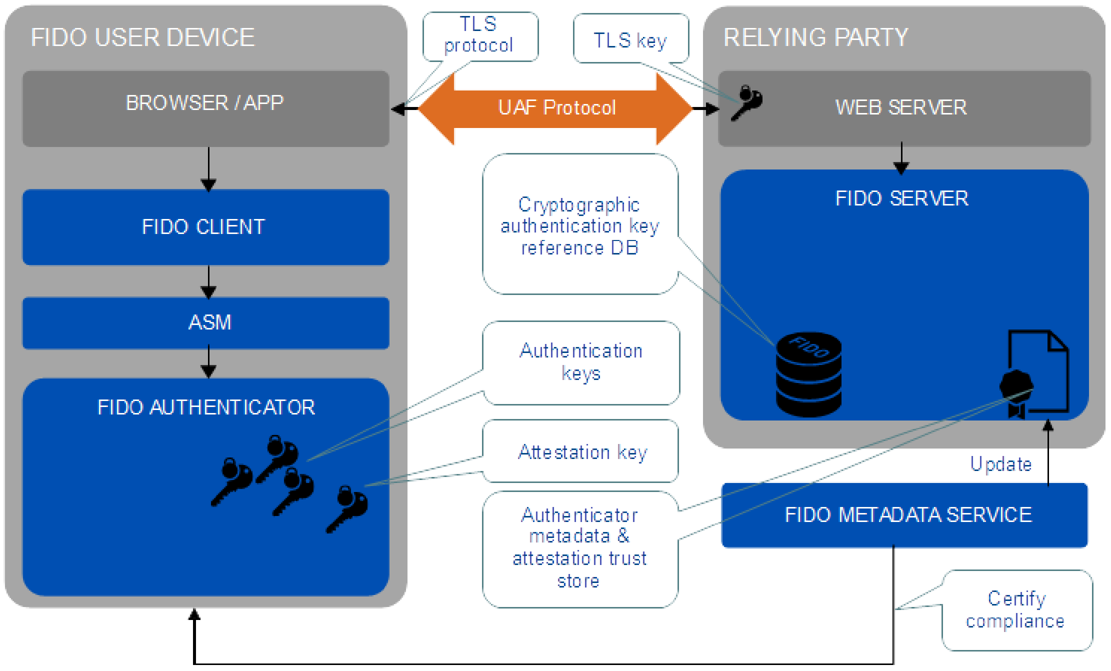


Fig. 1 The UAF Architecture

Of these entities, only these three directly create and/or process UAF protocol messages:

- FIDO Server, running on the relying party's infrastructure
- FIDO UAF Client, part of the user agent and running on the FIDO user device
- FIDO Authenticator, integrated into the FIDO user device

It is assumed in this document that a FIDO Server has access to the UAF Authenticator Metadata [FIDOMetadataStatement] describing all the authenticators it will interact with.

2.3 Protocol Conversation

The core UAF protocol consists of four conceptual conversations between a FIDO UAF Client and FIDO Server.

- **Registration:** UAF allows the relying party to register a FIDO Authenticator with the user's account at the relying party. The relying party can specify a policy for supporting various FIDO Authenticator types. A FIDO UAF Client will only register existing authenticators in accordance with that policy.

- **Authentication:** UAF allows the relying party to prompt the end user to authenticate using a previously registered FIDO Authenticator. This authentication can be invoked any time, at the relying party's discretion.

- **Transaction Confirmation:** In addition to providing a general authentication prompt, UAF offers support for prompting the user to confirm a specific transaction.

  This prompt includes the ability to communicate additional information to the client for display to the end user, using the client's transaction confirmation display. The goal of this additional authentication operation is to enable relying parties to ensure that the user is confirming a specified set of the transaction details (instead of authenticating a session to the user agent).

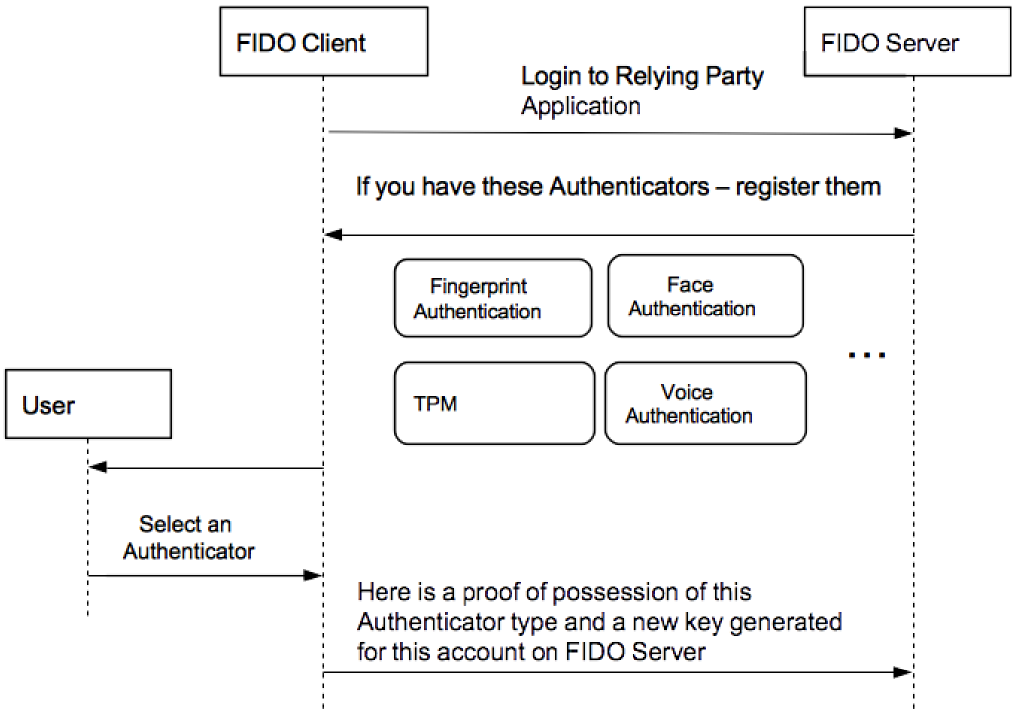
- **Deregistration:** The relying party can trigger the deletion of the account-related authentication key material.

Although this document defines the FIDO Server as the initiator of requests, in a real world deployment the first UAF operation will always follow a user agent's (e.g. HTTP) request to a relying party.

The following sections give a brief overview of the protocol conversation for individual operations. More detailed descriptions can be found in the sections Registration Operation, Authentication Operation, and Deregistration Operation.

2.3.1 Registration

The following diagram shows the message flows for registration.



FIDO Client
FIDO Server
Login to Relying Party Application
If you have these Authenticators – register them
Fingerprint Authentication
Face Authentication
...
User
TPM
Voice Authentication
Select an Authenticator
Here is a proof of possession of this Authenticator type and a new key generated for this account on FIDO Server

Fig. 2 UAF Registration Message Flow

NOTE

The client application should use the appropriate API to inform the FIDO UAF Client of the results of the operation (see section 2.3.1 in [UAFAppAPIAndTransport]) in order to allow the FIDO UAF Client to do some "housekeeping" tasks.

2.3.2 Authentication

The following diagram depicts the message flows for the authentication operation.

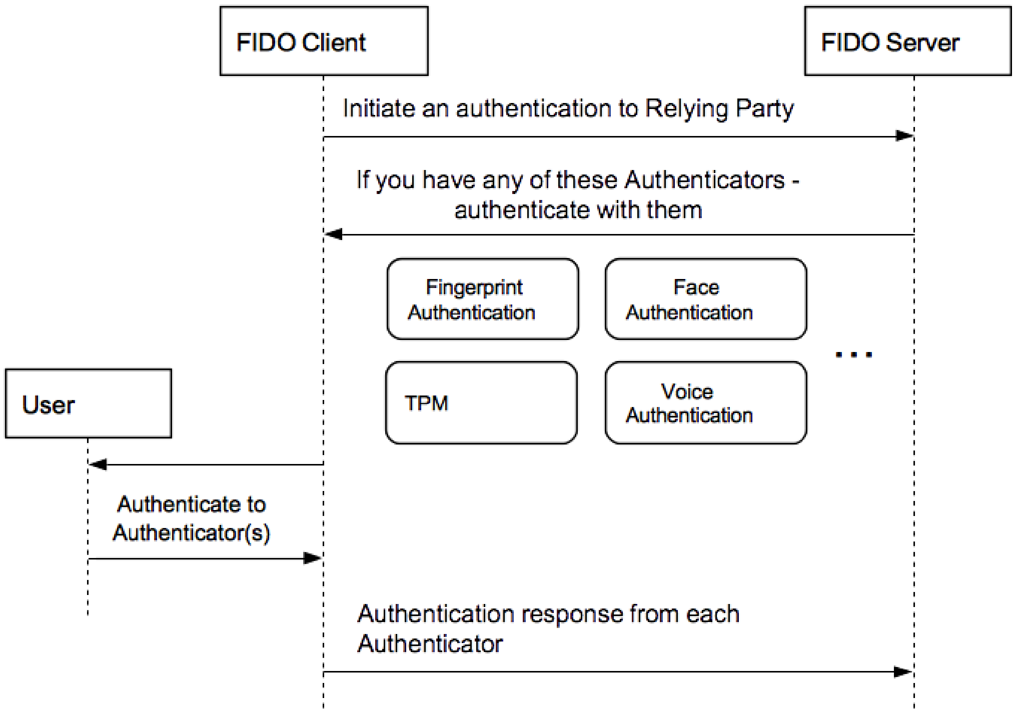

FIDO Client
FIDO Server
Initiate an authentication to Relying Party
If you have any of these Authenticators - authenticate with them
Fingerprint Authentication
Face Authentication
TPM
Voice Authentication
...
User
Authenticate to Authenticator(s)
Authentication response from each Authenticator

Fig. 3 Authentication Message Flow

NOTE

The client application should use the appropriate API to inform the FIDO UAF Client of the results of the operation (see section 2.3.1 in [UAFAppAPIAndTransport]) in order to allow FIDO UAF Client to do some "housekeeping" tasks.

2.3.3 Transaction Confirmation

The following figure depicts the transaction confirmation message flow.

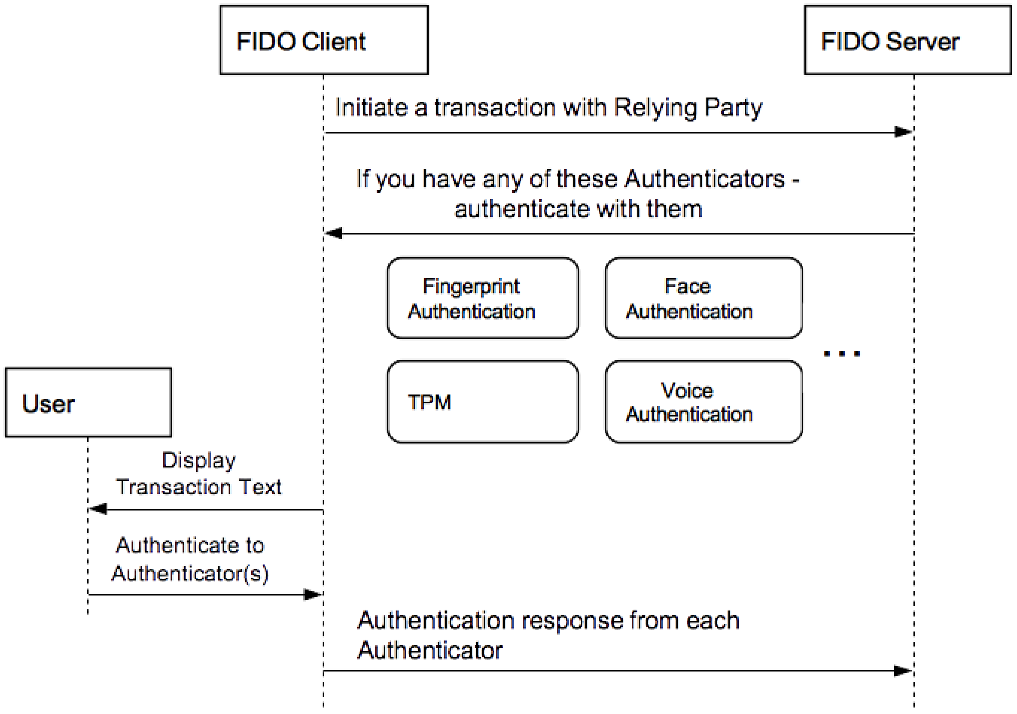

FIDO Client
FIDO Server
Initiate a transaction with Relying Party
If you have any of these Authenticators - authenticate with them
Fingerprint Authentication
Face Authentication
TPM
Voice Authentication
...
User
Display Transaction Text
Authenticate to Authenticator(s)
Authentication response from each Authenticator

Fig. 4 Transaction Confirmation Message Flow

NOTE

The client application should use the appropriate API to inform the FIDO UAF Client of the results of the operation (see section 2.3.1 in [UAFAppAPIAndTransport]) in order to allow the FIDO UAF Client to do some "housekeeping" tasks.

2.3.4 Deregistration

The following diagram depicts the deregistration message flow.

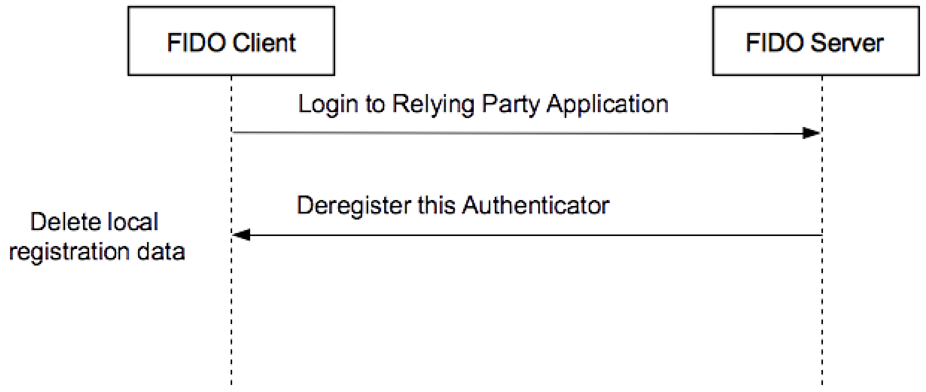

FIDO Client
FIDO Server
Login to Relying Party Application
Deregister this Authenticator
Delete local registration data

Fig. 5 Deregistration Message Flow

NOTE

The client application should use the appropriate API to inform the FIDO UAF Client of the results of the operation (see section 2.3.1 in [UAFAppAPIAndTransport]) in order to allow the FIDO UAF Client to do some "housekeeping" tasks.

2.4 Relationship to Other Specifications

The following data elements might be referenced by other specifications and hence should not be changed in their fundamental data type or high-level semantics without liaising with the other specifications:

1. **aaid**, data type byte string and identifying the authenticator model, i.e. identical values mean that they refer to the same authenticator model and different values mean they refer to different authenticator models.
2. **AppID**, data type string representing the Application Identifier, i.e. identical values mean that they refer to the same relying party.
3. **keyID**, data type byte string identifying a specific credential, i.e. identical values mean that they refer to the same credential and different values mean they refer to different credentials.

NOTE

Some of the data elements might have an internal structure that might change. Other specifications shall not rely on such internal structure.

3. Protocol Details

This section is normative.

This section provides a detailed description of operations supported by the UAF Protocol.

Support of all protocol elements is mandatory for conforming software, unless stated otherwise.

All string literals in this specification are constructed from Unicode codepoints within the set `U+0000`..`U+007F`.

Unless otherwise specified, protocol messages are transferred with a UTF-8 content encoding.

NOTE

All data used in this protocol must be exchanged using a secure transport protocol (such as TLS/HTTPS) established between the FIDO UAF Client and the relying party in order to follow the assumptions made in [FIDOSecRef]; details are specified in section 4.1.7 TLS Protected Communication.

The notation `base64url(byte[8..64])` reads as 8-64 bytes of data encoded in base64url, "Base 64 Encoding with URL and Filename Safe Alphabet" [RFC4648] *without padding*.

The notation `string[5]` reads as five unicode characters, represented as a UTF-8 [RFC3629] encoded string of the type indicated in the declaration, typically a WebIDL [WebIDL-ED] DOMString.

As the UTF-8 representation has variable length, the *maximum* byte length of `string[5]` is `string[4*5]`.

All strings are case-sensitive unless stated otherwise.

This document uses WebIDL [WebIDL-ED] to define UAF protocol messages.

Implementations MUST serialize the UAF protocol messages for transmission using UTF-8 encoded JSON [RFC4627].

3.1 Shared Structures and Types

This section defines types and structures shared by various operations.

3.1.1 Version Interface

Represents a generic version with major and minor fields.

WebIDL

```
interface Version {
    readonly    attribute unsigned short major;
    readonly    attribute unsigned short minor;
};
```

3.1.1.1 Attributes

`major` of type unsigned short, readonly
    Major version.

`minor` of type unsigned short, readonly
    Minor version.

3.1.2 Operation enumeration

Describes the operation type of a UAF message or request for a message.

WebIDL

```
enum Operation {
    "Reg",
    "Auth",
    "Dereg"
};
```

Enumeration description	
`Reg`	Registration
`Auth`	Authentication or Transaction Confirmation
`Dereg`	Deregistration

3.1.3 OperationHeader dictionary

Represents a UAF message Request and Response header

WebIDL

```
dictionary OperationHeader {
    required Version   upv;
    required Operation op;
    DOMString          appID;
    DOMString          serverData;
    Extension[]        exts;
};
```

3.1.3.1 Dictionary `OperationHeader` Members

`upv` of type required Version
UAF protocol version (`upv`). To conform with this version of the UAF spec set, the `major` value MUST be `1` and the `minor` value MUST be `2`.

`op` of type required Operation
Name of FIDO operation (`op`) this message relates to.

> NOTE
>
> "Auth" is used for both authentication and transaction confirmation.

`appID` of type DOMString
`string[0..512]`.

The application identifier that the relying party would like to assert.

There are three ways to set the `AppID` [FIDOAppIDAndFacets]:

1. If the element is missing or empty in the request, the FIDO UAF Client MUST set it to the `FacetID` of the caller.
2. If the `appID` present in the message is identical to the `FacetID` of the caller, the FIDO UAF Client MUST accept it.
3. If it is an URI with HTTPS protocol scheme, the FIDO UAF Client MUST use it to load the list of trusted facet identifiers from the specified URI. The FIDO UAF Client MUST only accept the request, if the facet identifier of the caller matches one of the trusted facet identifiers in the list returned from dereferencing this URI.

> NOTE
>
> The new key pair that the authenticator generates will be associated with this application identifier.
>
> *Security Relevance:* The application identifier is used by the FIDO UAF Client to verify the eligibility of an application to trigger the use of a specific `UAuth.Key`. See [FIDOAppIDAndFacets]

`serverData` of type DOMString
`string[1..1536]`.

A session identifier created by the relying party.

> NOTE
> The relying party can opaquely store things like expiration times for the registration session, protocol version used and other useful information in `serverData`. This data is opaque to FIDO UAF Clients. FIDO Servers may reject a response that is lacking this data or is containing unauthorized modifications to it.
>
> Servers that depend on the integrity of `serverData` should apply appropriate security measures, as described in Registration Request Generation Rules for FIDO Server and section ServerData and KeyHandle.

`exts` of type array of *Extension*
List of UAF Message Extensions.

3.1.4 Authenticator Attestation ID (AAID) typedef

WebIDL

```
typedef DOMString AAID;
```

`string[9]`

Each authenticator MUST have an `AAID` to identify UAF enabled authenticator models globally. The `AAID` MUST uniquely identify a specific authenticator model within the range of all UAF-enabled authenticator models made by all authenticator vendors, where authenticators of a specific model must share identical security characteristics within the model (see Security Considerations).

The `AAID` is a string with format "V#M", where

"#" is a separator

"V" indicates the authenticator Vendor Code. This code consists of 4 hexadecimal digits.

"M" indicates the authenticator Model Code. This code consists of 4 hexadecimal digits.

The Augmented BNF [ABNF] for the `AAID` is:

```
AAID = 4(HEXDIG) "#" 4(HEXDIG)
```

> NOTE
>
> *HEXDIG* is case insensitive, i.e. "03EF" and "03ef" are identical.

The FIDO Alliance is responsible for assigning authenticator vendor Codes.

Authenticator vendors are responsible for assigning authenticator model codes to their authenticators. Authenticator vendors MUST assign unique `AAIDs` to authenticators with different security characteristics.

AAIDs are unique and each of them must relate to a distinct authentication metadata file ([FIDOMetadataStatement])

> NOTE
>
> Adding new firmware/software features, or changing the underlying hardware protection mechanisms will typically change the security characteristics of an authenticator and hence would require a new `AAID` to be used. Refer to ([FIDOMetadataStatement]) for more details.

3.1.5 KeyID typedef

WebIDL

```
typedef DOMString KeyID;
```

`base64url(byte[32...2048])`

`KeyID` is a unique identifier (within the scope of an `AAID`) used to refer to a specific `UAuth.Key`. It is generated by the authenticator or ASM and registered with a FIDO Server.

The (`AAID`, `KeyID`) tuple MUST uniquely identify an authenticator's registration for a relying party. Whenever a FIDO Server wants to provide specific information to a particular authenticator it MUST use the (`AAID`, `KeyID`) tuple.

`KeyID` MUST be base64url encoded within the UAF message (see above).

During step-up authentication and deregistration operations, the FIDO Server SHOULD provide the `KeyID` back to the authenticator for the latter to locate the appropriate user authentication key, and perform the necessary operation with it.

Roaming authenticators which don't have internal storage for, and cannot rely on any ASM to store, generated key handles SHOULD provide the key handle as part of the `AuthenticatorRegistrationAssertion.assertion.KeyID` during the registration operation (see also section ServerData and KeyHandle) and get the key handle back from the FIDO Server during the step-up authentication (in the `MatchCriteria` dictionary which is part of the policy) or deregistration operations (see [UAFAuthnrCommands] for more details).

> NOTE
>
> The exact structure and content of a `KeyID` is specific to the authenticator / ASM implementation.

3.1.6 ServerChallenge typedef

WebIDL

```
typedef DOMString ServerChallenge;
```

`base64url(byte[8...64])`

`ServerChallenge` is a server-provided random challenge. *Security Relevance:* The challenge is used by the FIDO Server to verify whether an incoming response is new, or has already been processed. See section Replay Attack Protection for more details.

The ServerChallenge SHOULD be mixed into the entropy pool of the authenticator. *Security Relevance:* The FIDO Server SHOULD provide a challenge containing strong cryptographic randomness whenever possible. See section Server Challenge and Random Numbers.

NOTE

The minimum challenge length of 8 bytes follows the requirement in [SP800-63] and is equivalent to the 20 decimal digits as required in [RFC6287].

NOTE

The maximum length has been defined such that SHA-512 output can be used without truncation.

NOTE

The mixing of multiple sources of randomness is recommended to improve the quality of the random numbers generated by the authenticator, as described in [RFC4086].

3.1.7 FinalChallengeParams dictionary

WebIDL

```
dictionary FinalChallengeParams {
    required DOMString       appID;
    required ServerChallenge challenge;
    required DOMString       facetID;
    required ChannelBinding  channelBinding;
};
```

3.1.7.1 Dictionary `FinalChallengeParams` *Members*

appID of type required DOMString
`string[1..512]`

The value MUST be taken from the appID field of the **OperationHeader**

challenge of type required ServerChallenge

The value MUST be taken from the challenge field of the request (e.g. RegistrationRequest.challenge, AuthenticationRequest.challenge).

facetID of type required DOMString
`string[1..512]`

The value is determined by the FIDO UAF Client and it depends on the calling application. See [FIDOAppIDAndFacets] for more details. *Security Relevance:* The facetID is determined by the FIDO UAF Client and verified against the list of trusted facets retrieved by dereferencing the appID of the calling application.

channelBinding of type required ChannelBinding

Contains the TLS information to be sent by the FIDO Client to the FIDO Server, binding the TLS channel to the FIDO operation.

3.1.8 CollectedClientData dictionary

CollectedClientData is an alternative to the **FinalChallengeParams** structure. It is used by platforms supporting CTAP2 and Web Authentication. The exact definition of CollectedClientData can be found in [WebAuthn].

NOTE

WebIDL

```
dictionary CollectedClientData {
    required DOMString           challenge;
    required DOMString              origin;
    required AlgorithmIdentifier hashAlg;
    DOMString                       tokenBinding;
    WebAuthnExtensions              extensions;
};
```

Dictionary **`CollectedClientData`** *Members*

`challenge` of type required DOMString

Contains the base64url encoding of the challenge provided by the RP.

> This field plays a similar role as the `challenge` field in **`FinalChallengeParams`**.

`origin` of type required DOMString

The fully qualified origin of the requester, as provided to the authenticator by the client, in the synrax defined by [RFC6454].

> This field plays a similar role as the `facetID` field in **`FinalChallengeParams`**.

`hashAlg` of type required AlgorithmIdentifier

The hash algorithm used to compute the clientDataHash, e.g. "S256", etc.

> This field is relevant here as the client can freely select the hash algorithm - unlike **`FinalChallengeParams`**, where the authenticator MUST use the same algorithm as for signing the assertion.

`tokenBinding` of type DOMString

Contains the base64url encoding of the Token Binding ID provided by the client. The syntax is equivalent to the cid_pubkey in section ChannelBinding dictionary.

> This field plays a similar role as the `channelBinding` field in **`FinalChallengeParams`**.

`extensions` of type WebAuthnExtensions

Additional parameters generated by processing of extensions passed in by the relying party.

3.1.9 TLS ChannelBinding dictionary

ChannelBinding contains channel binding information [RFC5056].

NOTE

*Security Relevance:*The channel binding may be verified by the FIDO Server in order to detect and prevent MITM attacks.

At this time, the following channel binding methods are supported:

- TokenBinding ID (`tokenBinding` [RFC8471]
- TLS ChannelID (`cid_pubkey`) [ChannelID]
- serverEndPoint [RFC5929]
- tlsServerCertificate
- tlsUnique [RFC5929]

Further requirements:

1. If data related to any of the channel binding methods, described here, is available to the FIDO UAF Client (i.e. included in this dictionary), it MUST be used according to the relevant specification .
2. All channel binding methods described here MUST be supported by the FIDO Server. The FIDO Server MAY reject operations if the channel binding cannot be verified successfully.

NOTE

- If channel binding data or Token Binding ID is accessible to the web browser or client application, it must be relayed to the FIDO UAF Client in order to follow the assumptions made in [FIDOSecRef].
- If channel binding data or Token Binding ID is accessible to the web server, it must be relayed to the FIDO Server in order to follow the assumptions made in [FIDOSecRef]. The FIDO Server relies on the web server to provide accurate channel binding information.

WebIDL

```
dictionary ChannelBinding {
    DOMString serverEndPoint;
    DOMString tlsServerCertificate;
    DOMString tlsUnique;
    DOMString cid_pubkey;
    DOMString tokenBinding;
};
```

3.1.9.1 Dictionary `ChannelBinding` Members

`serverEndPoint` of type DOMString

The field `serverEndPoint` MUST be set to the base64url-encoded hash of the TLS server certificate if this is available. The hash function MUST be selected as follows:

1. if the certificate's `signatureAlgorithm` uses a single hash function and that hash function is either MD5 [RFC1321] or SHA-1 [RFC6234], then use SHA-256 [FIPS180-4];
2. if the certificate's `signatureAlgorithm` uses a single hash function and that hash function is neither MD5 nor SHA-1, then use the hash function associated with the certificate's`signatureAlgorithm`;
3. if the certificate's `signatureAlgorithm` uses no hash functions, or uses multiple hash functions, then this channel binding type's channel bindings are undefined at this time (updates to this channel binding type may occur to address this issue if it ever arises)

This field MUST be absent if the TLS server certificate is not available to the processing entity (e.g., the FIDO UAF Client) or the hash function cannot be determined as described.

`tlsServerCertificate` of type DOMString

This field MUST be absent if the TLS server certificate is not available to the FIDO UAF Client.

This field MUST be set to the base64url-encoded, DER-encoded TLS server certificate, if this data is available to the FIDO UAF Client.

`tlsUnique` of type DOMString

MUST be set to the base64url-encoded TLS channel `Finished` structure. It MUST, however, be absent, if this data is not available to the FIDO UAF Client [RFC5929].

The use of the tlsUnique is deprecated as the security of the `tls-unqiue` channel binding type [RFC5929] is broken, see [TLSAUTH].

`cid_pubkey` of type DOMString

MUST be absent if the client TLS stack doesn't provide TLS ChannelID [ChannelID] information to the processing entity (e.g., the web browser or client application).

MUST be set to "unused" if TLS ChannelID information is supported by the client-side TLS stack but has not been signaled by the TLS (web) server.

Otherwise, it MUST be set to the base64url-encoded serialized [RFC4627] `JwkKey` structure using UTF-8 encoding.

`tokenBinding` of type DOMString

MUST be absent if the client TLS stack doesn't provide Token Binding ID [RFC8471] information to the processing entity (e.g., the web browser or client application).

MUST be set to "unused" if Token Binding ID information is supported by the client-side TLS stack but has not been signaled by the TLS (web) server.

Otherwise, it MUST be set to the base64url-encoded serialized [RFC8471] TokenBindingID structure using UTF-8 encoding.

3.1.10 JwkKey dictionary

`JwkKey` is a dictionary representing a JSON Web Key encoding of an elliptic curve public key [JWK].

This public key is the ChannelID public key minted by the client TLS stack for the particular relying party. [ChannelID] stipulates using only a particular elliptic curve, and the particular coordinate type.

WebIDL

```
dictionary JwkKey {
    required DOMString kty = "EC";
    required DOMString crv = "P-256";
    required DOMString x;
    required DOMString y;
};
```

3.1.10.1 Dictionary `JwkKey` Members

`kty` of type required DOMString, defaulting to **`"EC"`**
: Denotes the key type used for Channel ID. At this time only elliptic curve is supported by [ChannelID], so it MUST be set to "EC" [JWA].

`crv` of type required DOMString, defaulting to **`"P-256"`**
: Denotes the elliptic curve on which this public key is defined. At this time only the NIST curve `secp256r1` is supported by [ChannelID], so the `crv` parameter MUST be set to "P-256".

`x` of type required DOMString
: Contains the base64url-encoding of the x coordinate of the public key (big-endian, 32-byte value).

`y` of type required DOMString
: Contains the base64url-encoding of the y coordinate of the public key (big-endian, 32-byte value).

3.1.11 Extension dictionary

FIDO extensions can appear in several places, including the UAF protocol messages, authenticator commands, or in the assertion signed by the authenticator.

Each extension has an identifier, and the namespace for extension identifiers is FIDO UAF global (i.e. doesn't depend on the message where the extension is present).

Extensions can be defined in a way such that a processing entity which doesn't understand the meaning of a specific extension MUST abort processing, or they can be specified in a way that unknown extension can (safely) be ignored.

Extension processing rules are defined in each section where extensions are allowed.

Generic extensions used in various operations.

WebIDL

```
dictionary Extension {
    required DOMString id;
    required DOMString data;
    required boolean   fail_if_unknown;
};
```

3.1.11.1 Dictionary `Extension` Members

`id` of type required DOMString
: `string[1..32]`.

  Identifies the extension.

`data` of type required DOMString
: Contains arbitrary data with a semantics agreed between server and client. Binary data is base64url-encoded.

  This field MAY be empty.

`fail_if_unknown` of type required boolean
: Indicates whether unknown extensions must be ignored (`false`) or must lead to an error (`true`).

- A value of false indicates that unknown extensions MUST be ignored
- A value of true indicates that unknown extensions MUST result in an error.

NOTE

The FIDO UAF Client might (a) process an extension or (b) pass the extension through to the ASM. Unknown extensions must be passed through.

The ASM might (a) process an extension or (b) pass the extension through to the FIDO authenticator. Unknown extensions must be passed through.

The FIDO authenticator must handle the extension or ignore it (only if it doesn't know how to handle it *and* fail_if_unknown is not set). If the FIDO authenticator doesn't understand the meaning of the extension and fail_if_unknown is set, it must generate an error (see definition of fail_if_unknown above).

When passing through an extension to the next entity, the fail_if_unknown flag must be preserved (see [UAFASM] [UAFAuthnrCommands]).

FIDO protocol messages are not signed. If the security depends on an extension being known or processed, then such extension should be accompanied by a related (and signed) extension in the authenticator assertion (e.g. TAG_UAFV1_REG_ASSERTION, TAG_UAFV1_AUTH_ASSERTION). If the security has been increased (e.g. the FIDO authenticator according to the description in the metadata statement accepts multiple fingers but in this specific case indicates that the finger used at registration was also used for authentication) there is no need to mark the extension as fail_if_unknown (i.e. tag 0x3E12 should be used [UAFAuthnrCommands]). If the security has been degraded (e.g. the FIDO authenticator according to the description in the metadata statement accepts only the finger used at registration for authentication but in this specific case indicates that a different finger was used for authentication) the extension must be marked as fail_if_unknown (i.e. tag 0x3E11 must be used [UAFAuthnrCommands]).

3.1.12 MatchCriteria dictionary

Represents the matching criteria to be used in the server policy.

The MatchCriteria object is considered to match an authenticator, if *all* fields in the object are considered to match (as indicated in the particular fields).

WebIDL

```
dictionary MatchCriteria {
    AAID[]           aaid;
    DOMString[]      vendorID;
    KeyID[]          keyIDs;
    unsigned long    userVerification;
    unsigned short   keyProtection;
    unsigned short   matcherProtection;
    unsigned long    attachmentHint;
    unsigned short   tcDisplay;
    unsigned short[] authenticationAlgorithms;
    DOMString[]      assertionSchemes;
    unsigned short[] attestationTypes;
    unsigned short   authenticatorVersion;
    Extension[]      exts;
};
```

3.1.12.1 Dictionary ***MatchCriteria*** *Members*

aaid of type array of *AAID*
List of AAIDs, causing matching to be restricted to certain AAIDs.

The field m.aaid MAY be combined with (one or more of) m.keyIDs, m.attachmentHint, m.authenticatorVersion, and m.exts, but m.aaid MUST NOT be combined with any other match criteria field.

If m.aaid is not provided - both m.authenticationAlgorithms and m.assertionSchemes MUST be provided.

The match succeeds if at least one AAID entry in this array matches AuthenticatorInfo.aaid [UAFASM].

NOTE

This field corresponds to MetadataStatement.aaid [FIDOMetadataStatement].

`vendorID` of type array of DOMString

The vendorID causing matching to be restricted to authenticator models of the given vendor. The first 4 characters of the AAID are the vendorID (see **`AAID`**)).

The match succeeds if at least one entry in this array matches the first 4 characters of the `AuthenticatorInfo.aaid` [UAFASM].

> NOTE
>
> This field corresponds to the first 4 characters of `MetadataStatement.aaid` [FIDOMetadataStatement].

`keyIDs` of type array of *KeyID*

A list of authenticator KeyIDs causing matching to be restricted to a given set of `KeyID` instances. (see TAG_KEYID in [UAFRegistry]).

This match succeeds if at least one entry in this array matches.

> NOTE
>
> This field corresponds to `AppRegistration.keyIDs` [UAFASM].

`userVerification` of type unsigned long

A set of 32 bit flags which may be set if matching should be restricted by the user verification method (see [FIDORegistry]).

> NOTE
> The match with `AuthenticatorInfo.userVerification` ([UAFASM]) succeeds, if the following condition holds (written in Java):

```
if (
        // They are equal
        (AuthenticatorInfo.userVerification == MatchCriteria.userVerification) ||

        // USER_VERIFY_ALL is not set in both of them and they have at least one common bit set
        (
            ((AuthenticatorInfo.userVerification & USER_VERIFY_ALL) == 0) &&
            ((MatchCriteria.userVerification & USER_VERIFY_ALL) == 0) &&
            ((AuthenticatorInfo.userVerification & MatchCriteria.userVerification) != 0)
        )
   )
```

> NOTE
> This field value can be derived from `MetadataStatement.userVerificationDetails` as follows (in order to write matchCriteria that apply to the respective authenticator model):
>
> For each entry in `MetadataStatement.userVerificationDetails` combine all sub-entries `MetadataStatement.userVerificationDetails[i][0].userVerification` to `MetadataStatement.userVerificationDetails[i][N-1].userVerification` into a single value using a bitwise OR operation.
>
> The combined bitflags will either all be interpreted as alternatives or as "and" combinations (depending on the flag USER_VERIFY_ALL). For example, an authenticator that allows Passcode OR (both, Voice AND Face), will either look like:
>
> 1. Passcode OR Voice OR Face, or it will look like
> 2. Passcode AND Voice AND Face.
>
> The algorithm above will encode it as alternative (1) if the USER_VERIFY_ALL flag is not set. It will encode it as alternative (2) if the USER_VERIFY_ALL flag is set.

`keyProtection` of type unsigned short

A set of 16 bit flags which may be set if matching should be restricted by the key protections used (see [FIDORegistry]).

This match succeeds, if at least one of the bit flags matches the value of `AuthenticatorInfo.keyProtection` [UAFASM].

> NOTE
>
> This field corresponds to `MetadataStatement.keyProtection` [FIDOMetadataStatement].

`matcherProtection` of type unsigned short
A set of 16 bit flags which may be set if matching should be restricted by the matcher protection (see [FIDORegistry]).

The match succeeds if at least one of the bit flags matches the value of `AuthenticatorInfo.matcherProtection` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.matcherProtection` metadata statement. See [FIDOMetadataStatement].

`attachmentHint` of type unsigned long
A set of 32 bit flags which may be set if matching should be restricted by the authenticator attachment mechanism (see [FIDORegistry]).

This field is considered to match, if at least one of the bit flags matches the value of `AuthenticatorInfo.attachmentHint` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.attachmentHint` metadata statement.

`tcDisplay` of type unsigned short
A set of 16 bit flags which may be set if matching should be restricted by the transaction confirmation display availability and type. (see [FIDORegistry]).

This match succeeds if at least one of the bit flags matches the value of `AuthenticatorInfo.tcDisplay` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.tcDisplay` metadata statement. See [FIDOMetadataStatement].

`authenticationAlgorithms` of type array of unsigned short
An array containing values of supported authentication algorithm TAG values (see [FIDORegistry], prefix `ALG_SIGN`) if matching should be restricted by the supported authentication algorithms. This field MUST be present, if field `aaid` is missing.

This match succeeds if at least one entry in this array matches the `AuthenticatorInfo.authenticationAlgorithm` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.authenticationAlgorithm` metadata statement. See [FIDOMetadataStatement].

`assertionSchemes` of type array of DOMString
A list of supported assertion schemes if matching should be restricted by the supported schemes. This field MUST be present, if field `aaid` is missing.

See section UAF Supported Assertion Schemes for details.

This match succeeds if at least one entry in this array matches `AuthenticatorInfo.assertionScheme` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.assertionScheme` metadata statement. See [FIDOMetadataStatement].

`attestationTypes` of type array of unsigned short
An array containing the preferred attestation TAG values (see [UAFRegistry], prefix `TAG_ATTESTATION`). The order of items MUST be preserved. The most-preferred attestation type comes first.

This match succeeds if at least one entry in this array matches one entry in `AuthenticatorInfo.attestationTypes` [UAFASM].

> NOTE
>
> This field corresponds to the `MetadataStatement.attestationTypes` metadata statement. See [FIDOMetadataStatement].

authenticatorVersion of type unsigned short

Contains an authenticator version number, if matching should be restricted by the authenticator version in use.

This match succeeds if the value is *lower or equal* to the field `AuthenticatorVersion` included in `TAG_UAFV1_REG_ASSERTION` or `TAG_UAFV1_AUTH_ASSERTION` or a corresponding value in the case of a different assertion scheme.

NOTE

Since the semantic of the `authenticatorVersion` depends on the AAID, the field `authenticatorVersion` should always be combined with a single `aaid` in `MatchCriteria`.

This field corresponds to the `MetadataStatement.authenticatorVersion` metadata statement. See [FIDOMetadataStatement].

The use of authenticatorVersion in the policy is deprecated since there is no standardized way for the FIDO Client to learn the authenticatorVersion. The authenticatorVersion is included in the auhentication assertion and hence can still be evaluated in the FIDO Server.

exts of type array of *Extension*

Extensions for matching policy.

3.1.13 Policy dictionary

Contains a specification of accepted authenticators and a specification of disallowed authenticators.

WebIDL

```
dictionary Policy {
    required MatchCriteria[][] accepted;
    MatchCriteria[]            disallowed;
};
```

3.1.13.1 Dictionary `Policy` Members

accepted of type array of array of required MatchCriteria

This field is a two-dimensional array describing the required authenticator characteristics for the server to accept either a FIDO registration, or authentication operation for a particular purpose.

This two-dimensional array can be seen as a list of sets. List elements (i.e. the sets) are alternatives (OR condition).

All elements within a set MUST be combined:

The first array index indicates OR conditions (i.e. the list). Any set of authenticator(s) satisfying these **`MatchCriteria`** in the first index is acceptable to the server for this operation.

Sub-arrays of MatchCriteria in the second index (i.e. the set) indicate that multiple authenticators (i.e. each set element) MUST be registered or authenticated to be accepted by the server.

The MatchCriteria array represents ordered preferences by the server. Servers MUST put their preferred authenticators first, and FIDO UAF Clients SHOULD respect those preferences, either by presenting authenticator options to the user in the same order, or by offering to perform the operation using only the highest-preference authenticator(s).

NOTE

This list MUST NOT be empty. If the FIDO Server accepts any authenticator, it can follow the example below.

EXAMPLE 1: Example for an 'any' policy

```
{
  "accepted":
  [
        [{ "userVerification": 1023 }]
  ]
}
```

NOTE

> 1023 = 0x3ff = USER_VERIFY_PRESENCE | USER_VERIFY_FINGERPRINT | ... | USER_VERIFY_NONE

`disallowed` of type array of *MatchCriteria*
: Any authenticator that matches any of MatchCriteria contained in the field disallowed MUST be excluded from eligibility for the operation, regardless of whether it matches any MatchCriteria present in the `accepted` list, or not.

3.2 Processing Rules for the Server Policy

This section is normative.

The FIDO UAF Client MUST follow the following rules while parsing server policy:

1. During registration:
    1. `Policy.accepted` is a list of combinations. Each combination indicates a list of criteria for authenticators that the server wants the user to register.
    2. Follow the priority of items in `Policy.accepted[][]`. The lists are ordered with highest priority first.
    3. Choose the combination whose criteria best match the features of the currently available authenticators
    4. Collect information about available authenticators
    5. Ignore authenticators which match the `Policy.disallowed` criteria
    6. Match collected information with the matching criteria imposed in the policy (see MatchCriteria dictionary for more details on matching)
    7. Guide the user to register the authenticators specified in the chosen combination
2. During authentication and transaction confirmation:

    > NOTE
    >
    > `Policy.accepted` is a list of combinations. Each combination indicates a set of criteria which is enough to completely authenticate the current pending operation

    1. Follow the priority of items in `Policy.accepted[][]`. The lists are ordered with highest priority first.
    2. Choose the combination whose criteria best match the features of the currently available authenticators
    3. Collect information about available authenticators
    4. Ignore authenticators which meet the `Policy.disallowed` criteria
    5. Match collected information with the matching criteria described in the policy
    6. Guide the user to authenticate with the authenticators specified in the chosen combination
    7. A pending operation will be approved by the server only after all criteria of a single combination are entirely met

3.2.1 Examples

This section is non-normative.

EXAMPLE 2: Policy matching either a FPS-, or Face Recognition-based Authenticator

```
{
  "accepted":
  [
        [{ "userVerification": 2, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}],
        [{ "userVerification": 16, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}]
  ]
}
```

EXAMPLE 3: Policy matching authenticators implementing FPS and Face Recognition as alternative combination of user verification methods.

```
{
  "accepted":
  [
        [{ "userVerification": 18, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}]
  ]
}
```

Combining these two bit-flags and the flag `USER_VERIFY_ALL` (USER_VERIFY_ALL = 1024) into a single `userVerification` value would match authenticators implementing FPS and Face Recognition as a *mandatory* combination of user verification methods.

EXAMPLE 4: Policy matching authenticators implementing FPS and Face Recognition as mandatory combination of user verification methods.

```
{
  "accepted": [ [{ "userVerification": 1042, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}] ]
}
```

The next example requires two authenticators to be used:

EXAMPLE 5: Policy matching the combination of a FPS based and a Face Recognition based authenticator

```
{
  "accepted":
  [
        [
          { "userVerification": 2, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]},
          { "userVerification": 16, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}
        ]
  ]
}
```

Other criteria can be specified in addition to the `userVerification`:

EXAMPLE 6: Policy requiring the combination of a bound FPS based and a bound Face Recognition based authenticator

```
{
  "accepted":
  [
        [
          { "userVerification": 2, "attachmentHint": 1, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes":
["UAFV1TLV"]},
          { "userVerification": 16, "attachmentHint": 1, "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes":
["UAFV1TLV"]}
        ]
  ]
}
```

The policy for accepting authenticators of vendor with ID `1234` only is as follows:

EXAMPLE 7: Policy accepting all authenticators from vendor with ID 1234

```
{
  "accepted":
  [ [{ "vendorID": "1234", "authenticationAlgorithms": [1, 2, 5, 6], "assertionSchemes": ["UAFV1TLV"]}] ]
}
```

3.3 Version Negotiation

The UAF protocol includes multiple versioned constructs: UAF protocol version, the version of Key Registration Data and Signed Data objects (identified by their respective tags, see [UAFRegistry]), and the ASM version, see [UAFASM].

NOTE

The Key Registration Data and Signed Data objects have to be parsed and verified by the FIDO Server. This verification is only possible if the FIDO Server understands their encoding and the content. Each UAF protocol version supports a set of Key Registration Data and SignedData object versions (called Assertion Schemes). Similarly each of the ASM versions supports a set Assertion Scheme versions.

As a consequence the FIDO UAF Client MUST select the authenticators which will generate the appropriately versioned constructs.

For version negotiation the FIDO UAF Client MUST perform the following steps:

1. Create a set (`FC_Version_Set`) of version pairs, ASM version (`asmVersion`) and UAF Protocol version (`upv`) and add all pairs supported by the FIDO UAF Client into `FC_Version_Set`
   - e.g. `[{upv1, asmVersion1}, {upv2, asmVersion1}, ...]`

   NOTE

   The ASM versions are retrieved from the `AuthenticatorInfo.asmVersion` field. The UAF protocol version is derived from the related `AuthenticatorInfo.assertionScheme` field.

2. Intersect `FC_Version_Set` with the set of `upv` included in UAF Message (i.e. keep only those pairs where the `upv` value is also contained in the UAF Message).
3. Select authenticators which are allowed by the UAF Message Policy. For each authenticator:
   - Construct a set (`Authnr_Version_Set`) of version pairs including authenticator supported `asmVersion` and the compatible `upv(s)`.
     - e.g. `[{upv1, asmVersion1}, {upv2, asmVersion1}, ...]`
   - Intersect `Authnr_Version_Set` with `FC_Version_Set` and select highest version pair from it.
     - Take the pair where the `upv` is highest. In all these pairs leave only the one with highest `asmVersion`.
   - Use the remaining version pair with this authenticator

NOTE

Each version consists of `major` and `minor` fields. In order to compare two versions - compare the Major fields and if they are equal compare the Minor fields.

Each UAF message contains a version field `upv`. UAF Protocol version negotiation is always between FIDO UAF Client and FIDO Server.

> A possible implementation optimization is to have the RP web application itself preemptively convey to the FIDO Server the UAF protocol version(s) (UPV) supported by the FIDO Client. This allows the FIDO Server to craft its UAF messages using the UAF version most preferred by both the FIDO client and server.

3.4 Registration Operation

NOTE

The Registration operation allows the FIDO Server and the FIDO Authenticator to agree on an authentication key.

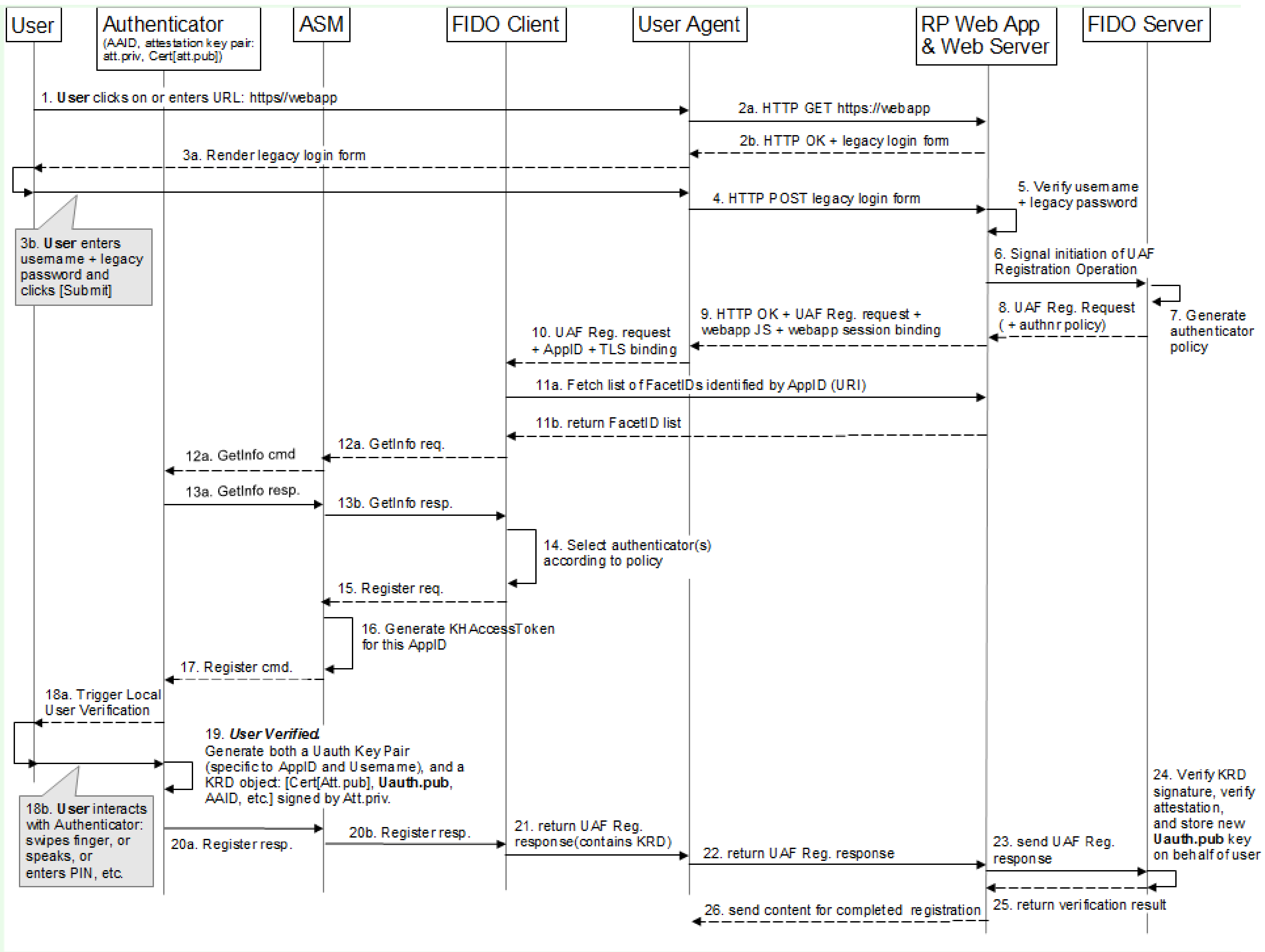

User
Authenticator
(AAID, attestation key pair: att.priv, Cert[att.pub])
ASM
FIDO Client
User Agent
RP Web App & Web Server
FIDO Server
1. User clicks on or enters URL: https//webapp
2a. HTTP GET https://webapp
2b. HTTP OK + legacy login form
3a. Render legacy login form
3b. User enters username + legacy password and clicks [Submit]
4. HTTP POST legacy login form
5. Verify username + legacy password
6. Signal initiation of UAF Registration Operation
7. Generate authenticator policy
8. UAF Reg. Request (+ authnr policy)
9. HTTP OK + UAF Reg. request + webapp JS + webapp session binding
10. UAF Reg. request + AppID + TLS binding
11a. Fetch list of FacetIDs identified by AppID (URI)
11b. return FacetID list
12a. GetInfo req.
12a. GetInfo cmd
13a. GetInfo resp.
13b. GetInfo resp.
14. Select authenticator(s) according to policy
15. Register req.
16. Generate KHAccessToken for this AppID
17. Register cmd.
18a. Trigger Local User Verification
18b. User interacts with Authenticator: swipes finger, or speaks, or enters PIN, etc.
19. User Verified. Generate both a Uauth Key Pair (specific to AppID and Username), and a KRD object: [Cert[Att.pub], Uauth.pub, AAID, etc.] signed by Att.priv.
20a. Register resp.
20b. Register resp.
21. return UAF Reg. response(contains KRD)
22. return UAF Reg. response
23. send UAF Reg. response
24. Verify KRD signature, verify attestation, and store new Uauth.pub key on behalf of user
25. return verification result
26. send content for completed registration

Fig. 6 UAF Registration Sequence Diagram

The steps 11a and 11b and 12 to 13 are not always necessary as the related data could be cached.

The following diagram depicts the cryptographic data flow for the registration sequence.

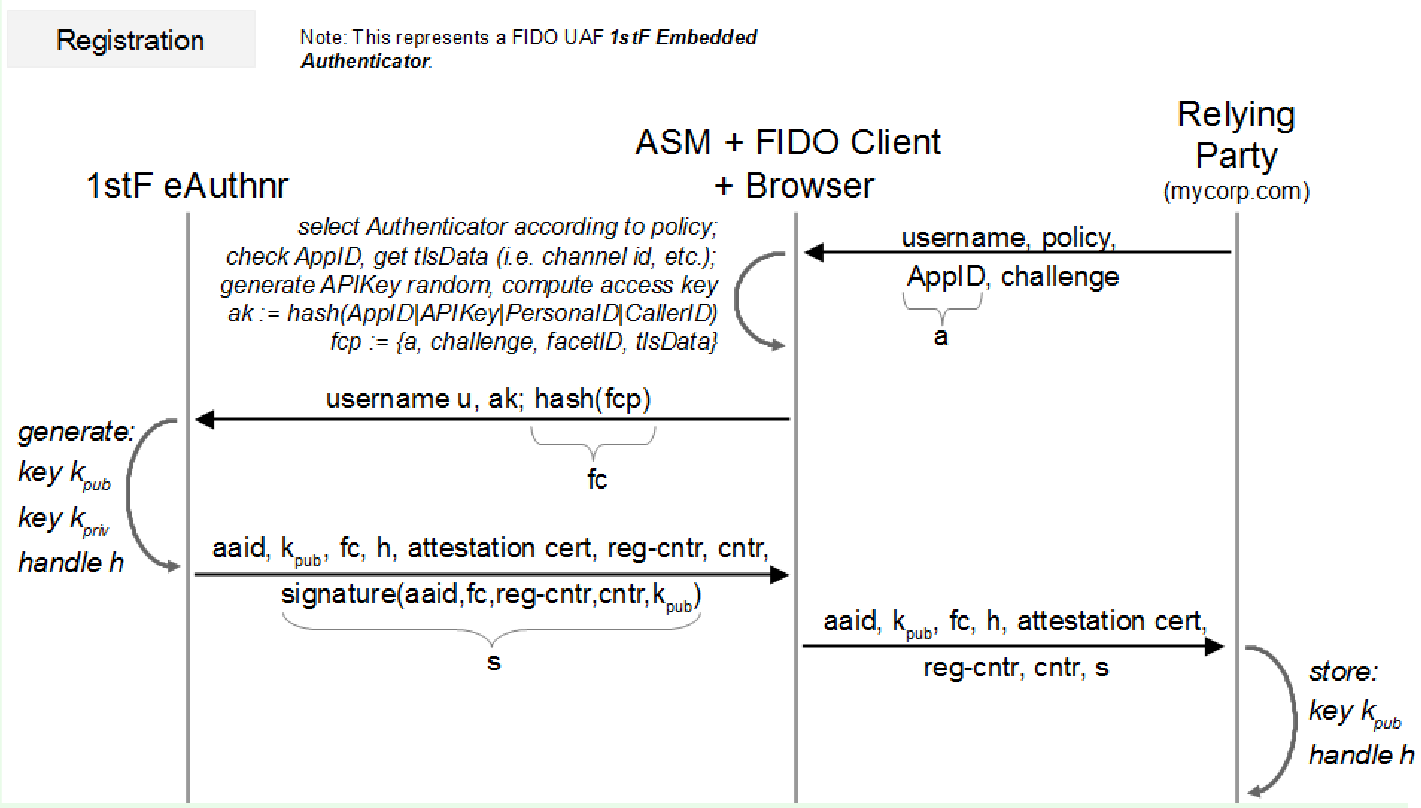

Registration
Note: This represents a FIDO UAF 1stF Embedded Authenticator.
1stF eAuthnr
ASM + FIDO Client + Browser
Relying Party (mycorp.com)
username, policy, AppID, challenge
a
select Authenticator according to policy; check AppID, get tlsData (i.e. channel id, etc.); generate APIKey random, compute access key ak := hash(AppID|APIKey|PersonalD|CallerID) fcp := {a, challenge, facetID, tlsData}
username u, ak; hash(fcp)
fc
generate: key k_pub key k_priv handle h
aaid, k_pub, fc, h, attestation cert, reg-cntr, cntr, signature(aaid,fc,reg-cntr,cntr,k_pub)
s
aaid, k_pub, fc, h, attestation cert, reg-cntr, cntr, s
store: key k_pub handle h

Fig. 7 UAF Registration Cryptographic Data Flow

The FIDO Server sends the `AppID` (see section AppID and FacetID Assertion), the authenticator Policy, the **`ServerChallenge`** and the `Username` to the FIDO UAF Client.

The FIDO UAF Client computes the **`FinalChallengeParams`** (FCP) from the **`ServerChallenge`** and some other values and sends the `AppID`, the `FCH` and the `Username` to the authenticator.

The ASM computes the finalChallengeHash (`FCH`) and calls the authenticator. The authenticator creates a Key Registration Data object (e.g. `TAG_UAFV1_KRD`, see [UAFAuthnrCommands]) containing the hash of `FCH`, the newly generated user public key (UAuth.pub) and some other values and signs it (see section Authenticator Attestation for more details). This KRD object is then cryptographically verified by the FIDO Server.

3.4.1 Registration Request Message

UAF Registration request message is represented as an array of dictionaries. The array MUST contain exactly one dictionary. The request is defined as RegistrationRequest dictionary.

EXAMPLE 8: UAF Registration Request

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Reg",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "ZQ_fRGDH2ar_LvrTM8JnQcl-wfnaOutiyCmpBgmMcuE"
    },
    "challenge": "Yb39SdUhU2B0089pS5L7VBW8afdlplnvR4B1Ana5vk4",
    "username": "alice@website.org",
    "policy": {
        "accepted": [
            [{
                "aaid": ["FFFF#FC03"]
            }],
            [{
                "userVerification": 512,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 4,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 2,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1, 3]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 2,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 32,
                "keyProtection": 2,
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 4,
                "keyProtection": 1,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            }]
        ],
        "disallowed": [
            {
                "userVerification": 512,
                "keyProtection": 16,
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 256,
                "keyProtection": 16
            },
            {
                "aaid":   ["FFFF#FC02"],
                "keyIDs": ["RfY_RDhsf4z5PCOhnZExMeVloZZmK0hxaSi10tkY_c4"]
            }
        ]
    }
}]
```

3.4.2 RegistrationRequest dictionary

RegistrationRequest contains a single, versioned, registration request.

WebIDL

```
dictionary RegistrationRequest {
    required OperationHeader header;
    required ServerChallenge challenge;
    required DOMString       username;
    required Policy          policy;
};
```

3.4.2.1 Dictionary `RegistrationRequest` Members

`header` of type required OperationHeader
: Operation header. `Header.op` MUST be "Reg"

`challenge` of type required ServerChallenge
: Server-provided challenge value

`username` of type required DOMString
: `string[1..128]`

  A human-readable user name intended to allow the user to distinguish and select from among different accounts at the same relying party.

`policy` of type required Policy
: Describes which types of authenticators are acceptable for this registration operation

3.4.3 AuthenticatorRegistrationAssertion dictionary

Contains the authenticator's response to a RegistrationRequest message:

WebIDL

```
dictionary AuthenticatorRegistrationAssertion {
    required DOMString                      assertionScheme;
    required DOMString                      assertion;
    DisplayPNGCharacteristicsDescriptor[] tcDisplayPNGCharacteristics;
    Extension[]                             exts;
};
```

3.4.3.1 Dictionary `AuthenticatorRegistrationAssertion` Members

`assertionScheme` of type required DOMString
: The name of the Assertion Scheme used to encode the `assertion`. See UAF Supported Assertion Schemes for details.

> NOTE
>
> This assertionScheme is not part of a signed object and hence considered the *suspected* assertionScheme.

`assertion` of type required DOMString
: `base64url(byte[1..4096])` Contains the `TAG_UAFV1_REG_ASSERTION` object containing the assertion scheme specific KeyRegistrationData (KRD) object which in turn contains the newly generated `UAuth.pub` and is signed by the Attestation Private Key.

: This assertion MUST be generated by the authenticator and it MUST be used only in this Registration operation. The format of this assertion can vary from one assertion scheme to another (e.g. for "UAFV1TLV" assertion scheme it MUST be `TAG_UAFV1_KRD`).

`tcDisplayPNGCharacteristics` of type array of DisplayPNGCharacteristicsDescriptor
: Supported transaction PNG type [FIDOMetadataStatement]. For the definition of the DisplayPNGCharacteristicsDescriptor structure See [FIDOMetadataStatement].

`exts` of type array of *Extension*
: Contains Extensions prepared by the authenticator

3.4.4 Registration Response Message

A UAF Registration response message is represented as an array of dictionaries. Each dictionary contains a registration response for a specific protocol version. The array MUST NOT contain two dictionaries of the same protocol version. The response is defined as RegistrationResponse dictionary.

EXAMPLE 9: Registration Response

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Reg",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "ZQ_fRGDH2ar_LvrTM8JnQcl-wfnaOutiyCmpBgmMcuE"
    },

    "fcParams": "eyJmYWNldElEIjoiaHR0cHM6Ly91YWYuZXhhbXBsZS5jb20iLCJhcHBJRCI6Imh0dHBzOi8vdWFmLmV4YW1
        wbGUuY29tL2ZhY2V0cy5qc29uIiwiY2hhbGxlbmdlIjoiWWIzOVNkVWhVMkIwMDg5cFM1TDdWQlc4YWZkbHBsbnZSNEI
        xQW5hNXZrNCIsImNoYW5uZWxCaW5kaW5nIjp7fX0",

    "assertions": [{
        "assertionScheme": "UAFV1TLV",
        "assertion": "AT73AgM-sQALLgkARkZGRiNGQzAzDi4HAAEAAQIAAAEKLiAAbkZZjz4ysihP9vVgevgoH8SEV2JITk
        TxKFfsKbAiofQJLiAA2onnfjAyZ0Uc3GL4VyOEdRgIkz7qogqzmITcEPLovP0NLggAAAAAAAEAAAAMLkEABNfRNiA1Hp
        QSfrvD_9Qug55Vw2oaKmjgbC8TdiFXGZ6hjP7jYHV0GtYqO0EvrRRvsNBbnyhXUpq6P_iNq9laDGsHPj4CBi5GADBEAi
        C57WZpOHWCTil_IuAYSEfuj3zgyY6KFp_rgNw5kO5OwwIgiZbTG6ZmY3T6ZqvdeOxcA6FBgn6YLCncK-Wyk0XVY8kFLv
        ABMIIB7DCCAZKgAwIBAgIBBDAKBggqhkjOPQQDAjBwMQswCQYDVQQGEwJOWjEjMCEGA1UEAwwaRklETyBDb25mb3JtYW
        NlIFRlc3QgVG9vbHMxFjAUBgNVBAoMDUZJRE8gQWxsaWFuY2UxJDAiBgNVBAsMG0NlcnRpZmljYXRpb24gV29ya2luZy
        BHcm91cDAeFw0xNzAyMjkxNDMxMTJaFw0yMjAyMjgxNDMxMTJaMHAxCzAJBgNVBAYTAk5aMSMwIQYDVQQDDBpGSURPIE
        NvbmZvcm1hY2UgVGVzdCBUb29sczEWMBQGA1UECgwNRklETyBBbGxpYW5jZTEkMCIGA1UECwwbQ2VydGlmaWNhdGlvbi
        BXb3JraW5nIEdyb3VwMFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEZaRKB92Abz8nqEZFf8Xz84ajfA7lLjt4O-i2wq
        1FnD_svIyTyEYm_QbOYJC0GUVE-L6V7OiD8K9Z4PfiBFRO-qMdMBswDAYDVR0TBAUwAwEB_zALBgNVHQ8EBAMCBsAwCg
        YIKoZIzj0EAwIDSAAwRQIgWDy1Oxu8PT6diGXycY0rxb1e16omexfQ-Iv9KOg5p9cCIQCFPPCArmDh3-EyxI_OaZFPvW
        2kG2hQBmi9PnC-bBrfYQ"
    }]
```

```
  }]
```

NOTE

Line breaks in fcParams have been inserted for improving readability.

3.4.5 RegistrationResponse dictionary

Contains all fields related to the registration response.

WebIDL

```
dictionary RegistrationResponse {
    required OperationHeader                      header;
    required DOMString                            fcParams;
    required AuthenticatorRegistrationAssertion[] assertions;
};
```

3.4.5.1 Dictionary `RegistrationResponse` Members

`header` of type required OperationHeader
: `Header.op` MUST be "Reg".

`fcParams` of type required DOMString
: The base64url-encoded serialized [RFC4627] `FinalChallengeParams` using UTF8 encoding (see FinalChallengeParams dictionary) or alternatively it contains the serialized `CollectedClientData` object. In both cases, all parameters required for the server to verify the Final Challenge are included.

`assertions` of type array of required AuthenticatorRegistrationAssertion
: Response data for each Authenticator being registered.

3.4.6 Registration Processing Rules

3.4.6.1 Registration Request Generation Rules for FIDO Server

The policy contains a two-dimensional array of allowed `MatchCriteria` (see Policy). This array can be considered a list (first dimension) of sets (second dimension) of authenticators (identified by `MatchCriteria`). All authenticators in a specific set MUST be registered simultaneously in order to match the policy. But any of those sets in the list are valid, as the list elements are alternatives.

The FIDO Server MUST follow the following steps:

1. Construct appropriate authentication policy `p`
    1. for each set of alternative authenticators do
        1. Create an array of MatchCriteria objects, containing the set of authenticators to be registered simultaneously that need to be identified by *separate* MatchCriteria objects `m`.
            1. For each collection of authenticators `a` to be registered simultaneously that can be identified by the *same rule*, create a MatchCriteria object `m`, where
                - `m.aaid` MAY be combined with (one or more of) `m.keyIDs`, `m.attachmentHint`, `m.authenticatorVersion`, and `m.exts`, but `m.aaid` MUST NOT be combined with any other match criteria field.
                - If `m.aaid` is not provided - both `m.authenticationAlgorithms` and `m.assertionSchemes` MUST be provided
            2. Add `m` to `v`, e.g. `v[j+1]=m`.
        2. Add `v` to `p.allowed`, e.g. `p.allowed[i+1]=v`
    2. Create MatchCriteria objects `m[]` for all disallowed Authenticators.
        1. For each already registered AAID for the current user
            1. Create a MatchCriteria object `m` and add AAID and corresponding KeyIDs to `m.aaid` and `m.KeyIDs`.

               The FIDO Server MUST include already registered AAIDs and KeyIDs into field `p.disallowed` to hint that the client should not register these again.
        2. Create a MatchCriteria object `m` and add the AAIDs of all disallowed Authenticators to `m.aaid`.

           The status (as provided in the metadata TOC (Table-of-Contents file) [FIDOMetadataService]) of some authenticators might be unacceptable. Such authenticators SHOULD be included in `p.disallowed`.

3. If needed - create MatchCriteria `m` for other disallowed criteria (e.g. unsupported authenticationAlgs)
4. Add all `m` to `p.disallowed`.

2. Create a `RegistrationRequest` object `r` with appropriate `r.header` for each supported version, and
    1. FIDO Servers SHOULD NOT assume any implicit integrity protection of `r.header.serverData`.

       FIDO Servers that depend on the integrity of `r.header.serverData` SHOULD apply and verify a cryptographically secure Message Authentication Code (MAC) to serverData and they SHOULD also cryptographically bind serverData to the related message, e.g. by re-including `r.challenge`, see also section ServerData and KeyHandle.

       NOTE

       All other FIDO components (except the FIDO server) will treat `r.header.serverData` as an opaque value. As a consequence the FIDO server can implement any suitable cryptographic protection method.

    2. Generate a random challenge and assign it to `r.challenge`
    3. Assign the username of the user to be registered to `r.username`
    4. Assign `p` to `r.policy`.
    5. Append `r` to the array `o` of message with various versions (`RegistrationRequest`)
3. Send `o` to the FIDO UAF Client

3.4.6.2 Registration Request Processing Rules for FIDO UAF Clients

The FIDO UAF Client MUST perform the following steps:

1. Choose the message `m` with upv set to the appropriate version number.
2. Parse the message `m`
3. If a mandatory field in UAF message is not present or a field doesn't correspond to its type and value - reject the operation
4. Filter the available authenticators with the given policy and present the filtered authenticators to User. Make sure to not include already registered authenticators for this user specified in `RegRequest.policy.disallowed[].keyIDs`
5. Obtain `FacetID` of the requesting Application. If the `AppID` is missing or empty, set the `AppID` to the `FacetID`.

   Verify that the `FacetID` is authorized for the `AppID` according to the algorithms in [FIDOAppIDAndFacets].

    - If the `FacetID` of the requesting Application is not authorized, reject the operation
6. Obtain TLS data if it is available
7. Create a **`FinalChallengeParams`** structure `fcp` and set `fcp.appID`, `fcp.challenge`, `fcp.facetID`, and `fcp.channelBinding` appropriately. Serialize [RFC4627] fcp using UTF8 encoding and base64url encode it.
    - `FinalChallenge = base64url(serialize(utf8encode(fcp)))`
8. For each authenticator that matches UAF protocol version (see section Version Negotiation) and user agrees to register:
    1. Add `AppID`, `Username`, `FinalChallenge`, `AttestationType` and all other required fields to the ASMRequest [UAFASM].

       The FIDO UAF Client MUST follow the server policy and find the single preferred attestation type. A single attestation type MUST be provided to the ASM.

    2. Send the ASMRequest to the ASM. If the ASM returns an error, handle that error appropriately. The status code returned by the ASM [UAFASM] must be mapped to a status code defined in [UAFAppAPIAndTransport] as specified in section 3.4.6.2.1 Mapping ASM Status Codes to ErrorCode.

3.4.6.2.1 Mapping ASM Status Codes to ErrorCode

ASMs are returning a status code in their responses to the FIDO Client. The FIDO Client needs to act on those responses and also map the status code returned the ASM [UAFASM] to an ErrorCode specified in [UAFAppAPIAndTransport].

The mapping of ASM status codes to ErrorCode is specified here:

ASM Status Code	ErrorCode	Comment

UAF_ASM_STATUS_OK	NO_ERROR	Pass-through success status.
UAF_ASM_STATUS_ERROR	UNKNOWN	Map to UNKNOWN.
UAF_ASM_STATUS_ACCESS_DENIED	AUTHENTICATOR_ACCESS_DENIED	Map to AUTHENTICATOR_ACCESS_DENIED
UAF_ASM_STATUS_USER_CANCELLED	USER_CANCELLED	Pass-through status code.
UAF_ASM_STATUS_CANNOT_RENDER_TRANSACTION_CONTENT	INVALID_TRANSACTION_CONTENT	Map to INVALID_TRANSACTION_CONTENT. This code indicates a problem to be resolved by the entity providing the transaction text.
UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY	KEY_DISAPPEARED_PERMANENTLY	Pass-through status code. It indicates that the Uauth key disappeared permanently and the RP App might want to trigger re-registration of the authenticator.
UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED	NO_SUITABLE_AUTHENTICATOR or WAIT_USER_ACTION	Retry operation with other suitable authenticators and map to NO_SUITABLE_AUTHENTICATOR if the problem persists. Return WAIT_USER_ACTION if being called while retrying.
UAF_ASM_STATUS_USER_NOT_RESPONSIVE	USER_NOT_RESPONSIVE	Pass-through status code. The RP App might want to retry the operation once the user pays attention to the application again.
UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES	INSUFFICIENT_AUTHENTICATOR_RESOURCES	The FIDO Client SHALL try other authenticators matching the policy. If none exist, pass-through status code.
UAF_ASM_STATUS_USER_LOCKOUT	USER_LOCKOUT	Pass-through status code.
UAF_ASM_STATUS_USER_NOT_ENROLLED	USER_NOT_ENROLLED	Pass-through status code.
UAF_ASM_STATUS_SYSTEM_INTERRUPTED	SYSTEM_INTERRUPTED	Pass-through status code.
Any other status code	UNKNOWN	Map any unknown error code to UNKNOWN. This might happen when a FIDO Client communicates with an ASM implementing a newer UAF specification than the FIDO Client.

3.4.6.3 Registration Request Processing Rules for FIDO Authenticator

See [UAFAuthnrCommands], section "Register Command".

3.4.6.4 Registration Response Generation Rules for FIDO UAF Client

The FIDO UAF Client MUST follow the steps:

1. Create a RegistrationResponse message
2. Copy RegistrationRequest.header into RegistrationResponse.header

> NOTE
>
> When the appID provided in the request was empty, the FIDO Client must set the appID in this header to the facetID (see [FIDOAppIDAndFacets]).
>
> The header might include extensions. Extension specific rules might affect the copy process. Those rules are defined in the related section in [UAFRegistry].

3. Set `RegistrationResponse.fcParams` to `FinalChallenge` (base64url encoded serialized and utf8 encoded FinalChallengeParams)
4. Append the response from each Authenticator into `RegistrationResponse.assertions`
5. Send `RegistrationResponse` message to FIDO Server

3.4.6.5 Registration Response Processing Rules for FIDO Server

NOTE

The following processing rules assume that Authenticator supports "UAFV1TLV" assertion scheme. Currently "UAFV1TLV" is the only defined and supported assertion scheme. When a new assertion scheme is added to UAF protocol - this section will be extended with corresponding processing rules.

The FIDO Server MUST follow the steps:

1. Parse the message
   1. If protocol version (`RegistrationResponse.header.upv`) is not supported – reject the operation
   2. If a mandatory field in UAF message is not present or a field doesn't correspond to its type and value - reject the operation
2. Verify that `RegistrationResponse.header.serverData`, if used, passes any implementation-specific checks against its validity. See also section ServerData and KeyHandle.
3. base64url decode `RegistrationResponse.fcParams` and convert it into an object (`fcp`)
4. If this `fcp` object is a **`FinalChallengeParams`** object, then verify each field in `fcp` and make sure it is valid:
   1. Make sure `fcp.appID` corresponds to the one stored by the FIDO Server

      NOTE

      When the `appID` provided in the request was empty, the FIDO Client must set the `appID` to the facetID (see [FIDOAppIDAndFacets]). In this case, the Uauth key cannot be used by other application facets.

   2. Make sure `fcp.facetID` is in the list of trusted FacetIDs [FIDOAppIDAndFacets]
   3. Make sure `fcp.channelBinding` is as expected (see section ChannelBinding dictionary)

      NOTE

      There might be legitimate situations in which some methods of channel binding fail (see section 4.3.4 TLS Binding).

   4. Make sure `fcp.challenge` has really been generated by the FIDO Server for this operation and it is not expired
   5. Reject the response if any of these checks fails
5. If this `fcp` object is a **`CollectedClientData`** object, then verify each field in `fcp` and make sure it is valid:
   1. Make sure `fcp.origin` is considered a legitimate origin for this registration request.
   2. Make sure `fcp.tokenBinding` is as expected (see field `cid_pubkey` in section ChannelBinding dictionary)

      NOTE

      There might be legitimate situations in which some methods of channel binding fail (see section 4.3.4 TLS Binding).

   3. Make sure `fcp.challenge` has really been generated by the FIDO Server for this operation and it is not expired
   4. Reject the response if any of these checks fails
6. For each assertion `a` in `RegistrationResponse.assertions`
   1. Parse data from `a.assertion` assuming it is encoded according to the suspected assertion scheme `a.assertionScheme` and make sure it contains all mandatory fields (indicated in Authenticator Metadata) it is supposed to have, verify that the assertion has a valid syntax, and verify that the assertion doesn't include unknown fields (identified by TAGs or IDs) that belong to extensions marked as "fail-if-unknown" set to true [FIDOMetadataStatement].
      - If it doesn't - continue with next assertion
   2. if `a.assertion` contains an object of type `TAG_UAFV1_REG_ASSERTION`, then

1. Retrieve the AAID from the assertion.

   > NOTE
   >
   > The AAID in `TAG_UAFV1_KRD` is contained in `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_AAID`.

2. Verify that `a.assertionScheme` matches `Metadata(AAID).assertionScheme`
   - If it doesn't match - continue with next assertion
3. Verify that the AAID indeed matches the policy specified in the registration request.

   > NOTE
   >
   > Depending on the policy (e.g. in the case of AND combinations), it might be required to evaluate other assertions included in this `RegistrationResponse` in order to determine whether this AAID matches the policy.

   - If it doesn't match the policy - continue with next assertion
4. Locate authenticator-specific authentication algorithms from the authenticator metadata [FIDOMetadataStatement] using the AAID.
5. If `fcp` is of type **`FinalChallengeParams`**, then hash `RegistrationResponse.fcParams` using hashing algorithm suitable for this authenticator type. Look up the hash algorithm in authenticator metadata, field `AuthenticationAlgs`. It is the hash algorithm associated with the first entry related to a constant with prefix ALG_SIGN.
   - `FCHash = hash(RegistrationResponse.fcParams)`
6. If `fcp` is of type **`CollectedClientData`**, then hash `RegistrationResponse.fcParams` using hashing algorithm specified in `fcp.hashAlg`.
   - `FCHash = hash(RegistrationResponse.fcParams)`
7. if `a.assertion.TAG_UAFV1_REG_ASSERTION` contains `TAG_UAFV1_KRD` as first element:
   1. Obtain `Metadata(AAID).AttestationType` for the AAID and make sure that `a.assertion.TAG_UAFV1_REG_ASSERTION` contains the most preferred attestation tag specified in field `MatchCriteria.attestationTypes` in `RegistrationRequest.policy` (if this field is present).
      - If `a.assertion.TAG_UAFV1_REG_ASSERTION` doesn't contain the preferred attestation - it is RECOMMENDED to skip this assertion and continue with next one
   2. Make sure that `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.FinalChallengeHash` == `FCHash`
      - If comparison fails - continue with next assertion
   3. Obtain `Metadata(AAID).AuthenticatorVersion` for the AAID and make sure that it is lower or equal to `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.AuthenticatorVersion`.
      - If `Metadata(AAID).AuthenticatorVersion` is higher (i.e. the authenticator firmware is outdated), it is RECOMMENDED to assume increased risk. See sections "StatusReport dictionary" and "Metadata TOC object Processing Rules" in [FIDOMetadataService] for more details on this.
   4. Check whether `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.RegCounter` is acceptable, i.e. it is either not supported (value is 0 or the field isKeyRestricted is set to 'false' in the related Metadata Statement) or it is not exceedingly high
      - If `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.RegCounter` is exceedingly high, this assertion might be skipped and processing will continue with next one
   5. If `a.assertion.TAG_UAFV1_REG_ASSERTION` contains `ATTESTATION_BASIC_FULL` tag
      1. If entry `AttestationRootCertificates` for the AAID in the metadata [FIDOMetadataStatement] contains at least one element:
         1. Obtain contents of all `TAG_ATTESTATION_CERT` tags from `a.assertion.TAG_UAFV1_REG_ASSERTION.ATTESTATION_BASIC_FULL` object. The occurrences are ordered (see [UAFAuthnrCommands]) and represent the attestation certificate followed by the related certificate chain.
         2. Obtain all entries of `AttestationRootCertificates` for the AAID in authenticator Metadata, field `AttestationRootCertificates`.
         3. Verify the attestation certificate and the entire certificate chain up to the Attestation Root Certificate using Certificate Path Validation as specified in [RFC5280]
            - If verification fails – continue with next assertion
         4. Verify `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.ATTESTATION_BASIC_FULL.Signature` using the attestation certificate (obtained before).
            - If verification fails – continue with next assertion

            2. If `Metadata(AAID).AttestationRootCertificates` for this AAID is empty - continue with next assertion
            3. Mark assertion as positively verified
         6. If `a.assertion.TAG_UAFV1_REG_ASSERTION` contains an object of type `ATTESTATION_BASIC_SURROGATE`
            1. There is no real attestation for the AAID, so we just assume the AAID is the real one.
            2. If entry `AttestationRootCertificates` for the AAID in the metadata is empty
               - Verify `a.assertion.TAG_UAFV1_REG_ASSERTION.ATTESTATION_BASIC_SURROGATE.Signature` using `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_PUB_KEY`
                  - If verification fails – continue with next assertion
            3. If entry `AttestationRootCertificates` for the AAID in the metadata is not empty - continue with next assertion (as the AAID obviously is expecting a different attestation method).
            4. Mark assertion as positively verified
         7. If `a.assertion.TAG_UAFV1_REG_ASSERTION` contains an object of type `ATTESTATION_ECDAA`
            1. If entry `ecdaaTrustAnchors` for the AAID in the metadata [FIDOMetadataStatement] contains at least one element:
               1. For each of the `ecdaaTrustAnchors` entries, perform the ECDAA Verify operation as specified in [FIDOEcdaaAlgorithm].
                  - If verification fails – continue with next `ecdaaTrustAnchors` entry
               2. If no ECDAA Verify operation succeeded – continue with next assertion
            2. If `Metadata(AAID).ecdaaTrustAnchors` for this AAID is empty - continue with next assertion
            3. Mark assertion as positively verified and the authenticator indeed is of model as indicated by the AAID.
         8. If `a.assertion.TAG_UAFV1_REG_ASSERTION` contains another `TAG_ATTESTATION` tag - verify the attestation by following appropriate processing rules applicable to that attestation. Currently this document defines the processing rules for Basic Attestation and direct anonymous attestation (ECDAA).
      8. if `a.assertion.TAG_UAFV1_REG_ASSERTION` contains a different object than `TAG_UAFV1_KRD` as first element, then follow the rules specific to that object.
      9. Extract `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.PublicKey` into PublicKey, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.KeyID` into KeyID, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.SignCounter` into SignCounter, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_ASSERTION_INFO.authenticatorVersion` into AuthenticatorVersion, `a.assertion.TAG_UAFV1_REG_ASSERTION.TAG_UAFV1_KRD.TAG_AAID` into AAID.
   3. if `a.assertion` doesn't contain an object of type `TAG_UAFV1_REG_ASSERTION`, then then follow the respective processing rules of that assertion format if supported - otherwise skip this assertion.
7. For each positively verified assertion `a`
   - Store PublicKey, KeyID, SignCounter, AuthenticatorVersion, AAID and `a.tcDisplayPNGCharacteristics` into a record associated with the user's identity. If an entry with the same pair of AAID and KeyID already exists then fail (should never occur).

3.5 Authentication Operation

NOTE

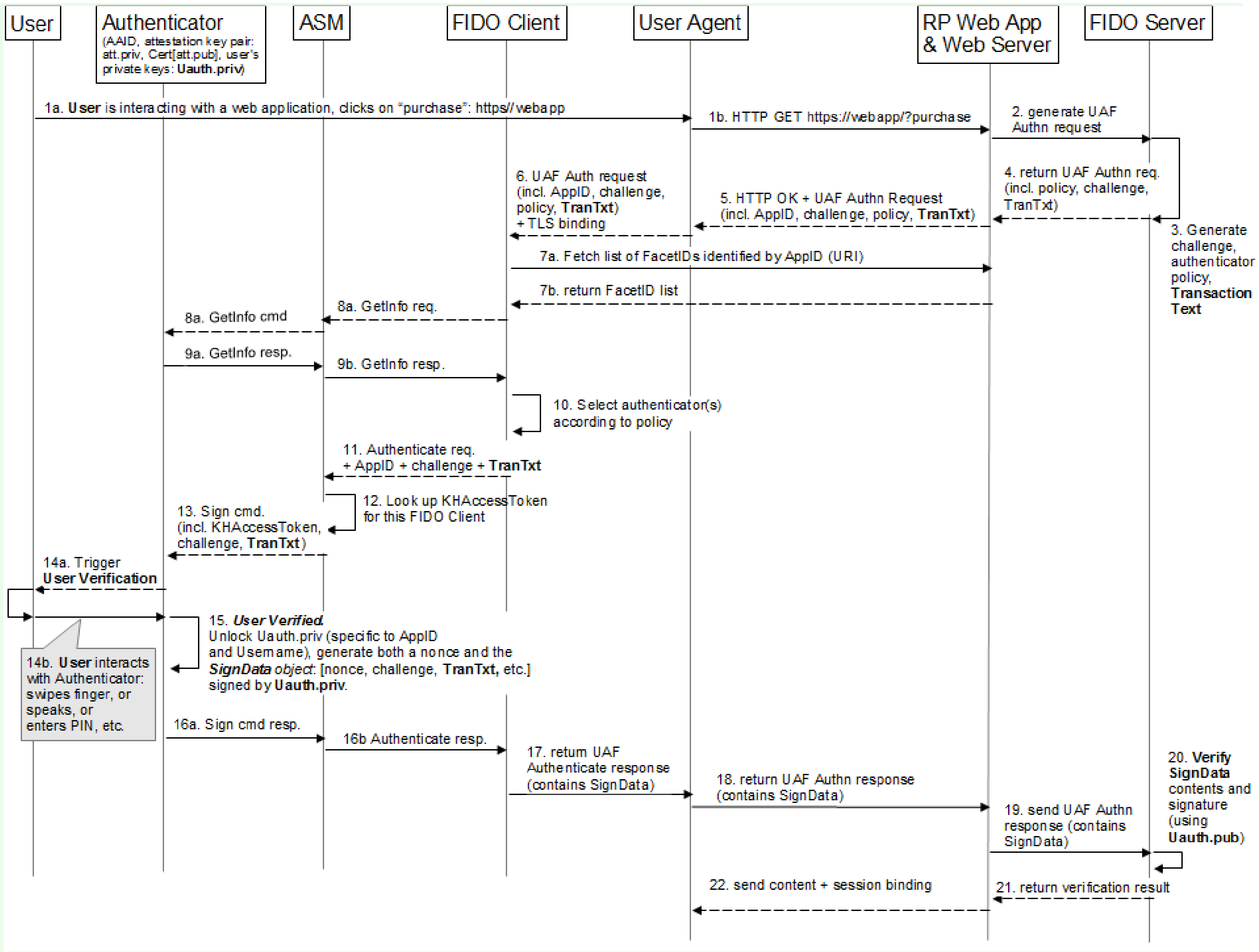

User
Authenticator (AAID, attestation key pair: att.priv, Cert[att.pub], user's private keys: Uauth.priv)
ASM
FIDO Client
User Agent
RP Web App & Web Server
FIDO Server
1a. User is interacting with a web application, clicks on "purchase": https//webapp
1b. HTTP GET https://webapp/?purchase
2. generate UAF Authn request
3. Generate challenge, authenticator policy, Transaction Text
4. return UAF Authn req. (incl. policy, challenge, TranTxt)
5. HTTP OK + UAF Authn Request (incl. AppID, challenge, policy, TranTxt)
6. UAF Auth request (incl. AppID, challenge, policy, TranTxt) + TLS binding
7a. Fetch list of FacetIDs identified by AppID (URI)
7b. return FacetID list
8a. GetInfo req.
8a. GetInfo cmd
9a. GetInfo resp.
9b. GetInfo resp.
10. Select authenticator(s) according to policy
11. Authenticate req. + AppID + challenge + TranTxt
12. Look up KHAccessToken for this FIDO Client
13. Sign cmd. (incl. KHAccessToken, challenge, TranTxt)
14a. Trigger User Verification
14b. User interacts with Authenticator: swipes finger, or speaks, or enters PIN, etc.
15. User Verified. Unlock Uauth.priv (specific to AppID and Username), generate both a nonce and the SignData object: [nonce, challenge, TranTxt, etc.] signed by Uauth.priv.
16a. Sign cmd resp.
16b Authenticate resp.
17. return UAF Authenticate response (contains SignData)
18. return UAF Authn response (contains SignData)
19. send UAF Authn response (contains SignData)
20. Verify SignData contents and signature (using Uauth.pub)
21. return verification result
22. send content + session binding

Fig. 8 UAF Authentication Sequence Diagram

The steps 7a and 7a and 8 to 9 are not always necessary as the related data could be cached.

The TransactionText (TranTxt) is only required in the case of Transaction Confirmation (see section 3.5.1 Transaction dictionary), it is absent in the case of a pure Authenticate operation.

During this operation, the FIDO Server asks the FIDO UAF Client to authenticate user with server-specified authenticators, and return an authentication response.

In order for this operation to succeed, the authenticator and the relying party must have a previously shared registration.

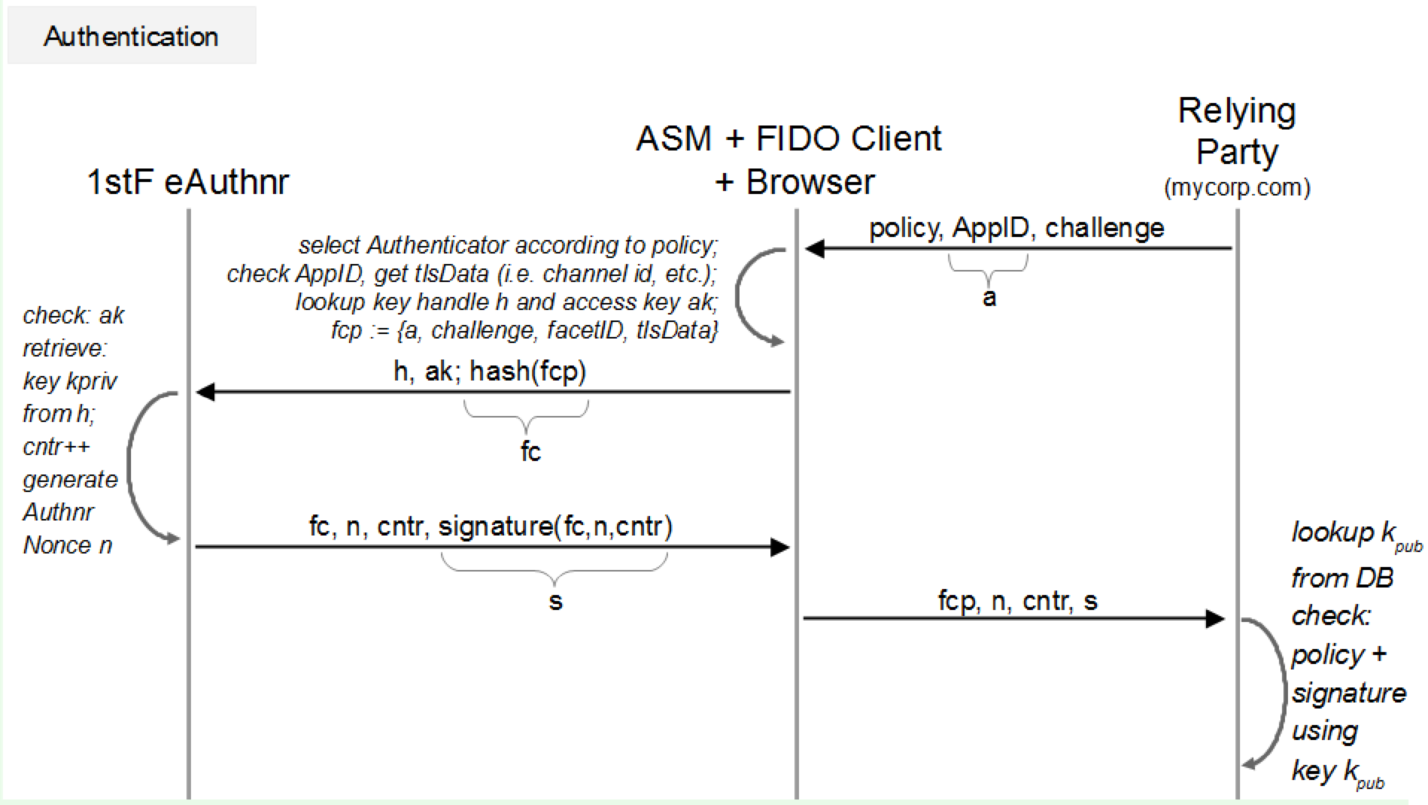

Authentication
1stF eAuthnr
ASM + FIDO Client + Browser
Relying Party (mycorp.com)
policy, AppID, challenge
a
select Authenticator according to policy; check AppID, get tlsData (i.e. channel id, etc.); lookup key handle h and access key ak; fcp := {a, challenge, facetID, tlsData}
h, ak; hash(fcp)
fc
check: ak retrieve: key kpriv from h; cntr++ generate Authnr Nonce n
fc, n, cntr, signature(fc,n,cntr)
s
fcp, n, cntr, s
lookup kpub from DB check: policy + signature using key kpub

Fig. 9 UAF Authentication Cryptographic Data Flow

Diagram of cryptographic flow:

The FIDO Server sends the `AppID` (see [FIDOAppIDAndFacets]), the authenticator policy and the **`ServerChallenge`** to the FIDO UAF Client.

The FIDO UAF Client computes the hash of the **`FinalChallengeParams`**, produced from the **`ServerChallenge`** and other values, as described in this document, and sends the `AppID` and hashed `FinalChallengeParams` to the Authenticator.

The authenticator creates the `SignedData` object (see `TAG_UAFV1_SIGNED_DATA` in [UAFAuthnrCommands]) containing the hash of the final challenge parameters, and some other values and signs it using the `UAuth.priv` key. This assertion is then cryptographically verified by the FIDO Server.

3.5.1 Transaction dictionary

Contains the Transaction Content provided by the FIDO Server:

WebIDL

```
dictionary Transaction {
    required DOMString                  contentType;
    required DOMString                  content;
    DisplayPNGCharacteristicsDescriptor tcDisplayPNGCharacteristics;
};
```

*3.5.1.1 Dictionary **`Transaction`** Members*

`contentType` of type required DOMString

Contains the MIME Content-Type supported by the authenticator according its metadata statement (see [FIDOMetadataStatement]).

NOTE

For best interoperability, at least the values `text/plain` and/or `image/png` should be supported.

`content` of type required DOMString

`base64url(byte[1...])`

Contains the base64url encoded transaction content according to the `contentType` to be shown to the user.

If `contentType` is "text/plain" then the content MUST be the base64url encoding of the UTF8 [RFC3629] encoded text with a maximum length of 200 characters. The Authenticator SHALL display the default character if it doesn't know how to display the intended one.

If contentType is "image/png" or any other type, then it must be base64url encoded (i.e. the base64url encoded PNG [PNG] image in the case of "image/png").

`tcDisplayPNGCharacteristics` of type DisplayPNGCharacteristicsDescriptor
Transaction content PNG characteristics. For the definition of the DisplayPNGCharacteristicsDescriptor structure See [FIDOMetadataStatement]. This field MUST be present if the contentType is "image/png".

3.5.2 Authentication Request Message

UAF Authentication request message is represented as an array of dictionaries. The array MUST contain exactly one dictionary. The request is defined as AuthenticationRequest dictionary.

EXAMPLE 10: UAF Authentication Request

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Auth",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "mz0YSKHLXDd_StbbDINZaRvW3Pa6sxrNMPYp2gOs3-Y"
    },
    "challenge": "4D8eUxdSzQ_Rbk7Gf0SooK7Xr9O2LU-g150stOpK0go",
    "policy": {
        "accepted": [
            [{
                "aaid": ["FFFF#FC01"]
            }],
            [{
                "userVerification": 512,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 4,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 2,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1, 3]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 2,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 32,
                "keyProtection": 2,
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 4,
                "keyProtection": 1,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            }]
        ]
    }
}]
```

EXAMPLE 11: UAF Authentication Request with text/plain Transaction

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Auth",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "DLbLt14MdqvuS4fESNCAPJmS8yIKPJ3Ad0xb1cMyu2Q"
    },
    "challenge": "vui9bgJ453N_kWlZbiwMz9q6uPvssjnXjkHYzk-LurY",
    "transaction": [
        {
            "contentType": "text/plain",
            "content": "VHJhbnNmZXIgMjAwMCQgdG8gRXZl"
        }
    ],
    "policy": {
        "accepted": [
            [{
                "aaid": ["FFFF#FC01"]
            }],
            [{
                "userVerification": 512,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1],
                "assertionSchemes": ["UAFV1TLV"]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 1,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 4,
                "tcDisplay": 1,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 4,
                "keyProtection": 2,
                "tcDisplay": 1,
                "authenticationAlgorithms": [1, 3]
            }],
            [{
                "userVerification": 2,
                "keyProtection": 2,
                "authenticationAlgorithms": [2]
            }],
            [{
                "userVerification": 32,
                "keyProtection": 2,
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 2,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            },
            {
                "userVerification": 4,
                "keyProtection": 1,
                "authenticationAlgorithms": [1, 3],
                "assertionSchemes": ["UAFV1TLV"]
            }]
        ]
    }
}]
```

3.5.3 AuthenticationRequest dictionary

Contains the UAF Authentication Request Message:

WebIDL

```
dictionary AuthenticationRequest {
    required OperationHeader header;
    required ServerChallenge challenge;
    Transaction[]            transaction;
    required Policy          policy;
};
```

3.5.3.1 Dictionary *`AuthenticationRequest`* Members

`header` of type required OperationHeader
: `Header.op` MUST be "Auth"

`challenge` of type required ServerChallenge
: Server-provided challenge value

`transaction` of type array of *Transaction*
: Transaction data to be explicitly confirmed by the user.

  The list contains the same transaction content in various content types and various image sizes. Refer to [FIDOMetadataStatement] for more information about Transaction Confirmation Display characteristics.

`policy` of type required Policy
: Server-provided policy defining what types of authenticators are acceptable for this authentication operation.

3.5.4 AuthenticatorSignAssertion dictionary

Represents a response generated by a specific Authenticator:

WebIDL

```
dictionary AuthenticatorSignAssertion {
    required DOMString assertionScheme;
    required DOMString assertion;
    Extension[]        exts;
};
```

3.5.4.1 Dictionary *`AuthenticatorSignAssertion`* Members

`assertionScheme` of type required DOMString
: The name of the Assertion Scheme used to encode `assertion`. See UAF Supported Assertion Schemes for details.

  NOTE

  This assertionScheme is not part of a signed object and hence considered the *suspected* assertionScheme.

`assertion` of type required DOMString
: `base64url(byte[1..4096])` Contains the assertion containing a signature generated by `UAuth.priv`, i.e. `TAG_UAFV1_AUTH_ASSERTION`.

`exts` of type array of *Extension*
: Any extensions prepared by the Authenticator

3.5.5 AuthenticationResponse dictionary

Represents the response to a challenge, including the set of signed assertions from registered authenticators.

WebIDL

```
dictionary AuthenticationResponse {
    required OperationHeader              header;
    required DOMString                    fcParams;
    required AuthenticatorSignAssertion[] assertions;
};
```

3.5.5.1 Dictionary *`AuthenticationResponse`* Members

`header` of type required OperationHeader
: `Header.op` MUST be "Auth"

`fcParams` of type required DOMString
: The field fcParams is the base64url-encoded serialized [RFC4627] FinalChallengeParams in UTF8 encoding (see FinalChallengeParams dictionary) or alternatively it contains the serialized **`CollectedClientData`** object. In both cases, all parameters required for the server to verify the Final Challenge are included.

`assertions` of type array of required AuthenticatorSignAssertion
  The list of authenticator responses related to this operation.

3.5.6 Authentication Response Message

UAF Authentication response message is represented as an array of dictionaries. The array MUST contain exactly one dictionary. The response is defined as AuthenticationResponse dictionary.

EXAMPLE 12: UAF Authentication Response

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Auth",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "mz0YSKHLXDd_StbbDINZaRvW3Pa6sxrNMPYp2gOs3-Y"
    },

    "fcParams": "eyJmYWNldElEIjoiaHR0cHM6Ly91YWYuZXhhbXBsZS5jb20iLCJhcHBJRCI6Imh0dHBzOi8vdWFmLmV4YW1
        wbGUuY29tL2ZhY2V0cy5qc29uIiwiY2hhbGxlbmdlIjoiNEQ4ZVV4ZFN6UV9SYms3R2YwU29vSzdYcjlPMkxVLWcxNTB
        zdE9wSzBnbyIsImNoYW5uZWxCaW5kaW5nIjp7fX0",

    "assertions": [{
        "assertionScheme": "UAFV1TLV",
        "assertion": "Aj7EAAQ-dgALLgkARkZGRiNGQzAzDi4FAAEAAQIADy4IAB4gsCir67EvCi4gAMYR1ZSqYuPLiNpYl
        omDJYGZZGQRGSlLlThqf8ZzF-k2EC4AAAkuIADaied-MDJnRRzcYvhXI4R1GAiTPuqiCrOYhNwQ8ui8_Q0uBAABAAAA
        Bi5GADBEAiDDt4-pzmEWZyakWcWGdtBQLIXSf75wL3tEjiCIry_QtQIgjw0oMlQqKOHdG2M26e1Z0bG4wGjfow_vu5z
        p-VkALFo"
    }]
}]
```

EXAMPLE 13: UAF Authentication Response for text/plain Transaction

```
[{
    "header": {
        "upv": {
            "major": 1,
            "minor": 2
        },
        "op": "Auth",
        "appID": "https://uaf.example.com/facets.json",
        "serverData": "mz0YSKHLXDd_StbbDINZaRvW3Pa6sxrNMPYp2gOs3-Y"
    },

    "fcParams": "eyJmYWNldElEIjoiaHR0cHM6Ly91YWYuZXhhbXBsZS5jb20vaW5kZXguaHRtbCIsImFwcElEIjoiaHR0cH
    M6Ly91YWYuZXhhbXBsZS5jb20vZmFjZXRzLmpzb24iLCJjaGFsbGVuZ2UiOiI0RDhlVXhkU3pRX1JiazdHZjBTb29LN1hyO
    U8yTFUtZzE1MHN0T3BLMGdvIiwiY2hhbm5lbEJpbmRpbmciOnt9fQ",

    "assertions": [{
        "assertionScheme": "UAFV1TLV",
        "assertion": "Aj7EAAQ-dgALLgkARkZGRiNGQzAzDi4FAAEAAQIADy4IAB4gsCir67EvCi4gAMYR1ZSqYuPLiNpYl
        omDJYGZZGQRGSlLlThqf8ZzF-k2EC4AAAkuIADaied-MDJnRRzcYvhXI4R1GAiTPuqiCrOYhNwQ8ui8_Q0uBAABAAAA
        Bi5GADBEAiDDt4-pzmEWZyakWcWGdtBQLIXSf75wL3tEjiCIry_QtQIgjw0oMlQqKOHdG2M26e1Z0bG4wGjfow_vu5z
        p-VkALFo"
    }]
}]
```

NOTE

Line breaks in fcParams have been inserted for improving readability.

3.5.7 Authentication Processing Rules

3.5.7.1 Authentication Request Generation Rules for FIDO Server

The policy contains a 2-dimensional array of allowed MatchCriteria (see Policy). This array can be considered a list (first dimension) of sets (second dimension) of authenticators (identified by MatchCriteria). All authenticators in a specific set MUST be used for authentication simultaneously in order to match the policy. But any of those sets in the list are valid, i.e. the list elements are alternatives.

The FIDO Server MUST follow the steps:

1. Construct appropriate authentication policy `p`
    1. for each set of alternative authenticators do
        1. Create an 1-dimensional array of MatchCriteria objects v containing the set of authenticators to be used for authentication simultaneously that need to be identified by *separate* MatchCriteria objects `m`.
            1. For each collection of authenticators `a` to be used for authentication simultaneously that can be identified by the *same rule*, create a MatchCriteria object `m`, where

            - m.aaid MAY be combined with (one or more of) m.keyIDs, m.attachmentHint, m.authenticatorVersion, and m.exts, but m.aaid MUST NOT be combined with any other match criteria field.
            - If m.aaid is not provided - both m.authenticationAlgorithms and m.assertionSchemes MUST be provided
            - In case of step-up authentication (i.e. in the case where it is expected the user is already known due to a previous authentication step) every item in Policy.accepted MUST include the AAID and KeyID of the authenticator registered for this account in order to avoid ambiguities when having multiple accounts at this relying party.
        2. Add m to v, e.g. v[j+1]=m.
    2. Add v to p.allowed, e.g. p.allowed[i+1]=v
2. Create MatchCriteria objects m[] for all disallowed authenticators.
    1. Create a MatchCriteria object m and add AAIDs of all disallowed authenticators to m.aaid.

       The status (as provided in the metadata TOC [FIDOMetadataService]) of some authenticators might be unacceptable. Such authenticators SHOULD be included in p.disallowed.
    2. If needed - create MatchCriteria m for other disallowed criteria (e.g. unsupported authenticationAlgs)
    3. Add all m to p.disallowed.

2. Create an AuthenticationRequest object r with appropriate r.header for the supported version, and
    1. FIDO Servers SHOULD NOT assume any implicit integrity protection of r.header.serverData. FIDO Servers that depend on the integrity of r.header.serverData SHOULD apply and verify a cryptographically secure Message Authentication Code (MAC) to serverData and they SHOULD also cryptographically bind serverData to the related message, e.g. by re-including r.challenge, see also section ServerData and KeyHandle.

       NOTE

       All other FIDO components (except the FIDO server) will treat r.header.serverData as an opaque value. As a consequence the FIDO server can implement any suitable cryptographic protection method.
    2. Generate a random challenge and assign it to r.challenge
    3. If this is a transaction confirmation operation - look up TransactionConfirmationDisplayContentTypes/ TransactionConfirmationDisplayPNGCharacteristics from authenticator metadata of every participating AAID, generate a list of corresponding transaction content and insert the list into r.transaction.
        - If the authenticator reported (a dynamic) AuthenticatorRegistrationAssertion.tcDisplayPNGCharacteristics during Registration - it MUST be preferred over the (static) value specified in the authenticator Metadata.
    4. Set r.policy to our new policy object p created above, e.g. r.policy = p.
    5. Add the authentication request message the array
3. Send the array of authentication request messages to the FIDO UAF Client

3.5.7.2 Authentication Request Processing Rules for FIDO UAF Client

The FIDO UAF Client MUST follow the steps:

1. Choose the message m with upv set to the appropriate version number.
2. Parse the message m
    - If a mandatory field in the UAF message is not present or a field doesn't correspond to its type and value then reject the operation
3. Obtain FacetID of the requesting Application. If the AppID is missing or empty, set the AppID to the FacetID.

   Verify that the FacetID is authorized for the AppID according to the algorithms in [FIDOAppIDAndFacets].
    - If the FacetID of the requesting Application is not authorized, reject the operation
4. Filter available authenticators with the given policy and present the filtered list to User.
5. Let the user select the preferred Authenticator.
6. Obtain TLS data if its available
7. Create a FinalChallengeParams structure fcp and set fcp.AppID, fcp.challenge, fcp.facetID, and fcp.channelBinding appropriately. Serialize [RFC4627] fcp using UTF8 encoding and base64url encode it.
    - FinalChallenge = base64url(serialize(utf8encode(fcp)))
8. For each authenticator that supports an Authenticator Interface Version AIV compatible with message version AuthenticationRequest.header.upv (see Version Negotiation) and user agrees to authenticate with:

    1. Add `AppID`, `FinalChallenge`, `Transactions` (if present), and all other fields to the ASMRequest.
    2. Send the ASMRequest to the ASM. If the ASM returns an error, handle that error appropriately. The status code returned by the ASM [UAFASM] must be mapped to a status code defined in [UAFAppAPIAndTransport] as specified in section 3.4.6.2.1 Mapping ASM Status Codes to ErrorCode.

3.5.7.3 Authentication Request Processing Rules for FIDO Authenticator

See [UAFAuthnrCommands], section "Sign Command".

3.5.7.4 Authentication Response Generation Rules for FIDO UAF Client

The FIDO UAF Client MUST follow the steps:

1. Create an AuthenticationResponse message
2. Copy `AuthenticationRequest.header` into `AuthenticationResponse.header`

    NOTE

    When the `appID` provided in the request was empty, the FIDO Client must set the `appID` in this header to the facetID (see [FIDOAppIDAndFacets]).

    The header might include extensions. Extension specific rules might affect the copy process. Those rules are defined in the related section in [UAFRegistry].

3. Fill out `AuthenticationResponse.FinalChallengeParams` with appropriate fields and then stringify it
4. Append the response from each authenticator into `AuthenticationResponse.assertions`
5. Send AuthenticationResponse message to the FIDO Server

3.5.7.5 Authentication Response Processing Rules for FIDO Server

NOTE

The following processing rules assume that authenticator supports "UAFV1TLV" assertion scheme. Currently "UAFV1TLV" is the only defined and supported assertion scheme. When a new assertion scheme is added to UAF protocol - this section will be extended with corresponding processing rules.

The FIDO Server MUST follow the steps:

1. Parse the message
    1. If protocol version (`AuthenticationResponse.header.upv`) is not supported – reject the operation
    2. If a mandatory field in UAF message is not present or a field doesn't correspond to its type and value - reject the operation
2. Verify that `AuthenticationResponse.header.serverData`, if used, passes any implementation-specific checks against its validity. See also section ServerData and KeyHandle.
3. base64url decode `AuthenticationResponse.fcParams` and convert into an object (`fcp`)
4. If this `fcp` object is a **`FinalChallengeParams`** object, then verify each field in `fcp` and make sure it's valid:
    1. Make sure `fcp.appID` corresponds to the one stored by the FIDO Server

        NOTE

        When the `appID` provided in the request was empty, the FIDO Client must set the `appID` to the facetID (see [FIDOAppIDAndFacets]). In this case, the Uauth key cannot be used by other application facets.

    2. Make sure `fcp.facetID` is in the list of trusted FacetIDs [FIDOAppIDAndFacets]
    3. Make sure `ChannelBinding` is as expected (see section ChannelBinding dictionary)

        NOTE

> There might be legitimate situations in which some methods of channel binding fail (see section 4.3.4 TLS Binding).

    4. Make sure `fcp.challenge` has really been generated by the FIDO Server for this operation and it is not expired
    5. Reject the response if any of the above checks fails
5. If this `fcp` object is a **`CollectedClientData`** object, then verify each field in `fcp` and make sure it's valid:
    1. Make sure `fcp.origin` is considered a legitimate origin for this registration request.
    2. Make sure `fcp.tokenBinding` is as expected (see field `cid_pubkey` in section ChannelBinding dictionary)

    > NOTE
    >
    > There might be legitimate situations in which some methods of channel binding fail (see section 4.3.4 TLS Binding).

    3. Make sure `fcp.challenge` has really been generated by the FIDO Server for this operation and it is not expired
    4. Reject the response if any of the above checks fails
6. For each assertion `a` in `AuthenticationResponse.assertions`
    1. Parse data from `a.assertion` assuming it is encoded according to the suspected assertion scheme `a.assertionScheme` and make sure it contains all mandatory fields (indicated in authenticator Metadata) it is supposed to have, verify that the assertion has a valid syntax, and verify that the assertion doesn't include unknown fields (identified by TAGs or IDs) that belong to extensions marked as "fail-if-unknown" set to true [FIDOMetadataStatement].
        - If it doesn't - continue with next assertion
    2. if `a.assertion` contains an object of type `TAG_UAFV1_AUTH_ASSERTION`, then
        1. if `a.assertion.TAG_UAFV1_AUTH_ASSERTION` contains `TAG_UAFV1_SIGNED_DATA` as first element:
            1. Retrieve the AAID from the assertion.

            > NOTE
            >
            > The AAID in `TAG_UAFV1_SIGNED_DATA` is contained in `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.TAG_AAID`.

            2. Verify that `a.assertionScheme` matches `Metadata(AAID).assertionScheme`
                - If it doesn't match - continue with next assertion
            3. Make sure that the AAID indeed matches the policy of the Authentication Request
                - If it doesn't meet the policy – continue with next assertion
            4. Obtain `Metadata(AAID).AuthenticatorVersion` for this AAID and make sure that it is lower or equal to `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.TAG_ASSERTION_INFO.AuthenticatorVersion`.
                - If `Metadata(AAID).AuthenticatorVersion` is higher (i.e. the authenticator firmware is outdated), it is RECOMMENDED to assume increased authentication risk. See "StatusReport dictionary" and "Metadata TOC object Processing Rules" in [FIDOMetadataService] for more details on this.
            5. Retrieve `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.TAG_KEYID` as KeyID
            6. Locate `UAuth.pub` public key associated with (AAID, KeyID) in the user's record.
                - If such record doesn't exist - continue with next assertion
            7. Verify the AAID against the AAID stored in the user's record at time of Registration.
                - If comparison fails – continue with next assertion
            8. Locate authenticator specific authentication algorithms from authenticator metadata (field `AuthenticationAlgs`)
            9. Check the Signature Counter `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.SignCounter` and make sure it is either not supported by the authenticator (i.e. the value provided and the value stored in the user's record are both 0 or the value isKeyRestricted is set to 'false' in the related Metadata Statement) or it has been incremented (compared to the value stored in the user's record)
                - If it is greater than 0, but didn't increment - continue with next assertion (as this is a cloned authenticator or a cloned authenticator has been used previously).
            10. If `fcp` is of type **`FinalChallengeParams`**, then hash `AuthenticationResponse.FinalChallengeParams` using the hashing algorithm suitable for this authenticator type. Look up the hash algorithm in authenticator Metadata, field `AuthenticationAlgs`. It is the hash algorithm associated with the first entry related to a constant with prefix ALG_SIGN.
                - `FCHash = hash(AuthenticationResponse.FinalChallengeParams)`

            `fcp` `AuthenticationResponse.fcParams`

            11. If is of type `CollectedClientData`, then hash using hashing algorithm specified in `fcp.hashAlg`.
                - `FCHash = hash(AuthenticationResponse.fcParams)`
            12. Make sure that `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.TAG_FINAL_CHALLENGE_HASH` == `FCHash`
                - If comparison fails – continue with next assertion
            13. If `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.TAG_ASSERTION_INFO.authenticationMode` == `2`

                NOTE

                The transaction hash included in this `AuthenticationResponse` must match the transaction content specified in the related `AuthenticationRequest`. As FIDO doesn't mandate any specific FIDO Server API, the transaction content could be cached by any relying party software component, e.g. the FIDO Server or the relying party Web Application.

                1. Make sure there is a transaction cached on Relying Party side.
                    - If not – continue with next assertion
                2. Go over all cached forms of the transaction content (potentially multiple cached PNGs for the same transaction) and calculate their hashes using hashing algorithm suitable for this authenticator (same hash algorithm as used for FinalChallenge).
                    - For each `cachedTransaction` add `hash(cachedTransaction)` into `cachedTransactionHashList`
                3. Make sure that `a.TransactionHash` is in `cachedTransactionHashList`
                    - If it's not in the list – continue with next assertion
            14. Use `UAuth.pub` key and appropriate authentication algorithm to verify `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_SIGNATURE`
                1. If signature verification fails – continue with next assertion
                2. Update `SignCounter` in user's record with `a.assertion.TAG_UAFV1_AUTH_ASSERTION.TAG_UAFV1_SIGNED_DATA.SignCounter`
        2. if `a.assertion.TAG_UAFV1_AUTH_ASSERTION` contains a different object than `TAG_UAFV1_SIGNED_DATA` as first element, then follow the rules specific to that object.
    3. if `a.assertion` doesn't contain an object of type `TAG_UAFV1_AUTH_ASSERTION`, then follow the respective processing rules of that assertion format if supported - otherwise skip this assertion.
    4. Treat this assertion `a` as positively verified.
7. Process all positively verified authentication assertions `a`.

3.6 Deregistration Operation

This operation allows FIDO Server to ask the FIDO Authenticator to delete keys related to the particular relying party.

The FIDO Server MAY explicitly enumerate the keys to be deleted, or the FIDO server MAY signal deregistration of all keys on all authenticators managed by the FIDO UAF Client and relating to a given appID.

NOTE
There are various deregistration use cases that both FIDO Server and FIDO Client implementations should allow for. Two in particular are:

1. FIDO Servers should trigger this operation in the event a user removes their account at the relying party.
2. FIDO Clients should ensure that relying party application facets -- e.g., mobile apps, web pages -- have means to initiate a deregistration operation without having necessarily received a UAF protocol message with an `op` value of "Dereg". This allows the relying party app facet to remove a user's keys from authenticators during events such as relying party app removal or installation.

3.6.1 Deregistration Request Message

The FIDO UAF Deregistration request message is represented as an array of dictionaries. The array MUST contain exactly one dictionary. The request is defined as DeregistrationRequest dictionary.

EXAMPLE 14: UAF Deregistration Request

```
[{
    "header": {
            "upv": {
                "major": 1,
                "minor": 2
            },
            "op": "Dereg",
            "appID": "https://uaf.example.com/facets.json"
        },
        "authenticators": [
            {
                "keyID": "kbufhLYGoFFLJPRCUvwiUu-fr1nh3sX3IjM9i9lcOrQ",
                "aaid": "FFFF#FC03"
            }
        ]
    }]
```

The example above contains a deregistration request. This request will deregister the key with the specified keyID registered for the authenticator with `aaid` "FFFF#FC03" for the given `appID`.

NOTE

There is no deregistration response object.

3.6.2 DeregisterAuthenticator dictionary

WebIDL

```
dictionary DeregisterAuthenticator {
    required AAID  aaid;
    required KeyID keyID;
};
```

3.6.2.1 Dictionary `DeregisterAuthenticator` Members

`aaid` of type required AAID
AAID of the authenticator housing the `UAuth.priv` key to deregister, or an empty string if all keys related to the specified `appID` are to be de-registered.

`keyID` of type required KeyID
The unique KeyID related to `UAuth.priv`. KeyID is assumed to be unique within the scope of an AAID only. If `aaid` is not an empty string, then:

1. `keyID` MAY contain a value of type KeyID, or,
2. `keyID` MAY be an empty string.

(1) signals deletion of a particular `UAuth.priv` key mapped to the (`AAID`, `KeyID`) tuple.

(2) signals deletion of all KeyIDs associated with the specified `aaid`.

If `aaid` is an empty string, then `keyID` MUST also be an empty string. This signals deregistration of all keys on all authenticators that are mapped to the specified `appID`.

3.6.3 DeregistrationRequest dictionary

WebIDL

```
dictionary DeregistrationRequest {
    required OperationHeader           header;
    required DeregisterAuthenticator[] authenticators;
};
```

3.6.3.1 Dictionary `DeregistrationRequest` Members

`header` of type required OperationHeader
`Header.op` MUST be "Dereg".

`authenticators` of type array of required DeregisterAuthenticator
List of authenticators to be deregistered.

3.6.4 Deregistration Processing Rules

3.6.4.1 Deregistration Request Generation Rules for FIDO Server

The FIDO Server MUST follow the steps:

1. Create a **`DeregistrationRequest`** message `m` with `m.header.upv` set to the appropriate version number.
2. If the FIDO Server intends to deregister all keys on all authenticators managed by the FIDO UAF Client for this `appID`, then:
    1. create one and only one **`DeregisterAuthenticator`** object `o`
    2. Set `o.aaid` and `o.keyID` to be empty string values
    3. Append `o` to `m.authenticators`, and go to step 5
3. If the FIDO Server intends to deregister all keys on all authenticators with a given AAID managed by the FIDO UAF Client for this `appID`, then:
    1. create one and only one **`DeregisterAuthenticator`** object `o`
    2. Set `o.aaid` to the intended AAID and set `o.keyID` to be an empty string.
    3. Append `o` to `m.authenticators`, and go to step 5
4. Otherwise, if the FIDO Server intends to deregister specific (`AAID`, `KeyID`) tuples, then for each tuple to be deregistered:
    1. create a **`DeregisterAuthenticator`** object `o`
    2. Set `o.aaid` and `o.keyID` appropriately
    3. Append `o` to `m.authenticators`
5. delete related entry (or entries) in FIDO Server's account database
6. Send message to FIDO UAF Client

3.6.4.2 Deregistration Request Processing Rules for FIDO UAF Client

The FIDO UAF Client MUST follow the steps:

1. Choose the message `m` with upv set to the appropriate version number.
2. Parse the message
    - If a mandatory field in **`DeregistrationRequest`** message is not present or a field doesn't correspond to its type and value – reject the operation
    - Empty string values for `o.aaid` and `o.keyID` MUST occur in the first and only DeregisterAuthenticator object o, otherwise reject the operation
3. Obtain `FacetID` of the requesting Application. If the `AppID` is missing or empty, set the `AppID` to the `FacetID`.

   Verify that the `FacetID` is authorized for the `AppID` according to the algorithms in [FIDOAppIDAndFacets].

    - If the `FacetID` of the requesting Application is not authorized, reject the operation
4. If the set of authenticators compatible with **the message version `DeregistrationRequest.header.upv` and having an AAID matching one of the provided `AAID`s (an AAID of an authenticator matches if it is either (a) equal to one of the `AAID`s in the `DeregistrationRequest` or if (b) the `AAID` in the `DeregistrationRequest` is an empty string)** is empty, then return NO_SUITABLE_AUTHENTICATOR.
5. For each authenticator compatible with **the message version `DeregistrationRequest.header.upv` and having an AAID matching one of the provided `AAID`s (an AAID of an authenticator matches if it is either (a) equal to one of the `AAID`s in the `DeregistrationRequest` or if (b) the `AAID` in the `DeregistrationRequest` is an empty string)**:
    1. Create appropriate `ASMRequest` for Deregister function and send it to the ASM. If the ASM returns an error, handle that error appropriately. The status code returned by the ASM [UAFASM] must be mapped to a status code defined in [UAFAppAPIAndTransport] as specified in section 3.4.6.2.1 Mapping ASM Status Codes to ErrorCode.

3.6.4.3 Deregistration Request Processing Rules for FIDO Authenticator

See [UAFASM] section "Deregister request".

4. Considerations

This section is non-normative.

4.1 Protocol Core Design Considerations

This section describes the important design elements used in the protocol.

4.1.1 Authenticator Metadata

It is assumed that FIDO Server has access to a list of all supported authenticators and their corresponding Metadata. Authenticator metadata [FIDOMetadataStatement] contains information such as:

- Supported Registration and Authentication Schemes
- Authentication Factor, Installation type, supported content-types and other supplementary information, etc.

In order to make a decision about which authenticators are appropriate for a specific transaction, FIDO Server looks up the list of authenticator metadata by AAID and retrieves the required information from it.

NORMATIVE

Each entry in the authenticator metadata repository MUST be identified with a unique authenticator Attestation ID (AAID).

4.1.2 Authenticator Attestation

Authenticator Attestation is the process of validating authenticator model identity during registration. It allows Relying Parties to cryptographically verify that the authenticator reported by FIDO UAF Client is really what it claims to be.

Using authenticator Attestation, a relying party "example-rp.com" will be able to verify that the authenticator model of the "example-Authenticator", reported with AAID "1234#5678", is not malware running on the FIDO User Device but is really a authenticator of model "1234#5678".

NORMATIVE

FIDO Authenticators SHOULD support "Basic Attestation" or "ECDAA" described below. New Attestation mechanisms may be added to the protocol over time.

NORMATIVE

FIDO Authenticators not providing sufficient protection for Attestation keys (non-attested authenticators) MUST use the UAuth.priv key in order to formally generate the same KeyRegistrationData object as attested authenticators. This behavior MUST be properly declared in the Authenticator Metadata.

4.1.2.1 Basic Attestation

NORMATIVE

There are two different flavors of Basic Attestation:

Full Basic Attestation
Based on an attestation private key shared among a class of authenticators (e.g. same model).

Surrogate Basic Attestation
Just syntactically a Basic Attestation. The attestation object self-signed, i.e. it is signed using the UAuth.priv key, i.e. the key corresponding to the UAuth.pub key included in the attestation object. As a consequence it **does not** provide a cryptographic proof of the security characteristics. But it is the best thing we can do if the authenticator is not able to have an attestation private key.

4.1.2.1.1 Full Basic Attestation

NOTE

FIDO Servers must have access to a trust anchor for verifying attestation public keys (i.e. Attestation Certificate trust store) in order to follow the assumptions made in [FIDOSecRef]. Authenticators must provide its attestation signature during the registration process for the same reason. The attestation trust anchor is shared with FIDO Servers out of band (as part of the Metadata). This sharing process shouldt be done according to [FIDOMetadataService].

NOTE

The protection measures of the Authenticator's attestation private key depend on the specific authenticator model's implementation.

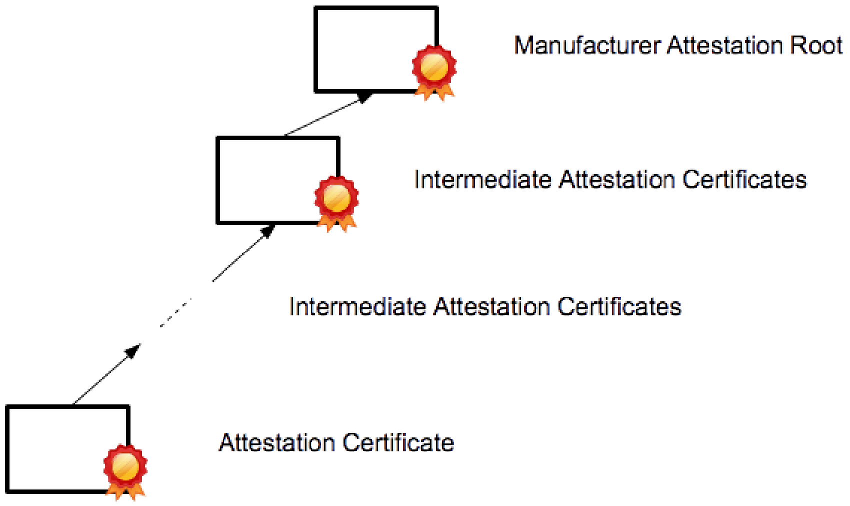
NOTE

The FIDO Server must load the appropriate Authenticator Attestation Root Certificate from its trust store based on the AAID provided in KeyRegistrationData object.

In this Full Basic Attestation model, a large number of authenticators must share the same Attestation certificate and Attestation Private Key in order to provide non-linkability (see Protocol Core Design Considerations). Authenticators can only be identified on a production batch level or an AAID level by their Attestation Certificate, and not individually. A large number of authenticators sharing the same Attestation Certificate provides better privacy, but also makes the related private key a more attractive attack target.

NOTE

When using Full Basic Attestation: A given set of authenticators sharing the same manufacturer and essential characteristics must not be issued a new Attestation Key before at least 100,000 devices are issued the previous shared key.



Manufacturer Attestation Root
Intermediate Attestation Certificates
Intermediate Attestation Certificates
Attestation Certificate

Fig. 10 Attestation Certificate Chain

4.1.2.1.2 Surrogate Basic Attestation

NORMATIVE

In this attestation method, the UAuth.priv key MUST be used to sign the Registration Data object. This behavior MUST be properly declared in the Authenticator Metadata.

NOTE

FIDO Authenticators not providing sufficient protection for Attestation keys (non-attested authenticators) must use this attestation method.

4.1.2.2 Direct Anonymous Attestation (ECDAA)

The FIDO Basic Attestation scheme uses attestation "group" keys shared across a set of authenticators with identical characteristics in order to preserve privacy by avoiding the introduction of global correlation handles. If such an attestation key is extracted from one single authenticator, it is possible to create a "fake" authenticator using the same key and hence indistinguishable from the original authenticators by the relying party. Removing trust for registering new authenticators with the related key would affect the entire set of authenticators sharing the same "group" key. Depending on the number of authenticators, this risk might be unacceptable high.

This is especially relevant when the attestation key is primarily protected against malware attacks as opposed to targeted physical attacks.

An alternative approach to "group" keys is the use of individual keys combined with a Privacy-CA [TPMv1-2-Part1]. Translated to FIDO, this approach would require one Privacy-CA interaction for each Uauth key. This means relatively high load and high availability requirements for the Privacy-CA. Additionally the Privacy-CA aggregates sensitive information (i.e. knowing the relying parties the user interacts with). This might make the Privacy-CA an interesting attack target.

Another alternative is the Direct Anonymous Attestation [BriCamChe2004-DAA]. Direct Anonymous Attestation is a cryptographic scheme combining privacy with security. It uses the Authenticator specific secret once to communicate with a single DAA Issuer (either at manufacturing time or after being sold before first use) and uses the resulting DAA credential in the DAA-Sign protocol with each relying party. The (original) DAA scheme has been adopted by the Trusted Computing Group for TPM v1.2 [TPMv1-2-Part1].

ECDAA (see [FIDOEcdaaAlgorithm] for details) is an improved DAA scheme based on elliptic curves and bilinear pairings [CheLi2013-ECDAA]. This scheme provides significantly improved performance compared with the original DAA and it is part of the TPMv2 specification [TPMv2-Part1].

NORMATIVE

The ECDAA attestation algorithm is used as specified in [FIDOEcdaaAlgorithm].

4.1.3 Error Handling

NOTE

FIDO Servers must inform the calling Relying Party Web Application Server (see FIDO Interoperability Overview) about any error conditions encountered when generating or processing UAF messages through their proprietary API.

NORMATIVE

FIDO Authenticators MUST inform the FIDO UAF Client (see FIDO Interoperability Overview) about any error conditions encountered when processing commands through the Authenticator Specific Module (ASM). See [UAFASM] and [UAFAuthnrCommands] for details.

4.1.4 Assertion Schemes

UAF Protocol is designed to be compatible with a variety of existing authenticators (TPMs, Fingerprint Sensors, Secure Elements, etc.) and also future authenticators designed for FIDO. Therefore extensibility is a core capability designed into the protocol.

It is considered that there are two particular aspects that need careful extensibility. These are:

- Cryptographic key provisioning (KeyRegistrationData)
- Cryptographic authentication and signature (SignedData)

The combination of KeyRegistrationData and SignedData schemes is called an Assertion Scheme.

The UAF protocol allows plugging in new Assertion Schemes. See also UAF Supported Assertion Schemes.

The Registration Assertion defines how and in which format a cryptographic key is exchanged between the authenticator and the FIDO Server.

The Authentication Assertion defines how and in which format the authenticator generates a cryptographic signature.

The generally-supported Assertion Schemes are defined in [UAFRegistry].

4.1.5 Username in Authenticator

FIDO UAF supports authenticators acting as first authentication factor (i.e. replacing username and password). As part of the FIDO UAF Registration, the Uauth key is registered (linked) to the related user account at the RP. The authenticator stores the username (allowing the user to select a specific account at the RP in the case he has multiple ones). See [UAFAuthnrCommands], section "Sign Command" for details.

4.1.6 Silent Authenticators

FIDO UAF supports authenticators not requiring any types of user verification or user presence check. Such authenticators are called ***Silent Authenticators***.

In order to meet user's expectations, such Silent Authenticators need specific properties:

- It must be possible for a user to effectively remove a Uauth key maintained by a Silent Authenticator (in order to avoid being tracked) at the user's discretion (see [UAFAuthnrCommands]). This is not compatible with statelesss implementations storing the Uauth private key wrapped inside a KeyHandle on the FIDO Server.

- TransactionConfirmation is not supported (as it would require user input which is not intended), see [UAFAuthnrCommands].
- They might not operate in first factor mode (see [UAFAuthnrCommands]) as this might violate the privacy principles.

The MetadataStatement has to truthfully reflect the Silent Authenticator, i.e. field userVerification needs to be set to USER_VERIFY_NONE.

4.1.7 TLS Protected Communication

NOTE

In order to protect the data communication between FIDO UAF Client and FIDO Server a protected TLS channel must be used by FIDO UAF Client (or User Agent) and the Relying Party for all protocol elements.

1. The server endpoint of the TLS connection must be at the Relying Party
2. The client endpoint of the TLS connection must be either the FIDO UAF Client or the User Agent / App
3. TLS Client and Server should use TLS v1.2 or newer and should only use TLS v1.1 if TLS v1.2 or higher are not available. The "anon" and "null" TLS crypto suites are not allowed and must be rejected; insecure crypto-algorithms in TLS (e.g. MD5, RC4, SHA1) should be avoided [SP800-131A] [RFC7525].
4. TLS Extended Master Secret Extension [RFC7627] and TLS Renegotiation Indication Extension [RFC5746] should be used to protect against MITM attacks.
5. The use of the tls-unique method is deprecated as its security is broken, see [TLSAUTH].

We recommend, that the

1. TLS Client verifies and validates the server certificate chain according to [RFC5280], section 6 "Certificate Path Validation". The certificate revocation status should be checked (e.g. using OCSP [RFC2560] or CRL based validation [RFC5280]) and the TLS server identity should be checked as well [RFC6125].
2. TLS Client's trusted certificate root store is properly maintained and at least requires the CAs included in the root store to annually pass Web Trust or ETSI (ETSI TS 101 456, or ETSI TS 102 042) audits for SSL CAs.

See [TR-03116-4] and [SHEFFER-TLS] for more recommendations on how to use TLS.

4.2 Implementation Considerations

4.2.1 Server Challenge and Random Numbers

NOTE

A `ServerChallenge` needs appropriate random sources in order to be effective (see [RFC4086] for more details). The (pseudo-)random numbers used for generating the Server Challenge should successfully pass the randomness test specified in [Coron99] and they should follow the guideline given in [SP800-90b].

4.2.2 Revealing KeyIDs

FIDO UAF uses key identifiers (KeyIDs) to identify Uauth keys registered by an authenticator to a relying party. By design (see [UAFAuthnrCommands], section 6.2.4), KeyIDs do not reveal any secret information. However, if an attacker could provide a username to a relying party and the relying party server would reveal the related KeyID if an account for that username exists or give an error otherwise, the attacker would implicitly learn whether the user has an account at that relying party.

As a consequence, relying parties should reveal a KeyID only after performing some basic authentication steps, e.g. verifying the existence of a Cookie, authentication using FIDO Silent Authenticator, etc.).

4.3 Security Considerations

There is no "one size fits all" authentication method. The FIDO goal is to decouple the user verification method from the authentication protocol and the authentication server, and to support a broad range of user verification methods and a broad range of assurance levels. FIDO authenticators should be able to leverage capabilities of existing computing hardware, e.g. mobile devices or smart cards.

The overall assurance level of electronic user authentications highly depends (a) on the security and integrity of the user's equipment involved and (b) on the authentication method being used to authenticate the user.

When using FIDO, users should have the freedom to use any available equipment and a variety of authentication methods. The relying party needs reliable information about the security relevant parts of the equipment and the authentication method itself in order to determine whether the overall risk of an electronic authentication is acceptable in a particular business context. The FIDO Metadata Service [FIDOMetadataService] is intended to provide such information.

It is important for the UAF protocol to provide this kind of reliable information about the security relevant parts of the equipment and the authentication method itself to the FIDO server.

The overall security is determined by the weakest link. In order to support scalable security in FIDO, the underlying UAF protocol needs to provide a very high conceptual security level, so that the protocol isn't the weakest link.

Relying Parties define Acceptable Assurance Levels. The FIDO Alliance envisions a broad range of FIDO UAF Clients, FIDO Authenticators and FIDO Servers to be offered by various vendors. Relying parties should be able to select a FIDO Server providing the appropriate level of security. They should also be in a position to accept FIDO Authenticators meeting the security needs of the given business context, to compensate assurance level deficits by adding appropriate implicit authentication measures, and to reject authenticators not meeting their requirements. FIDO does not mandate a very high assurance level for FIDO Authenticators, instead it provides the basis for authenticator and user verification method competition.

Authentication vs. Transaction Confirmation. Existing Cloud services are typically based on authentication. The user launches an application (i.e. User Agent) assumed to be trusted and authenticates to the Cloud service in order to establish an authenticated communication channel between the application and the Cloud service. After this authentication, the application can perform any actions to the Cloud service using the authenticated channel. The service provider will attribute all those actions to the user. Essentially the user authenticates all actions performed by the application in advance until the service connection or authentication times out. This is a very convenient way as the user doesn't get distracted by manual actions required for the authentication. It is suitable for actions with low risk consequences.

However, in some situations it is important for the relying party to know that a user really has seen and accepted a particular content before he authenticates it. This method is typically being used when non-repudiation is required. The resulting requirement for this scenario is called What You See Is What You Sign (WYSIWYS).

UAF supports both methods; they are called "Authentication" and "Transaction Confirmation". The technical difference is, that with Authentication the user confirms a random challenge, where in the case of Transaction Confirmation the user also confirms a human readable content, i.e. the contract. From a security point, in the case of authentication the application needs to be trusted as it performs any action once the authenticated communication channel has been established. In the case of Transaction Confirmation only the transaction confirmation display component implementing WYSIWYS needs to be trusted, not the entire application.

Distinct Attestable Security Components. For the relying party in order to determine the risk associated with an authentication, it is important to know details about some components of the user's environment. Web Browsers typically send a "User Agent" string to the web server. Unfortunately any application could send any string as "User Agent" to the relying party. So this method doesn't provide strong security. FIDO UAF is based on a concept of cryptographic attestation. With this concept, the component to be attested owns a cryptographic secret and authenticates its identity with this cryptographic secret. In FIDO UAF the cryptographic secret is called "Authenticator Attestation Key". The relying party gets access to reference data required for verifying the attestation.

In order to enable the relying party to appropriately determine the risk associated with an authentication, all components performing significant security functions need to be attestable.

In FIDO UAF significant security functions are implemented in the "FIDO Authenticators". Security functions are:

1. Protecting the attestation key.
2. Generating and protecting the Authentication key(s), typically one per relying party and user account on relying party.
3. Verifying the user.
4. Providing the WYSIWYS capability ("Transaction Confirmation Display" component).

Some FIDO Authenticators might implement these functions in software running on the FIDO User Device, others might implement these functions in "hardware", i.e. software running on a hardware segregated from the FIDO User Device. Some FIDO Authenticators might even be formally evaluated and accredited to some national or international scheme. Each FIDO Authenticator model has an attestation ID (AAID), uniquely identifying the related security characteristics. Relying parties get access to these security properties of the FIDO Authenticators and the reference data required for verifying the attestation.

Resilience to leaks from other verifiers. One of the important issues with existing authentication solutions is a weak server side implementation, affecting the security of authentication of typical users to other relying parties. It is the goal of the FIDO UAF protocol to decouple the security of different relying parties.

Decoupling User Verification Method from Authentication Protocol. In order to decouple the user verification method from the authentication protocol, FIDO UAF is based on an extensible set of cryptographic authentication algorithms. The cryptographic secret will be unlocked after user verification by the Authenticator. This secret is then used for the authenticator-to-relying party authentication. The set of cryptographic algorithms is chosen according to the capabilities of existing cryptographic hardware and computing devices. It can be extended in order to support new cryptographic hardware.

Privacy Protection. Different regions in the world have different privacy regulations. The FIDO UAF protocol should be acceptable in all regions and hence must support the highest level of data protection. As a consequence, FIDO UAF doesn't require transmission of biometric data to the relying party nor does it require the storage of biometric reference data [ISOBiometrics] at the relying party. Additionally, cryptographic secrets used for different relying parties shall not allow the parties to link actions to the same user entity. UAF supports this concept, known as non-linkability. Consequently, the UAF protocol doesn't require a trusted third party to be involved in every transaction.

Relying parties can interactively discover the AAIDs of all enabled FIDO Authenticators on the FIDO User Device using the Discovery interface [UAFAppAPIAndTransport]. The combination of AAIDs adds to the entropy provided by the client to relying parties. Based on such information, relying parties can fingerprint clients on the internet (see Browser Uniqueness at eff.org and https://wiki.mozilla.org/Fingerprinting). In order to minimize the entropy added by FIDO, the user can enable/disable individual authenticators – even when they are embedded in the device (see [UAFAppAPIAndTransport], section "privacy considerations").

4.3.1 FIDO Authenticator Security

See [UAFAuthnrCommands].

4.3.2 Cryptographic Algorithms

In order to keep key sizes small and to make private key operations fast enough for small devices, it is suggested that implementers prefer ECDSA [ECDSA-ANSI] in combination with SHA-256 / SHA-512 hash algorithms. However, the RSA algorithm is also supported. See [FIDORegistry] "Authentication Algorithms" and "Public Key Representation Formats" for a list of generally supported cryptographic algorithms.

One characteristic of ECDSA is that it needs to produce, for each signature generation, a fresh random value. For effective security, this value must be chosen randomly and uniformly from a set of modular integers, using a cryptographically secure process. Even slight biases in that process may be turned into attacks on the signature schemes.

NOTE

If such random values cannot be provided under all possible environmental conditions, then a deterministic version of ECDSA should be used (see [RFC6979]).

4.3.3 FIDO Client Trust Model

The FIDO environment on a FIDO User Device comprises 4 entities:

- User Agents (a native app or a browser)
- FIDO UAF Clients (a shared service potentially used by multiple User Agents)
- Authenticator Specific Modules (ASMs)
- Authenticators

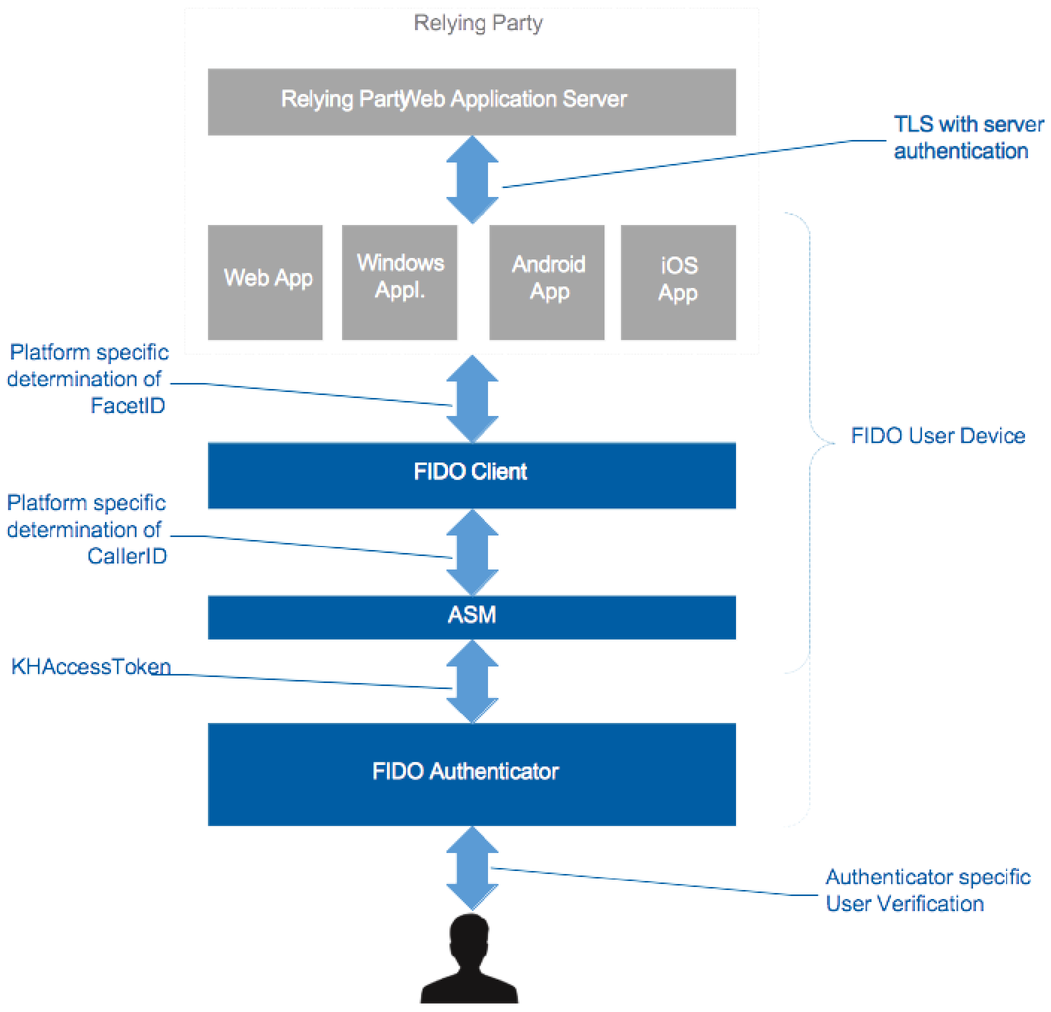

Relying Party
Relying PartyWeb Application Server
TLS with server authentication
Web App
Windows Appl.
Android App
iOS App
Platform specific determination of FacetID
FIDO User Device
FIDO Client
Platform specific determination of CallerID
ASM
KHAccessToken
FIDO Authenticator
Authenticator specific User Verification

Fig. 11 UAF Client Trust Model

The security and privacy principles that underpin mobile operating systems require certain behaviours from apps. FIDO must uphold those principles wherever possible. This means that each of these components has to enforce specific trust relationships with the others to avoid the risk of rogue components subverting the integrity of the solution.

One specific requirement on handsets is that apps originating from different vendors must not be allowed directly to view or edit each other's data (e.g. FIDO UAF credentials).

Given that FIDO UAF Clients are intended to provide a shared service, the principle of siloed app data has been applied to the FIDO UAF Client, rather than individual apps. This means that if two or more FIDO UAF Clients are present on a device, then each FIDO UAF Client is unable to access authentication keys created by another FIDO UAF Client. A given FIDO UAF Client may however provide services to multiple User Agents, so that the same authentication key can authenticate to different facets of the same Relying Party, even if one facet is a 3rd party browser.

This exclusive access restriction is enforced through the KHAccessToken. When a FIDO UAF Client communicates with an ASM, the ASM reads the identity of the FIDO UAF Client caller1 and includes that Client ID in the KHAccessToken that it sends to the authenticator. Subsequent calls to the authenticator must include the same Client ID in the KHAccessToken. Each authentication key is also bound to the ASM that created it, by means of an ASMToken (a random unique ID for the ASM) that is also included in the KHAccessToken.

Finally, the User Agents that a FIDO UAF Client will recognise are determined by the Relying Party itself. The FIDO UAF Client requests a list of Trusted Apps from the RP as part of the Registration and Authentication protocols. This prevents User Agents that have not been explicitly authorized by the Relying Party from using the FIDO credentials.

In this manner, in a compliant FIDO installation, UAF credentials can only be accessed via apps that the relying party explicitly trusts and through the same client and ASM that performed the original registration.

It should be noted that the specification allows for FIDO UAF Clients to be built directly into User Agents. However, such implementations will restrict the ability to support multiple facets for relying party applications unless they also expose the UAF Client API for other User Agents to consume.

4.3.3.1 Isolation using KHAccessToken

Authenticators might be implemented in dedicated hardware and hence might not be able to verify the calling software entity (i.e. the ASM).

The KHAccessToken allows restricting access to the keys generated by the FIDO Authenticator to the intended ASM. It is based on a Trust On First Use (TOFU) concept.

FIDO Authenticators are capable of binding UAuth.Key with a key provided by the caller (i.e. the ASM). This key is called KHAccessToken.

This technique allows making sure that registered keys are only accessible by the caller that originally registered them. A malicious App on a mobile platform won't be able to access keys by bypassing the related ASM (assuming that this ASM originally registered these keys).

The KHAccessToken is typically specific to the AppID, PersonaID, ASMToken and the CallerID. See [UAFASM] for more details.

NOTE

On some platforms, the ASM additionally might need special permissions in order to communicate with the FIDO Authenticator. Some platforms do not provide means to reliably enforce access control among applications.

4.3.4 TLS Binding

Various channel binding methods have been proposed (e.g. [RFC5929] and [ChannelID]).

UAF relies on TLS server authentication for binding authentication keys to AppIDs. There are threats:

1. Attackers might fraudulently get a TLS server certificate for the same AppID as the relying party and they might be able to manipulate the DNS system.
2. Attackers might be able to steal the relying party's TLS server private key and certificate and they might be able to manipulate the DNS system.

And there are functionality requirements:

1. UAF transactions might span across multiple TLS sessions. As a consequence, "tls-unique" defined in [RFC5929] might be difficult to implement.
2. Data centers might use SSL concentrators.
3. Data centers might implement load-balancing for TLS endpoints using different TLS certificates. As a consequence, "tls-server-end-point" defined in [RFC5929], i.e. the hash of the TLS server certificate might be inappropriate.
4. Unfortunately, hashing of the TLS server certificate (as in "tls-server-end-point") also limits the usefulness of the channel binding in a particular, but quite common circumstance. If the client is operated behind a trusted (to that client) proxy that acts as a TLS man-in-the-middle, your client will see a different certificate than the one the server is using. This is actually quite common on corporate or military networks with a high security posture that want to inspect all incoming and outgoing traffic. If the FIDO Server just gets a hash value, there's no way to distinguish this from an attack. If sending the entire certificate is acceptable from a performance perspective, the server can examine it and determine if it is a certificate for a valid name from a non-standard issuer (likely administratively trusted) or a certificate for a different name (which almost certainly indicates a forwarding attack).

See ChannelBinding dictionary for more details.

4.3.5 Session Management

FIDO does not define any specific session management methods. However, several FIDO functions rely on a robust session management being implemented by the relying party's web application:

FIDO Registration
: A web application might trigger FIDO Registration after authenticating an existing user via legacy credentials. So the session is used to maintain the authentication state until the FIDO Registration is completed.

FIDO Authentication
: After success FIDO Authentication, the session is used to maintain the authentication state during the operations performed by the user agent or mobile app.

Best practices should be followed to implement robust session management (e.g. [OWASP2013]).

4.3.6 Personas

FIDO supports unlinkability [AnonTerminology] of accounts at different relying parties by using relying party specific keys.

Sometimes users have multiple accounts at a particular relying party and even want to maintain unlinkability between these accounts.

Today, this is difficult and requires certain measures to be strictly applied.

FIDO does not want to add more complexity to maintaining unlinkability between accounts at a relying party.

In the case of roaming authenticators, it is recommended to use different authenticators for the various personas (e.g. "business", "personal"). This is possible as roaming authenticators typically are small and not excessively expensive.

In the case of bound authenticators, this is different. FIDO recommends the "Persona" concept for this situation.

All relevant data in an authenticator are related to one Persona (e.g. "business" or "personal"). Some administrative interface (not standardized by FIDO) of the authenticator may allow maintaining and switching Personas.

NORMATIVE

The authenticator MUST only "know" / "recognize" data (e.g. authentication keys, usernames, KeyIDs, …) related to the Persona being active at that time.

With this concept, the User can switch to the "Personal" Persona and register new accounts. After switching back to "Business" Persona, these accounts will not be recognized by the authenticator (until the User switches back to "Personal" Persona again).

In order to support the persona feature, the FIDO Authenticator-specific Module API [UAFASM] supports the use of a 'PersonaID' to identify the persona in use by the authenticator. How Personas are managed or communicated with the user is out of scope for FIDO.

4.3.7 ServerData and KeyHandle

Data contained in the field serverData (see Operation Header dictionary) of UAF requests is sent to the FIDO UAF Client and will be echoed back to the FIDO Server as part of the related UAF response message.

NOTE

The FIDO Server should not assume any kind of implicit integrity protection of such data nor any implicit session binding. The FIDO Server must explicitly bind the serverData to an active session.

NOTE

In some situations, it is desirable to protect sensitive data such that it can be stored in arbitrary places (e.g. in serverData or in the KeyHandle). In such situations, the confidentiality and integrity of such sensitive data must be protected. This can be achieved by using a suitable encryption algorithm, e.g. AES with a suitable cipher mode, e.g. CBC or CTR [CTRMode]. This cipher mode needs to be used correctly. For CBC, for example, a fresh random IV for each encryption is required. The data might have to be padded first in order to obtain an integral number of blocks in length. The integrity protection can be achieved by adding a MAC or a digital signature on the ciphertext, using a different key than for the encryption, e.g. using HMAC [FIPS198-1]. Alternatively, an authenticated encryption scheme such as AES-GCM [SP800-38D] or AES-CCM [SP800-38C] could be used. Such a scheme provides both integrity and confidentiality in a single algorithm and using a single key.

NOTE

When protecting serverData, the MAC or digital signature computation should include some data that binds the data to its associated message, for example by re-including the challenge value in the authenticated serverData.

4.3.8 Authenticator Information retrieved through UAF Application API vs. Metadata

Several authenticator properties (e.g. UserVerificationMethods, KeyProtection, TransactionConfirmationDisplay, ...) are available in the metadata [FIDOMetadataStatement] and through the FIDO UAF Application API. The properties included in the metadata are authoritative and are provided by a trusted source. When in doubt, decisions should be based on the properties retrieved from the Metadata as opposed to the data retrieved through the FIDO UAF Application API.

However, the properties retrieved through the FIDO UAF Application API provide a good "hint" what to expect from the Authenticator. Such "hints" are well suited to drive and optimize the user experience.

4.3.9 Policy Verification

FIDO UAF Response messages do not include all parameters received in the related FIDO UAF request message into the to-be-signed object. As a consequence, any MITM could modify such entries.

FIDO Server will detect such changes if the modified value is unacceptable.

For example, a MITM could replace a generic policy by a policy specifying only the weakest possible FIDO Authenticator. Such a change will be detected by FIDO Server if the weakest possible FIDO Authenticator does not match the initial policy (see Registration Response Processing Rules and Authentication Response Processing Rules).

4.3.10 Replay Attack Protection

The FIDO UAF protocol specifies two different methods for replay-attack protection:

1. Secure transport protocol (TLS)
2. Server Challenge.

The TLS protocol by itself protects against replay-attacks when implemented correctly [TLS].

Additionally, each protocol message contains some random bytes in the `ServerChallenge` field. The FIDO server should only accept incoming FIDO UAF messages which contain a valid `ServerChallenge` value. This is done by verifying that the `ServerChallenge` value, sent by the client, was previously generated by the FIDO server. See **`FinalChallengeParams`**.

It should also be noted that under some (albeit unlikely) circumstances, random numbers generated by the FIDO server may not be unique, and in such cases, the same `ServerChallenge` may be presented more than once, making a replay attack harder to detect.

4.3.11 Protection against Cloned Authenticators

FIDO UAF relies on the UAuth.Key to be protected and managed by an authenticator with the security characteristics specified for the model (identified by the AAID). The security is better when only a single authenticator with that specific UAuth.Key instance exists. Consequently FIDO UAF specifies some protection measures against cloning of authenticators.

Firstly, if the UAuth private keys are protected by appropriate measures then cloning should be hard as such keys cannot be extracted easily.

Secondly, UAF specifies a Signature Counter (see Authentication Response Processing Rules and [UAFAuthnrCommands]). This counter is increased by every signature operation. If a cloned authenticator is used, then the subsequent use of the original authenticator would include a signature counter lower to or equal to the previous (malicious) operation. Such an incident can be detected by the FIDO Server.

4.3.12 Anti-Fraud Signals

There is the potential that some attacker misuses a FIDO Authenticator for committing fraud, more specifically they would:

1. Register the authenticator to some relying party for one account
2. Commit fraud
3. Deregister the Authenticator
4. Register the authenticator to some relying party for another account
5. Commit fraud
6. Deregister the Authenticator
7. and so on...

> NOTE
>
> Authenticators might support a Registration Counter (`RegCounter`). The `RegCounter` will be incremented on each registration and hence might become exceedingly high in such fraud scenarios. See [UAFAuthnrCommands] for more details.

4.4 Interoperability Considerations

FIDO supports Web Applications, Mobile Applications and Native PC Applications. Such applications are referred to as FIDO enabled applications.

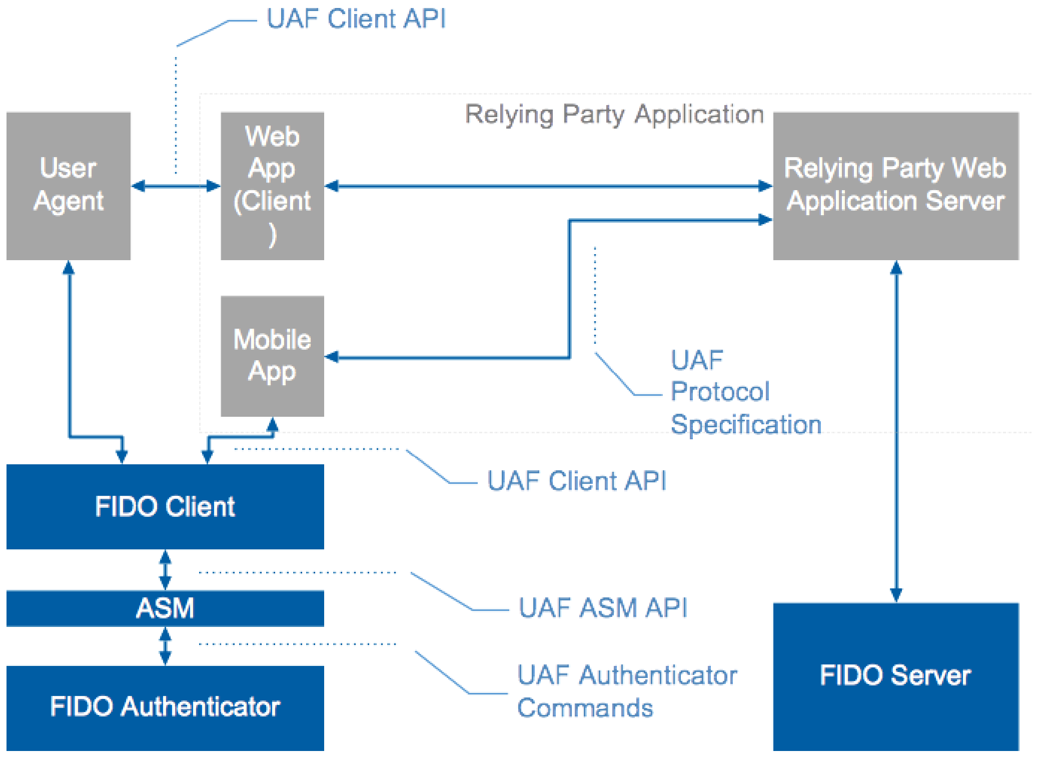


Fig. 12 FIDO Interoperability Overview

Web applications typically consist of the web application server and the related Web App. The Web App code (e.g. HTML and JavaScript) is rendered and executed on the client side by the User Agent. The Web App code talks to the User Agent via a set of JavaScript APIs, e.g. HTML DOM. The FIDO DOM API is defined in [UAFAppAPIAndTransport]. The protocol between the Web App and the Relying Party Web Application Server is typically proprietary.

Mobile Apps play the role of the User Agent and the Web App (Client). The protocol between the Mobile App and the Relying Party Web Application Server is typically proprietary.

Native PC Applications play the role of the User Agent, the Web App (Client). Those applications are typically expected to be independent from any particular Relying Party Web Application Server.

It is recommended for FIDO enabled applications to use the FIDO messages according to the format specified in this document.

It is recommended for FIDO enabled application to use the UAF HTTP Binding defined in [UAFAppAPIAndTransport].

NOTE

The KeyRegistrationData and SignedData objects [UAFAuthnrCommands] are generated and signed by the FIDO Authenticators and have to be verified by the FIDO Server. Verification will fail if the values are modified during transport.

The ASM API [UAFASM] specifies the standardized API to access authenticator Specific Modules (ASMs) on Desktop PCs and Mobile Devices.

The document [UAFAuthnrCommands] does not specify a particular protocol or API. Instead it lists the minimum data set and a specific message format which needs to be transferred to and from the FIDO Authenticator.

5. UAF Supported Assertion Schemes

This section is normative.

5.1 Assertion Scheme "UAFV1TLV"

This scheme is mandatory to implement for FIDO Servers. This scheme is mandatory to implement for FIDO Authenticators.

This Assertion Scheme allows the authenticator and the FIDO Server to exchange an asymmetric authentication key generated by the Authenticator.

This assertion scheme is using Tag Length Value (TLV) compact encoding to encode registration and authentication assertions generated by authenticators. This is the default assertion scheme for UAF protocol.

TAGs and Algorithms are defined in [UAFRegistry].

The authenticator MUST use a dedicated key pair (UAuth.pub/UAuth.priv) suitable for the authentication algorithm specified in the metadata statement [FIDOMetadataStatement] for each relying party. This key pair SHOULD be generated as part of the registration operation.

Conforming FIDO Servers MUST implement all authentication algorithms and key formats listed in document [FIDORegistry] unless they are explicitly marked as optional in [FIDORegistry].

Conforming FIDO Servers MUST implement all attestation types (`TAG_ATTESTATION_*`) listed in document [UAFRegistry] unless they are explicitly marked as optional in [UAFRegistry].

Conforming authenticators MUST implement (at least) one attestation type defined in [UAFRegistry], as well as one authentication algorithm and one key format listed in [FIDORegistry].

5.1.1 KeyRegistrationData

See [UAFAuthnrCommands], section "TAG_UAFV1_KRD".

5.1.2 SignedData

See [UAFAuthnrCommands], section "TAG_UAFV1_SIGNED_DATA".

6. Definitions

See [FIDOGlossary].

7. Table of Figures

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FIDO UAF Registry of Predefined Values

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The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

This document defines all the strings and constants reserved by UAF protocols. The values defined in this document are referenced by various UAF specifications.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us . All comments are welcome.

This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance 's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

1.1 Key Words

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

2. Overview

This section is non-normative.

This document defines the registry of UAF-specific constants that are used and referenced in various UAF specifications. It is expected that, over time, new constants will be added to this registry. For example new authentication algorithms and new types of authenticator characteristics will require new constants to be defined for use within the specifications.

FIDO-specific constants that are common to multiple protocol families are defined in [FIDORegistry].

3. Authenticator Characteristics

This section is normative.

3.1 Assertion Schemes

Names of assertion schemes are strings with a length of 8 characters.

`UAF TLV based assertion scheme "UAFV1TLV"`
This assertion scheme allows the authenticator and the FIDO Server to exchange an asymmetric authentication key generated by the authenticator. The authenticator MUST generate a key pair (UAuth.pub/UAuth.priv) to be used with algorithm suites listed in [FIDORegistry] section "Authentication Algorithms" (with prefix `ALG_`). This assertion scheme is using a compact Tag Length Value (TLV) encoding for the KRD and SignData messages generated by the authenticators. This is the default assertion scheme for the UAF protocol.

4. Predefined Tags

This section is normative.

The internal structure of UAF authenticator commands is a "Tag-Length-Value" (TLV) sequence. The tag is a 2-byte unique unsigned value describing the type of field the data represents, the length is a 2-byte unsigned value indicating the size of the value in bytes, and the value is the variable-sized series of bytes which contain data for this item in the sequence.

Although 2 bytes are allotted for the tag, only the first 14 bits (values up to 0x3FFF) should be used to accommodate the limitations of some hardware platforms.

A tag that has the 14th bit (0x2000) set indicates that it is critical and a receiver must abort processing the entire message if it cannot process that tag.

A tag that has the 13th bit (0x1000) set indicates a composite tag that can be parsed by recursive descent.

4.1 Tags used in the protocol

The following tags have been allocated for data types in UAF protocol messages:

`TAG_UAFV1_REG_ASSERTION 0x3E01`
The content of this tag is the authenticator response to a Register command.

`TAG_UAFV1_AUTH_ASSERTION 0x3E02`
The content of this tag is the authenticator response to a Sign command.

`TAG_UAFV1_KRD 0x3E03`
Indicates Key Registration Data.

`TAG_UAFV1_SIGNED_DATA 0x3E04`
Indicates data signed by the authenticator using UAuth.priv key.

`TAG_APCV1CBOR_AUTH_ASSERTION 0x3E05`
The content of this tag is the authenticator response to a Sign command.

`TAG_APCV1CBOR_SIGNED_DATA 0x3E06`
Indicates Android Protected Confirmation data signed by the authenticator using UAuth.priv key.

`TAG_ATTESTATION_CERT 0x2E05`
Indicates DER encoded attestation certificate.

`TAG_SIGNATURE 0x2E06`
Indicates a cryptographic signature.

`TAG_KEYID 0x2E09`
Represents a generated KeyID.

`TAG_FINAL_CHALLENGE_HASH 0x2E0A`
Represents a generated final challenge hash as defined in [UAFProtocol].

`TAG_AAID 0x2E0B`
Represents an Authenticator Attestation ID as defined in [UAFProtocol].

`TAG_PUB_KEY 0x2E0C`
Represents a generated public key.

`TAG_COUNTERS 0x2E0D`
Represents the use counters for an authenticator.

`TAG_ASSERTION_INFO 0x2E0E`
Represents authenticator information necessary for message processing.

`TAG_AUTHENTICATOR_NONCE 0x2E0F`
Represents a nonce value generated by the authenticator.

`TAG_TRANSACTION_CONTENT_HASH 0x2E10`

Represents a hash of the transaction content sent to the authenticator.

TAG_EXTENSION 0x3E11, 0x3E12
: This is a composite tag indicating that the content is an extension.

TAG_EXTENSION_ID 0x2E13
: Represents extension ID. Content of this tag is a UINT8[] encoding of a UTF-8 string.

TAG_EXTENSION_DATA 0x2E14
: Represents extension data. Content of this tag is a UINT8[] byte array.

TAG_RAW_USER_VERIFICATION_INDEX 0x0103
: This is the raw UVI as it might be used internally by authenticators. This TAG SHALL NOT appear in assertions leaving the authenticator boundary as it could be used as global correlation handle.

TAG_USER_VERIFICATION_INDEX 0x0104
: The user verification index (UVI) is a value uniquely identifying a user verification data record.

Each UVI value MUST be specific to the related key (in order to provide unlinkability). It also must contain sufficient entropy that makes guessing impractical. UVI values MUST NOT be reused by the Authenticator (for other biometric data or users).

The UVI data can be used by FIDO Servers to understand whether an authentication was authorized by the exact same biometric data as the initial key generation. This allows the detection and prevention of "friendly fraud".

As an example, the UVI could be computed as SHA256(KeyID | SHA256(rawUVI)), where the rawUVI reflects (a) the biometric reference data, (b) the related OS level user ID and (c) an identifier which changes whenever a factory reset is performed for the device, e.g. rawUVI = biometricReferenceData | OSLevelUserID | FactoryResetCounter.

FIDO Servers supporting UVI extensions MUST support a length of up to 32 bytes for the UVI value.

Example of the TLV encoded UVI extension (contained in an assertion, i.e. TAG_UAFV1_REG_ASSERTION or TAG_UAFV1_AUTH_ASSERTION)

```
...
04 01                          -- TAG_USER_VERIFICATION_INDEX (0x0104)
20                             -- length of UVI
00 43 B8 E3 BE 27 95 8C        -- the UVI value itself
28 D5 74 BF 46 8A 85 CF
46 9A 14 F0 E5 16 69 31
DA 4B CF FF C1 BB 11 32
82
...
```

TAG_RAW_USER_VERIFICATION_STATE 0x0105
: This is the raw UVS as it might be used internally by authenticators. This TAG SHALL NOT appear in assertions leaving the authenticator boundary as it could be used as global correlation handle.

TAG_USER_VERIFICATION_STATE 0x0106
: The user verification state (UVS) is a value uniquely identifying the set of active user verification data records.

Each UVS value MUST be specific to the related key (in order to provide unlinkability). It also must contain sufficient entropy that makes guessing impractical. UVS values MUST NOT be reused by the Authenticator (for other biometric data sets or users).

The UVS data can be used by FIDO Servers to understand whether an authentication was authorized by one of the biometric data records already known at the initial key generation.

As an example, the UVS could be computed as SHA256(KeyID | SHA256(rawUVS)), where the rawUVS reflects (a) the biometric reference data sets, (b) the related OS level user ID and (c) an identifier which changes whenever a factory reset is performed for the device, e.g. rawUVS = biometricReferenceDataSet | OSLevelUserID | FactoryResetCounter.

FIDO Servers supporting UVS extensions MUST support a length of up to 32 bytes for the UVS value.

Example of the TLV encoded UVS extension (contained in an assertion, i.e. TAG_UAFV1_REG_ASSERTION or TAG_UAFV1_AUTH_ASSERTION)

```
...
06 01                          -- TAG_USER_VERIFICATION_STATE (0x0106)
20                             -- length of UVS
00 18 C3 47 81 73 2B 65        -- the UVS value itself
83 E7 43 31 46 8A 85 CF
93 6C 36 F0 AF 16 69 14
DA 4B 1D 43 FE C7 43 24
45
...
```

TAG_USER_VERIFICATION_CACHING 0x0108
: This extension allows an app to specify such user verification caching time, i.e. the time for which the user verification status can be "cached" by the authenticator.

The value of this extension is defined as follows:

TLV Structure		Description
1	UINT16 Tag	TAG_USER_VERIFICATION_CACHING
1.1	UINT16 Length	Length of UVC structure in bytes
1.2	UINT16	maxUVC in seconds
1.3	UINT8	(optional) verifyIfExceeded. If 0(=:false): return error if maxUVC exceeded. If non-zero (=:true): verify user if maxUVC exceeded.

Example of the TLV encoded UVC extension (contained in an authentication request)

```
...
08 01         -- TAG_USER_VERIFICATION_CACHING (0x0108)
05            -- length of UVC
2c 01 00 00   -- the UVC value itself: maxUVC = 0x012c (300 secs),
01            -- followd by verifyIfExceeded = 1 (true)
...
```

TAG_RESIDENT_KEY 0x0109
Is the key resident in the authenticator. The value is a boolean. See section Require Resident Key Extension for details.

TAG_RESERVED_5 0x0201
Reserved for future use. Name of the tag will change, value is fixed.

5. Predefined Extensions

This section is normative.

5.1 User Verification Method Extension

This extension can be added

- by FIDO Servers to the UAF Request object (request extension) in the `OperationHeader` in order to ask the authenticator for using a specific user verification method and confirm that in the related response extension.
- by FIDO Clients to the ASM Request object (request extension) in order to ask the authenticator for using a specific user verification method and confirm that in the related response extension.
- by ASMs to the authenticator command (request extension) in order to ask the authenticator for using a specific user verification method and confirm that in the related response extension.
- by Authenticators to the assertion generated in response to a request in order to confirm a specifc user verification method that was used for the action.

Extension identifier
fido.uaf.uvm

When present in a request (request extension)
Same as described in Authenticator argument.

FIDO Client processing

The client SHOULD pass the (request) extension through to the Authenticator.

Authenticator argument

The payload of this extension is an array of:

```
UINT32 userVerificationMethod
```

The array can have multiple entries. Each entry SHALL have a single bit flag set. In this case the authenticator SHALL verify the user using all (multiple) methods as indicated.

The semantics of the fields are as follows:

userVerificationMethod
The authentication method used by the authenticator to verify the user. Available values are defined in [FIDORegistry], "User Verification Methods" section.

Authenticator processing
The authenticator supporting this extension

1. SHOULD limit the user verification methods selectable by the user to the user verification method(s) specified in the request extension.
2. SHALL truthfully report the selected user verification method(s) back in the related response extension added to the assertion.

Authenticator data

The payload of this extension is an array of the following structure:

```
UINT32 userVerificationMethod
UINT16 keyProtection
UINT16 matcherProtection
```

The array can have multiple entries describing all user verification methods used.

The semantics of the fields are as follows:

userVerificationMethod
The authentication method used by the authenticator to verify the user. Available values are defined in [FIDORegistry], "User Verification Methods" section.
keyProtection
The method used by the authenticator to protect the FIDO registration private key material. Available values are defined in [FIDORegistry], "Key Protection Types" section. This value has no meaning in the request extension.
matcherProtection
The method used by the authenticator to protect the matcher that performs user verification. Available values are defined in [FIDORegistry], "Matcher Protection Types" section.

Server processing
If the FIDO Server requested the UVM extension,

1. it SHOULD verify that a proper response is provided (if client side support can be assumed), and
2. it SHOULD verify that the UVM response extension specifies one or more acceptable user verification method(s).

5.2 User ID Extension

This extension can be added

- by FIDO Servers to the UAF Request object (request extension) in the `OperationHeader`.
- by FIDO Clients to the ASM Request object (request extension).
- by ASMs to the `TAG_UAFV1_REGISTER_CMD` object using `TAG_EXTENSION` (request extension).
- by Authenticators to the registration or authentication assertion using `TAG_EXTENSION` (response extension).

The main purpose of this extension is to allow relying parties finding the related user record by an existing index (i.e. the user ID). This user ID is not intended to be displayed.

Authenticators SHOULD truthfully indicate support for this extension in their Metadata Statement.

Extension identifier
fido.uaf.userid
Extension fail-if-unknown flag
`false`, i.e. this (request and response) extension can safely be ignored by all entities.
Extension `data` value
Content of this tag is the UINT8[] encoding of the user ID as UTF-8 string.

5.3 Android SafetyNet Extension

This extension can be added

- by FIDO Servers to the UAF Request object (request extension) in the `OperationHeader` in order to trigger generation of the related response extension.
- by FIDO Clients to the ASM Request object (request extension) in order to trigger generation of the related response extension.
- by the ASM to the respective `exts` array in the `ASMResponse` object (response extension).
- by the FIDO Client to the respective `exts` array in either the `OperationHeader`, or the `AuthenticatorRegistrationAssertion`, or the `AuthenticatorSignAssertion` of the UAF Response object (response extension).

Extension identifier
fido.uaf.safetynet

Extension fail-if-unknown flag
`false`, i.e. this (request and response) extension can safely be ignored by all entities.

Extension `data` value

When present in a request (request extension)
empty string, i.e. the FIDO Server might add this extension to the UAF Request with an empty `data` value in order to trigger the generation of this extension for the UAF Response.

EXAMPLE 1: SafetyNet Request Extension

```
"exts": [{"id": "fido.uaf.safetynet", "data": "", "fail_if_unknown": false}]
```

When present in a response (response extension)

- If the request extension was successfully processed, the `data` value is set to the JSON Web Signature attestation response as returned by the call to `com.google.android.gms.safetynet.SafetyNetApi.AttestationResponse`.
- If the FIDO Client or the ASM support this extension, but the underlying Android platform does not support it (e.g. Google Play Services is not installed), the `data` value is set to the string "p" (i.e. platform issue).

EXAMPLE 2: SafetyNet Response Extension - not supported by platform

```
"exts": [{"id": "fido.uaf.safetynet", "data": "p", "fail_if_unknown": false}]
```

- If the FIDO Client or the ASM support this extension and the underlying Android platform supports it, but the functionality is temporarily unavailable (e.g. Google servers are unreachable), the `data` value is set to the string "a" (i.e. availability issue).

EXAMPLE 3: SafetyNet Response Extension - temporarily unavailable

```
"exts": [{"id": "fido.uaf.safetynet", "data": "a", "fail_if_unknown": false}]
```

NOTE

If neither the FIDO Client nor the ASM support this extension, it won't be present in the response object.

FIDO Client processing

FIDO Clients running on Android should support processing of this extension.

If the FIDO Client finds this (request) extension with empty `data` value in the UAF Request and it supports processing this extension, then the FIDO Client

1. MUST call the Android API `SafetyNet.SafetyNetApi.attest(mGoogleApiClient, nonce)` (see SafetyNet online documentation) and add the response (or an error code as described above) as extension to the response object.
2. MUST NOT copy the (request) extension to the ASM Request object (deviating from the general rule in [UAFProtocol], section 3.4.6.2 and 3.5.7.2).

If the FIDO Client does not support this extension it MUST copy this extension from the UAF Request to the ASM Request object (according to the general rule in [UAFProtocol], section 3.4.6.2 and 3.5.7.2).

If the ASM supports this extension it MUST call the SafetyNet API (see above) and add the response as extension to the ASM Response object. The FIDO Client MUST copy the extension in the ASM Response to the UAF Response object (according to sections 3.4.6.4. and 3.5.7.4 step 4 in [UAFProtocol]).

When calling the Android API, the nonce parameter MUST be set to the serialized JSON object with the following structure:

```
{
  "hashAlg": "S256", // the hash algorithm
  "fcHash": "..."    // the finalChallengeHash
}
```

Where

- `hashAlg` identifies the hash algorithm according to [FIDOSignatureFormat], section IANA Considerations.
- `fcHash` is the base64url encoded hash value of FinalChallenge (see section 3.6.3 and 3.7.4 in [UAFASM] for details on how to compute `finalChallengeHash`).
  We use this method to bind this SafetyNet extension to the respective FIDO UAF message.

  Only hash algorithms belonging to the Authentication Algorithms mentioned in [FIDORegistry] SHALL be used (e.g. SHA256 because it belongs to `ALG_SIGN_SECP256R1_ECDSA_SHA256_RAW`).

Authenticator argument
N/A

Authenticator processing
N/A. This extension is related to the Android platform in general and not to the authenticator in particular. As a consequence there is no need for an authenticator to receive the (request) extension nor to process it.

Authenticator data
N/A

Server processing
If the FIDO Server requested the SafetyNet extension,

1. it SHOULD verify that a proper response is provided (if client side support can be assumed), and
2. it SHOULD verify the SafetyNet AttestationResponse (see SafetyNet online documentation).

> NOTE
>
> The package name in AttestationResponse might relate to either the FIDO Client or the ASM.

> NOTE
>
> The response extension is not part of the signed assertion generated by the authenticator. If an MITM or MITB attacker would remove the response extension, the FIDO server might not be able to distinguish this from the "SafetyNet extension not supported by FIDO Client/ASM" case.

5.4 Android Key Attestation

This extension can be added

- by FIDO Servers to the UAF Registration Request object (request extension) in the `OperationHeader` in order to trigger generation of the related response extension.
- by FIDO Clients to the ASM Registration Request object (request extension) in order to trigger generation of the related response extension.
- by the ASM to the respective `exts` array in the `ASMResponse` object related to a registration response (response extension).
- by the FIDO Client to the respective `exts` array in either the `OperationHeader`, or the `AuthenticatorRegistrationAssertion` of the UAF Registration Response object (response extension).

Extension identifier

fido.uaf.android.key_attestation

Extension fail-if-unknown flag

`false`, i.e. this (request and response) extension can safely be ignored by all entities.

Extension `data` value

When present in a request (request extension)

empty string, i.e. the FIDO Server might add this extension to the UAF Request with an empty `data` value in order to trigger the generation of this extension for the UAF Response.

EXAMPLE 4: Android KeyAttestation Request Extension

```
"exts": [{"id": "fido.uaf.android.key_attestation", "data": "", "fail_if_unknown": false}]
```

When present in a response (response extension)

- If the request extension was successfully processed, the `data` value is set to a JSON array containing the base64 encoded entries of the array returned by the call to the KeyStore API function getCertificateChain.

EXAMPLE 5: Retrieve KeyAttestation and add it as extension

```
Calendar notBefore = Calendar.getInstance();
Calendar notAfter = Calendar.getInstance();
notAfter.add(Calendar.YEAR, 10);

KeyPairGenerator kpGenerator = KeyPairGenerator.getInstance(
  KeyProperties.KEY_ALGORITHM_EC, "AndroidKeyStore");
kpGenerator.initialize(
  new KeyGenParameterSpec.Builder(keyUUID, KeyProperties.PURPOSE_SIGN)
    .setDigests(KeyProperties.DIGEST_SHA256)
    .setAlgorithmParameterSpec(new ECGenParameterSpec("prime256v1"))
    .setCertificateSubject(
      new X500Principal(String.format("CN=%s, OU=%s",
        keyUUID, aContext.getPackageName())))
    .setCertificateSerialNumber(BigInteger.ONE)
    .setKeyValidityStart(notBefore.getTime())
    .setKeyValidityEnd(notAfter.getTime())
    .setUserAuthenticationRequired(true)
    .setAttestationChallenge(fcHash) -- bind to Final Challenge
    .build());

kpGenerator.generateKeyPair(); // generate Uauth key pair

Certificate[] certarray=myKeyStore.getCertificateChain(keyUUID);
String certArray[]=new String[certarray.length];
int i=0;
for (Certificate cert : certarray) {
    byte[] buf = cert.getEncoded();
    certArray[i] = new String(Base64.encode(buf, Base64.DEFAULT))
            .replace("\n", "");
    i++;
}

JSONArray jarray=new JSONArray(certArray);
String key_attestation_data=jarray.toString();
```

EXAMPLE 6: Example of successfull key attestation extension response

```
"exts": [{"id": "fido.uaf.android.key_attestation", "data": "
[\"MIIClDCCAjugAwIBAgIBATAKBggqhkjOPQQD
AjCBiDELMAkGA1UEBhMCVVMxEzARBgNVBAgMCkNhbGlmb3JuaWExFTATBgNVBAoMDEdvb2dsZSwgSW5jLjEQMA4GA1UECwwHQW5k

cm9pZDE7MDkGA1UEAwwyQW5kcm9pZCBLZXlzdG9yZSBTb2Z0d2FyZSBBdHRlc3RhdGlvbiBJbnRlcm1lZGlhdGUwIBcNNzAwMTAx

MDAwMDAwWhgPMjEwNjAyMDcwNjI4MTVaMB8xHTAbBgNVBAMMFEFuZHJvaWQgS2V5c3RvcmUgS2V5MFkwEwYHKoZIzj0CAQYIKoZI

zj0DAQcDQgAEJ/As4L+Kgbcxwcx+5LPQi35quIxg981k/TeWr2IPBLh8+NJ+buDBhQ9O5ln6B7JjbJc4Fvko1Pdz7spKTQdWpKOB

+zCB+DALBgNVHQ8EBAMCB4AwgccGCisGAQQB1nkCAREEgbgwgbUCAQIKAQACAQEKAQEEBkZDSEFTSAQAMGm/hT0IAgYBXtPjz6C/

hUVZBFcwVTEvMC0EKGNvbS5hbmRyb2lkLmtleXN0b3JlLmFuZHJvaWRrZXlzdG9yZWRlbW8CAQExIgQgdM/LUHSI9SkQhZHHpQWR

nzJ3MvvB2ANSauqYAAbS2JgwMqEFMQMCAQKiAwIBA6MEAgIBAKUFMQMCAQSqAwIBAb+DeAMCAQK/hT4DAgEAv4U/AgUAMB8GA1Ud

IwQYMBaAFD/8rNYasTqegSC41SUcxWW7HpGpMAoGCCqGSM49BAMCA0cAMEQCICgYLmk24alwS9Lm06y2lLiqWDddrWh4gmUUv4+A

5k2TAiAEttheSBBaNbQJGQCh3mY92v8nP5obU60IKjpPetRswQ==\",\"MIICeDCCAh6gAwIBAgICEAEwCgYIKoZIzj0EAwIwgZg

xCzAJBgNVBAYTAlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMRYwFAYDVQQHDA1Nb3VudGFpbiBWaWV3MRUwEwYDVQQKDAxHb29nbGU

sIEluYy4xEDAOBgNVBAsMB0FuZHJvaWQxMzAxBgNVBAMMKkFuZHJvaWQgS2V5c3RvcmUgU29mdHdhcmUgQXR0ZXN0YXRpb24gUm9

vdDAeFw0xNjAxMTEwMDQ2MDlaFw0yNjAxMDgwMDQ2MDlaMIGIMQswCQYDVQQGEwJVUzETMBEGA1UECAwKQ2FsaWZvcm5pYTEVMBM

GA1UECgwMR29vZ2xlLCBJbmMuMRAwDgYDVQQLDAdBbmRyb2lkMTswOQYDVQQDDDJBbmRyb2lkIEtleXN0b3JlIFNvZnR3YXJlIEF

0dGVzdGF0aW9uIEludGVybWVkaWF0ZTBZMBMGByqGSM49AgEGCCqGSM49AwEHA0IABOueefhCY1msyyqRTImGzHCtkGaTgqlzJhP
+rMv4ISdMIXSXSir+pblNf2bU4GUQZjW8U7ego6ZxWD7bPhGuEBSjZjBkMB0GA1UdDgQWBBQ//KzWGrE6noEguNUlHMVlux6RqTA
fBgNVHSMEGDAWgBTIrel3TEXDo88NFhDkeUM6IVowzzASBgNVHRMBAf8ECDAGAQH/AgEAMA4GA1UdDwEB/wQEAwIChDAKBggqhkj
OPQQDAgNIADBFAiBLipt77oK8wDOHri/AiZi03cONqycqRZ9pDMfDktQPjgIhAO7aAV229DLp1IQ7YkyUBO86fMy9Xvsiu+f+uXc
/WT/7\",\"MIICizCCAjKgAwIBAgIJAKIFntEOQ1tXMAoGCCqGSM49BAMCMIGYMQswCQYDVQQGEwJVUzETMBEGA1UECAwKQ2FsaW
Zvcm5pYTEWMBQGA1UEBwwNTW91bnRhaW4gVmlldzEVMBMGA1UECgwMR29vZ2xlLCBJbmMuMRAwDgYDVQQLDAdBbmRyb2lkMTMwMQ
YDVQQDDCpBbmRyb2lkIEtleXN0b3JlIFNvZnR3YXJlIEF0dGVzdGF0aW9uIFJvb3QwHhcNMTYwMTExMDA0MzUwWhcNMzYwMTA2MD
A0MzUwWjCBmDELMAkGA1UEBhMCVVMxEzARBgNVBAgMCkNhbGlmb3JuaWExFjAUBgNVBAcMDU1vdW50YWluIFZpZXcxFTATBgNVBA
oMDEdvb2dsZSwgSW5jLjEQMA4GA1UECwwHQW5kcm9pZDEzMDEGA1UEAwwqQW5kcm9pZCBLZXlzdG9yZSBTb2Z0d2FyZSBBdHRlc3
RhdGlvbiBSb290MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAE7l1ex+HA220Dpn7mthvsTWpdamguD/9/SQ59dx9EIm29sa/6Fs
vHrcV30lacqrewLVQBXT5DKyqO107sSHVBpKNjMGEwHQYDVR0OBBYEFMit6XdMRcOjzw0WEOR5QzohWjDPMB8GA1UdIwQYMBaAFM
it6XdMRcOjzw0WEOR5QzohWjDPMA8GA1UdEwEB/wQFMAMBAf8wDgYDVR0PAQH/BAQDAgKEMAoGCCqGSM49BAMCA0cAMEQCIDUho+
+LNEYenNVg8x1YiSBq3KNlQfYNns6KGYxmSGB7AiBNC/NR2TB8fVvaNTQdqEcbY6WFZTytTySn502vQX3xvw==\"]",
"fail_if_unknown": false}]
```

NOTE

Line-breaks been added for readibility.

- If the FIDO Client or the ASM support this extension, but the underlying Android platform does not support it (e.g. Android version doesn't yet support it), the `data` value is set to the string "p" (i.e. platform issue).

EXAMPLE 7: KeyAttestation Response Extension - not supported by platform

```
"exts": [{"id": "fido.uaf.android.key_attestation", "data": "p", "fail_if_unknown": false}]
```

- If the FIDO Client or the ASM support this extension and the underlying Android platform supports it, but the functionality is temporarily unavailable (e.g. Google servers are unreachable), the `data` value is set to the string "a".

EXAMPLE 8: KeyAttestation Response Extension - temporarily unavailable

```
"exts": [{"id": "fido.uaf.android.key_attestation", "data": "a", "fail_if_unknown": false}]
```

NOTE

If neither the FIDO Client nor the ASM support this extension, it won't be present in the response object.

FIDO Client processing

FIDO Clients running on Android MUST pass this (request) extension with empty `data` value to the ASM.

If the ASM supports this extension it MUST call the KeyStore API (see above) and add the response as extension to the ASM Response object. The FIDO Client MUST copy the extension in the ASM Response to the UAF Response object (according to section 3.4.6.4 step 4 in [UAFProtocol]).

More details on Android key attestation can be found at:

- https://developer.android.com/training/articles/keystore.html
- https://developer.android.com/training/articles/security-key-attestation
- https://source.android.com/security/keystore/
- https://source.android.com/security/keystore/implementer-ref.html

Authenticator argument

N/A

Authenticator processing

The authenticator generates the attestation response. The call keyStore.getCertificateChain is finally processed by the authenticator.

Authenticator data

N/A

Server processing

If the FIDO Server requested the key attestation extension,

1. it MUST follow the registration response processing rules (see FIDO UAF Protocol, section 3.4.6.5) before processing this extension
2. it MUST verify the syntax of the key attestation extension and it MUST perform RFC5280 compliant chain validation of the entries in the array to one attestationRootCertificate specified in the Metadata Statement - **accepting that that the keyCertSign bit in the key usage extension of the certificate issuing the leaf certificate is NOT set (which is a deviation from RFC5280)**.
3. it MUST determine the leaf certificate from that chain, and it MUST perform the following checks on this leaf certificate
    1. Verify that KeyDescripion.attestationChallenge == FCHash (see FIDO UAF Protocol, section 3.4.6.5 Step 6.)
    2. Verify that the public key included in the leaf certificate is identical to the public key included in the FIDO UAF Surrogate attestation block
    3. If the related Metadata Statement claims keyProtection KEY_PROTECTION_TEE, then refer to KeyDescription.teeEnforced using "authzList". If the related Metadata Statement claims keyProtection KEY_PROTECTION_SOFTWARE, then refer to KeyDescription.softwareEnforced using "authzList".
    4. Verify that
        1. authzList.origin == KM_TAG_GENERATED
        2. authzList.purpose == KM_PURPOSE_SIGN
        3. authzList.keySize is acceptable, i.e. =2048 (bit) RSA or =256 (bit) ECDSA.
        4. authzList.digest == KM_DIGEST_SHA_2_256.
        5. authzList.userAuthType only contains acceptable user verification methods.
        6. authzList.authTimeout == 0 (or *not* present).
        7. authzList.noAuthRequired is *not* present (unless the Metadata Statement marks this authenticator as silent authenticator, i.e. userVerificaton set to USER_VERIFY_NONE).
        8. authzList.allApplications is *not* present, since FIDO Uauth keys MUST be bound to the generating app (AppID).

> NOTE
>
> The response extension is not part of the signed assertion generated by the authenticator. If an MITM or MITB attacker would remove the response extension, the FIDO server might not be able to distinguish this from the "KeyAttestation extension not supported by ASM/Authenticator" case.

ExtensionDescriptor `data` value (for Metadata Statement)

In the case of extension id="fido.uaf.android.key_attestation", the data field of the ExtensionDescriptor as included in the Metadata Statement will contain a dictionary containing the following data fields

DOMString attestationRootCertificates[]

Each element of this array represents a PKIX [RFC5280] X.509 certificate that is valid for this authenticator model. Multiple certificates might be used for different batches of the same model. The array does not represent a certificate chain, but only the trust anchor of that chain.

Each array element is a base64-encoded (section 4 of [RFC4648]), DER-encoded [ITU-X690-2008] PKIX certificate value.

> NOTE
>
> A certificate listed here is either a root certificate or an intermediate CA certificate.

> NOTE
>
> The field `data` is specified with type DOMString in [FIDOMetadataStatement] and hence will contain the serialized object as described above.

An example for the `supportedExtensions` field in the Metadata Statement could look as follows (with line breaks to improve readability):

EXAMPLE 9: Example of a supportedExtensions field in Metadata Statement

```
"supportedExtensions": [{
        "id": "fido.uaf.android.key_attestation",
        "data": "{ \"attestationRootCertificates\": [
\"MIICPTCCAeOgAwIBAgIJAOuexvU3Oy2wMAoGCCqGSM49BAMCMHsxIDAeBgNVBAMM
F1NhbXBsZSBBdHRlc3RhdGlvbiBSb290MRYwFAYDVQQKDA1GSURPIEFsbGlhbmNl
MREwDwYDVQQLDAhVQUYgVFdHLDESMBAGA1UEBwwJUGFsbyBBbHRvMQswCQYDVQQI
DAJDQTELMAkGA1UEBhMCVVMwHhcNMTQwNjE4MTMzMzMyWhcNNDExMTAzMTMzMzMy
WjB7MSAwHgYDVQQDDBdTYW1wbGUgQXR0ZXN0YXRpb24gUm9vdDEWMBQGA1UECgwN
RklETyBBbGxpYW5jZTERMA8GA1UECwwIVUFGIFRXRywxEjAQBgNVBAcMCVBhbG8g
QWx0bzELMAkGA1UECAwCQ0ExCzAJBgNVBAYTAlVTMFkwEwYHKoZIzj0CAQYIKoZI
zj0DAQcDQgAEH8hv2D0HXa59/BmpQ7RZehL/FMGzFd1QBg9vAUpOZ3ajnuQ94PR7
aMzH33nUSBr8fHYDrqOBb58pxGqHJRyX/6NQME4wHQYDVR0OBBYEFPoHA3CLhxFb
C0It7zE4w8hk5EJ/MB8GA1UdIwQYMBaAFPoHA3CLhxFbC0It7zE4w8hk5EJ/MAwG
A1UdEwQFMAMBAf8wCgYIKoZIzj0EAwIDSAAwRQIhAJ06QSXt9ihIbEKYKIjsPkri
VdLIgtfsbDSu7ErJfzr4AiBqoYCZf0+zI55aQeAHjIzA9Xm63rruAxBZ9ps9z2XN
lQ==\"] }",
        "fail_if_unknown": false
                      }]
```

5.5 User Verification Caching

In several cases it is good enough for the relying party to know whether the user was verified by the authenticator "some time" ago. This extension allows an app to specify such user verification caching time, i.e. the time for which the user verification status can be "cached" by the authenticator.

For example: Do not ask the user for a fresh user verification to authorize a payment of 4€ if the user was verified by this authenticator within the past 300 seconds.

This extension allows the authenticator to bridge the gap between a "silent" authenticator, i.e. an authenticator never verifying the user and a "traditional" authenticator, i.e. an authenticator always asking for fresh user verification.

We formally define one extension for the request and a separate extension for the response as the request extension can be safely ignored, but the response extension cannot.

Authenticator supporting this extension MUST truthfully specify both, the UVC Request and UVC Response extension in the `supportedExtensions` list of the related Metadata Statement [FIDOMetadataStatement]. The TAG of the UVC Response extension must be specified in that list.

5.5.1 UVC Request

This extension can be added by FIDO Servers to the UAF Request object (request extension) in the `OperationHeader` in order to trigger generation of the related response extension.

Extension Identifier
fido.uaf.uvc-req

Extension fail-if-unknown flag
`false`, i.e. the *request* extension can safely be ignored by all entities.

UVC Extension data value
A (base64url-encoded) TLV object as defined in the description of `TAG_USER_VERIFICATION_CACHING`. In the UVC Extension provided through the DOM API [UAFAppAPIAndTransport], the field `verifyIfExceeded` MAY NOT be present. The FIDO Client MAY add the field `verifyIfExceeded` in order to improve processing.

FIDO Client processing

- In a registration request: Simple pass-through to the platform preferred authenticator.
- In a sign request: Simple pass-through to an authenticator which would *not* require fresh user verification and still meets all other authentication selection criteria (if such authenticator exists). If this is not possible, then use the preferred authenticator (as normal) but pass-through this extension.

Authenticator argument

Same TLV object as defined in "Extension data value", but as binary object included in the Registration / Authentication command.

Authenticator processing

In a registration request:

The Authenticator MUST always freshly verify the user and create a key marked with the maximum user verification caching time as specified (referred to as ***regMaxUVC***), i.e. in signAssertion the acceptable maximum user verification time can never exceed this value. The field (`verifyIfExceeded`) is not allowed in a registration request.

In a sign request:

If the authenticator supports specifying user verification caching time in a sign request:

1. compute ***maxUVC*** = min(maxUVC , regMaxUVC)
2. compute ***elapsedTime***, i.e. the time since last user verification.
3. If (elapsedTime > maxUVC) AND verifyIfExceeded==false then return error
4. If (elapsedTime > maxUVC) AND ((verifyIfExceeded==true)OR(verifyIfExceeded is NOT PRESENT)) then verify user
5. If (elapsedTime ≤ maxUVC) then Sign the assertion as normal
6. Add the UVC Response extension to the assertion.

If the authenticator does not support specifying user verification caching time in a sign request, this extension will be ignored by the authenticator. This will be detected by the server since no extension output will be generated by the authenticator.

Authenticator data

N/A

Server processing

N/A

5.5.2 UVC Response

This extension can be added by the Authenticator to the `AuthenticatorRegistrationAssertion`, or the `AuthenticatorSignAssertion` of the UAF Response object (response extension).

Extension Identifier

fido.uaf.uvc-resp (TAG_USER_VERIFICATION_CACHING)

Extension fail-if-unknown flag

`true`, i.e. the *response* extension (included in the UAF assertion) MAY NOT be ignored if unknown. If the server is not prepared to process the UVC response extension, it MUST fail.

Extension data value

N/A

FIDO Client processing

N/A

Authenticator argument

N/A

Authenticator processing

N/A

Authenticator data

If the extension is supported and the request extension was received and evaluated during the respective call, then the binary TLV object as described in the description of `TAG_USER_VERIFICATION_CACHING` will be included in the assertion generated by the Authenticator.

Where the field maxUVC contains an upper bound of ***trueUVC*** and where the field `verifyIfExceeded` will *not* be present.

The upper bound value is to be computed as follows:

1. Compute the elapsed seconds since last user verification (=:trueUVC).
2. Compute some upper bound of trueUVC, must not exceed min(command.maxUVC, regMaxUVC).

   Where `command.maxUVC` refers to the maxUVC value of the related UVC Request .

   Where regMaxUVC is the maxUVC value specified in the related registration call (see above) or 0 if no such value was provided at registration time.

For example, use min(maxUVC, createMaxUVC) or min(round trueUVC to 5 seconds, maxUVC, createMaxUVC).

Server processing

If the FIDO Server requested the UVC extension,

1. Verify that the Metadata Statement related to this Authenticator indicates support for this extension in the field `supportedExtensions`
2. Verify that assertion.maxUVC is less or equal to request.maxUVC, fail if it isn't.
3. Verify that assertion.maxUVC is acceptable, fail if it isn't.

If the FIDO Server did not request the UVC extension (but encounters it in the response) or if the server doesn't understand the UVC response extension, it MUST fail.

5.5.3 Privacy Considerations

Using the UVC Request extension with `verifyIfExceeded` set to `FALSE` might allow the caller to triage the last time the user was verified without requiring any input from the user and without notifying the user. We do not allow this field to be set through the DOM API (i.e. by web pages). However, native applications can use this field and hence could be able to determine the last time the user was verified. Native applications have substantially more permissions and hence can have more detailed knowledge about the user's behavior than web pages (e.g. track whether the device is used by evaluating accelerometers).

In the UVC Response extension the Authenticator can provide an upper bound of the `trueUVC` value in order to prevent disclosure of exact time of user verification.

5.5.4 Security Considerations

FIDO Servers not expecting user verification being used, might expect a fresh user verification and an explicit user consent being provided. Authenticators supporting this extension shall only use it when they are asked for that (i.e. UVC Request extension is present). Additionally the authenticator must indicate if the user was *not* freshly verified using the UVC Response extension. This response extension is marked with "fail-if-unknown" set to true, to make sure that servers receiving this extension know that the user might not have been freshly verified.

5.6 Require Resident Key Extension

This extension is intended to simplify the integration of authenticators implementing [FIDOCTAP] with FIDO UAF [UAFProtocol].

Extension Identifier
fido.uaf.rk (TAG_RESIDENT_KEY)

Extension fail-if-unknown flag
`false`, i.e. the extension MAY be ignored if unknown.

Extension data value
boolean, i.e. rk=true or rk=false.

FIDO Client processing
N/A

Authenticator argument
boolean, i.e. rk=true or rk=false.

Authenticator processing
If the authenticator supports this extension, it should

1. persistently store the credential's cryptographic key material internally is rk=true
2. NOT persistently store the credential's cryptographic key material internally is rk=false

NOTE
It is expected that

1. authenticators with `isSecondFactorOnly=false` in their Metadata Statement will persistently store the credential's cryptographic key material internally if the extension is missing.
2. authenticators with `isSecondFactorOnly=true` in their Metadata Statement will NOT persistently store the credential's cryptographic key material internally if the extension is missing.

Authenticator data
boolean, i.e. rk=true or rk=false in an assertion, indicating whether the current credential is resident in the authenticator or not.

Server processing

A response extension `fido.uaf.rk` set to false indicates that the FIDO Server needs to provide a keyHandle for triggering authentication. This means that the authenticator can only be used as a second factor (see also `isSecondFactorOnly` in [FIDOMetadataStatement].

If the FIDO Server did not request the `fido.uaf.rk` extension (but encounters it in the response) or if the server doesn't understand the `fido.uaf.rk` response extension, it can silently ignore the extension.

5.7 Attestation Conveyance Extension

This extension is intended to simplify the integration of authenticators implementing [FIDOCTAP] with FIDO UAF [UAFProtocol].

Extension Identifier
fido.uaf.ac

Extension fail-if-unknown flag
`false`, i.e. the extension MAY be ignored if unknown.

Extension data value
string, i.e. ac='direct', ac='indirect', or ac='none'.

FIDO Client processing
If the ac value is

direct
the FIDO Client SHALL pass-through the attestation statement as received from the Authenticator.

indirect
the FIDO Client SHALL either

1. pass-through the attestation statement as received from the Authenticator or
2. replace the attestation statement received from the Authenticator using some anonymization CA.

none
the FIDO Client SHALL remove the attestation statement received from the Authenticator.

Authenticator argument
N/A

Authenticator processing
If the authenticator supports this extension, it should

1. return an attestation statement according to the conveyance indicated.

Authenticator data
N/A (only indirectly through the generated attestation statement)

Server processing
The server should verify the attestation statement if it asked for it (i.e. ac='direct' or ac='indirect').

If the FIDO Server specified ac='none', but received an attestation statement, it can silently ignore it.

6. Other Identifiers specific to FIDO UAF

6.1 FIDO UAF Application Identifier (AID)

This AID [ISOIEC-7816-5] is used to identify FIDO UAF authenticator applications in a Secure Element.

The FIDO UAF AID consists of the following fields:

Field	RID	AC	AX
Value	0xA000000647	0xAF	0x0001

Table 1: FIDO UAF Applet AID

A. References

A.1 Normative references

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FIDO UAF WebAuthentication Assertion Format

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The English version of this specification is the only normative version. Non-normative translations may also be available.

Abstract

This document defines the assertion format "WAV1CBOR" in order to use Web Authentication assertions through the FIDO UAF protocol.

Status of This Document

This section describes the status of this document at the time of its publication. Other documents may supersede this document. A list of current FIDO Alliance publications and the latest revision of this technical report can be found in the FIDO Alliance specifications index at https://fidoalliance.org/specifications/.

This document was published by the FIDO Alliance as a Proposed Standard. If you wish to make comments regarding this document, please Contact Us. All comments are welcome.

This document has been reviewed by FIDO Aliance Members and is endorsed as a Proposed Standard. It is a stable document and may be used as reference material or cited from another document. FIDO Alliance's role in making the Recommendation is to draw attention to the specification and to promote its widespread deployment.

Table of Contents

1. Notation

Type names, attribute names and element names are written as `code`.

String literals are enclosed in “”, e.g. “UAF-TLV”.

In formulas we use “|” to denote byte wise concatenation operations.

UAF specific terminology used in this document is defined in [FIDOGlossary].

All diagrams, examples, notes in this specification are non-normative.

1.1 Key Words

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

2. Overview

This section is non-normative.

This document defines the assertion format "WAV1CBOR" in order to use Web Authentication assertions through the FIDO UAF protocol.

3. Data Structures for WAV1CBOR

This section is normative.

3.1 Registration Assertion

The registration assertion for the assertion format "WAV1CBOR" is a TLV encoded object containing the CBOR encoded `authenticatorData`, the name of the attestation format, and the atestation statement itself.

TLV Structure		Description
1	UINT16 Tag	TAG_WAV1CBOR_REG_ASSERTION
1.1	UINT16 Length	Length of the structure.
1.2	UINT16 Tag	TAG_WAV1CBOR_REG_DATA
1.2.1	UINT16 Length	Length of the structure.
1.2.2	UINT8 tbsData	The binary `authenticatorData` structure as specified in section 6.1 in [WebAuthn] with non-empty `attestedCredentialData` field being present followed by (i.e. binary concatenation) the `clientDataHash`.

1.3	UINT16 Tag	TAG_ATTESTATION_FORMAT
1.3.1	UINT16 Length	Length of Attestation Format
1.3.2	UINT8[] Attestation Format	Authenticator Attestation Format, see field "fmt" in section sctn-attestation in [WebAuthn]
1.4	UINT16 Tag	TAG_ATTESTATION_STATEMENT
1.4.1	UINT16 Length	Length of Attestation Statement
1.4.2	UINT8[] Attestation Statement	Authenticator Attestation Statement, see field "stmt" in section sctn-attestation in [WebAuthn]. This field contains the signature in sub-field "sig".

3.2 Authentication Assertion

The authentication assertion is a TLV structure containing the CBOR encoded `authenticatorData` object, the authenticator model name (AAGUID), the key identifier and the signature of the `authenticatorData` object.

TLV Structure		Description
1	UINT16 Tag	TAG_WAV1CBOR_AUTH_ASSERTION
1.1	UINT16 Length	Length of the structure.
1.2	UINT16 Tag	TAG_WAV1CBOR_SIGNED_DATA
1.2.1	UINT16 Length	Length of the structure.
1.2.2	UINT8 tbsData	As described in step 11 in section 6.3.3 in [WebAuthn]: The binary `authenticatorData` structure as specified in section 6.1 in [WebAuthn] with empty `attestedCredentialData` field being present followed by (i.e. binary concatenation) the `clientDataHash`.
1.3	UINT16 Tag	TAG_AAGUID
1.3.1	UINT16 Length	Length of AAGUID
1.3.2	UINT8[] AAGUID	Authenticator Attestation GUID, see section 6.4.1 in [WebAuthn]
1.4	UINT16 Tag	TAG_KEYID
1.4.1	UINT16 Length	Length of KeyID
1.4.2	UINT8[] KeyID	(binary value of) Credential ID (see definition of CredentialID in [WebAuthn])
1.5	UINT16 Tag	TAG_SIGNATURE
1.5.1	UINT16 Length	Length of Signature

1.5.2	UINT8[] Signature	Signature calculated using UAuth.priv over tbsData - *not* including any TAGs nor the KeyID and AAGUID.

4. Processing Rules

This section is normative.

4.1 Registration Response Processing Rules for ASM

See [UAFASM] for details of the ASM API.

Refer to [UAFAuthnrCommands] document for more information about the TAGs and structure mentioned in this paragraph.

1. Locate authenticator using `authenticatorIndex`. If the authenticator cannot be located, then fail with error code `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.
2. Connect to the Authenticator and call `authenticatorGetInfo` [FIDOCTAP]. Remember whether the authenticator supports residentKeys (`rk`), `clientPin`, User Presence (`up`), User Verification (`uv`). Also remember whether the authenticator is a roaming authenticator (`plat=false`), or a platform authenticator (`plat=true`). If the connection fails, then fail with error code `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.
3. If `clientPin` is the requested user verification method (see UVM extension), but step 2 indicated that clientPin is not yet set (i.e. `clientPin` present but set to false), then ask user to set (enroll) clientPin.
    - If neither the ASM nor the Authenticator can trigger the enrollment process, return `UAF_ASM_STATUS_USER_NOT_ENROLLED`.
    - If enrollment fails, return `UAF_ASM_STATUS_ACCESS_DENIED`
4. Hash the provided `ASMRequest.args.finalChallenge` using the authenticator-specific hash function and store the result in `FinalChallengeHash`.

   An authenticator's preferred hash function information MUST meet the algorithm defined in the `AuthenticatorInfo.authenticationAlgorithm` field.

5. for each extension included in `ASMRequest.exts`
    - If the extension "fido.uaf.rk" is found, set parameter `rk` to the value of that extension and continue with the next extension.
    - If the extension "fido.uaf.ac" is found, set parameter `ac` to the value of that extension and continue with the next extension.
    - If the extension was not handled before, create a corresponding WebAuthn/FIDO2 extension (see [WebAuthn]) extension in `extensionsCBOR`. If no corresponding WebAuthn/FIDO2 extension is specified, ignore this extension (if `fail_if_unknown` is false) or return `UAF_ASM_STATUS_ERROR` (if `fail_if_unknown` is true).
6. Call authenticatorMakeCredential [FIDOCTAP] (either via CTAP or via a platform proprietary API), send the required information and receive `result` containing the error code of that operation.

   NOTE

   This interface has the following input parameters (see [FIDOCTAP]):

   1. clientDataHash (required, byte array).
   2. rp (required, PublicKeyCredentialRpEntity). Identity of the relying party.
   3. user (required, PublicKeyCredentialUserEntity).
   4. pubKeyCredParams (required, CBOR array).
   5. excludeList (optional, sequence of PublicKeyCredentialDescriptors).
   6. extensions (optional, CBOR map). Parameters to influence authenticator operation.
   7. options (optional, sequence of authenticator options, i.e. parameters `rk`, `uv`, and `up`).
   8. pinAuth (optional, byte array).
   9. pinProtocol (optional, unsigned integer).

   The output parameters are (see [FIDOCTAP]):

   1. authData (required, sequence of bytes). The authenticator data object.

2. fmt (required, String). The attestation statement format identifier.
3. attStmt (required, sequence of bytes). The attestation statement.

Use the following values for the respective parameters:

- Set `rp.rpId` to the `ASMRequest.args.AppID`
- Set `user.Id` to the `fido.uaf.userid` extension retrieved from `ASMRequest.exts`; set `user.displayName` to `ASMRequest.args.username`. Fail if the `fido.uaf.userid` extension is missing in `ASMRequest.exts`.
- Set `clientDataHash` to `FinalChallengeHash`
- Set `pubKeyCredParams.type` to "public-key" and `pubKeyCredParams.alg` to the preferred algorithm, e.g. "ES256".
- Set `excludeList` to an empty list
- Set `extensions` to the CBOR map `extensionsCBOR`
- Set `pinAuth` and `pinProtocol` to the respective values supported by this ASM (to the extent the underlying platform allows specifying these values).
- Set `options` to an empty object and add items as follows
    1. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and `uvm.userVerificationMethod` includes one or more of the flags `USER_VERIFY_FINGERPRINT`, `USER_VERIFY_PASSCODE`, `USER_VERIFY_VOICEPRINT`, `USER_VERIFY_FACEPRINT`, `USER_VERIFY_LOCATION`, `USER_VERIFY_EYEPRINT`, `USER_VERIFY_PATTERN`, or `USER_VERIFY_HANDPRINT` set `options.userVerification` to `true` and set `options.userPresence` to `true`.
    2. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and `uvm.userVerificationMethod` is equal to `USER_VERIFY_CLIENTPIN` set `options.userVerification` to `true` and set `options.userPresence` to `false`.
    3. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and `uvm.userVerificationMethod` is equal to `USER_VERIFY_PRESENCE` set `options.userVerification` to `false` and set `options.userPresence` to `true`.
    4. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and `uvm.userVerificationMethod` is eequal to `USER_VERIFY_NONE` set `options.userVerification` to `false` and set `options.userPresence` to `false`.

NOTE

If the authenticator uses clientPin but the clientPin was not set (indicated by `CTAP2_ERR_PIN_NOT_SET`), the ASM should ask the user for the clientPin and provide it to the authenticator.

7. If `result` is not equal to `CTAP2_OK` and retry cannot fix the problem, then map the CTAP error code to a UAF ASM error code using the table in section 5. Mapping CTAP2 error codes to ASM error codes and return the resulting error code.
8. Create a `TAG_WAV1CBOR_REG_ASSERTION` structure:
    1. Copy result.AuthData concatenated with the `finalChallengeHash` into field `TAG_WAV1CBOR_SIGNED_DATA`
    2. Copy result.fmt into field `TAG_ATTESTATION_FORMAT`
    3. Copy result.stmt into field `TAG_ATTESTATION_STATEMENT`
9. Create a `RegisterOut` object
    1. Set `RegisterOut.assertionScheme` to "WAV1CBOR"
    2. Encode the content of `TAG_WAV1CBOR_REG_ASSERTION` in base64url format and set as `RegisterOut.assertion`.
10. set `ASMResponse.responseData` to `RegisterOut`.
11. set `ASMResponse.statusCode` to the correct status code corresponding to the `result` received earlier.
12. set `ASMResponse.exts` to empty
13. Return `ASMResponse` object

4.2 Registration Response Processing Rules for FIDO Server

Instead of skipping the assertion as described in step 6.8 in section 3.4.6.5 [UAFProtocol], follow these rules:

1. if `a.assertionScheme` == "WAV1CBOR" AND `a.assertion.TAG_WAV1CBOR_REG_ASSERTION` contains `TAG_WAV1CBOR_SIGNED_DATA` as first element:
    1. extract `authenticatorData` from `TAG_WAV1CBOR_SIGNED_DATA.tbsData`
    2. read `claimedAAGUID` from `authenticatorData.attestedCredentialData.AAGUID`.
    3. Verify that `a.assertionScheme` matches `Metadata(claimedAAGUID).assertionScheme`

- If it doesn't match - continue with next assertion

4. Verify that the `claimedAAGUID` indeed matches the policy specified in the registration request.

   > NOTE
   >
   > Depending on the policy (e.g. in the case of AND combinations), it might be required to evaluate other assertions included in this `RegistrationResponse` in order to determine whether this AAGUID matches the policy.

   - If it doesn't match the policy - continue with next assertion
5. Locate authenticator-specific authentication algorithms from the authenticator metadata [FIDOMetadataStatement] identified by `claimedAAGUID` (field `authenticationAlgs`).
6. If `fcp` is of type FinalChallengeParams [UAFProtocol], then hash `RegistrationResponse.fcParams` using hashing algorithm suitable for this authenticator type. Look up the hash algorithm in authenticator metadata, field `AuthenticationAlgs`. It is the hash algorithm associated with the first entry related to a constant with prefix ALG_SIGN.
   - `FCHash = hash(RegistrationResponse.fcParams)`
7. If `fcp` is of type CollectedClientData [UAFProtocol], then hash `RegistrationResponse.fcParams` using hashing algorithm specified in `fcp.hashAlg`.
   - `FCHash = hash(RegistrationResponse.fcParams)`
8. Obtain `Metadata(claimedAAGUID).AttestationType` for the `claimedAAGUID` and make sure that `a.assertion.TAG_WAV1CBOR_REG_ASSERTION` contains the most preferred attestation tag specified in field `MatchCriteria.attestationTypes` in `RegistrationRequest.policy` (if this field is present).
   - If `a.assertion.TAG_WAV1CBOR_REG_ASSERTION` doesn't contain the preferred attestation - it is RECOMMENDED to skip this assertion and continue with next one
9. set `tbsData` to the data contained in `a.assertion.tbsData`.
10. set `authenticatorData` to the CBOR object `tbsData` starts with. Use the "length" field of the CBOR object to determine its end.
11. set `clientDataHash` to the remaining bytes of the `tbsData` (i.e. the bytes following the CBOR object).
12. Make sure that `clientDataHash` == `FCHash`
    - If comparison fails - continue with next assertion
13. Extract the `up` and `uv` bits from `authenticatorData`. Verify whether these bits match the `UVM` extension sent in the request. Fail if the verification result is not acceptable.

    > NOTE
    >
    > - `up`=false and `uv`=false means silent authentication (`USER_VERIFY_NONE`)
    > - `up`=true and `uv`=false means user presence check only (`USER_VERIFY_PRESENCE`)
    > - `up`=false and `uv`=true means user verification that doesn't provide user presence check, e.g. client Pin or some other user verification method not necessarily implemented fully inside the authenticator boundary (`USER_VERIFY_CLIENTPIN`)
    > - `up`=true and `uv`=true means user verification using a user verification method implemented inside the authenticator boundary (e.g. USER_VERIFY_FINGERPRINT, ...) or client Pin plus user presence check (`USER_VERIFY_CLIENTPIN`) AND `USER_VERIFY_PRESENCE` - depending on the authenticator capabilities as declared in the related Metadata Statement.

14. If a `UVM` extension is included in the response, extract this value and compare it verify whether it matches the extension from the request. Fail if the verification result is not acceptable.
15. If `a.assertion.TAG_WAV1CBOR_REG_ASSERTION.TAG_ATTESTATION_STATEMENT` contains `ATTESTATION_BASIC_FULL` tag
    1. If entry `AttestationRootCertificates` for the claimedAAGUID in the metadata [FIDOMetadataStatement] contains at least one element:
       1. Obtain contents of all `TAG_ATTESTATION_CERT` tags from `a.assertion.TAG_WAV1CBOR_REG_ASSERTION.ATTESTATION_BASIC_FULL` object. The occurrences are ordered (see [UAFAuthnrCommands]) and represent the attestation certificate followed by the related certificate chain.
       2. Obtain all entries of `AttestationRootCertificates` for the claimedAAGUID in authenticator Metadata, field `AttestationRootCertificates`.

        3. Verify the attestation certificate and the entire certificate chain up to the Attestation Root Certificate using Certificate Path Validation as specified in [RFC5280]
            - If verification fails – continue with next assertion
        4. Verify `a.assertion.TAG_WAV1CBOR_REG_ASSERTION.TAG_ATTESTATION_STATEMENT.sig` using the attestation certificate (obtained before).
            - If verification fails – continue with next assertion
    2. If `Metadata(claimedAAGUID).AttestationRootCertificates` for this claimedAAGUID is empty - continue with next assertion
    3. Mark assertion as positively verified

16. if `a.assertion.TAG_WAV1CBOR_REG_ASSERTION.TAG_ATESTATION_STATEMENT` contains an object of type `ATTESTATION_BASIC_SURROGATE`
    1. There is no real attestation for the AAGUID, so we just assume the claimedAAGUID is the real one.
    2. If entry `AttestationRootCertificates` for the claimedAAGUID in the metadata is not empty - continue with next assertion (as the AAGUID obviously is expecting a different attestation method).
    3. Verify that extension "fido.uaf.android.key_attestation" is present and check whether it is positively verified according to its server processing rules as specified [UAFRegistry].
        - If verification fails – continue with next assertion
    4. Mark assertion as positively verified
17. If `a.assertion.TAG_WAV1CBOR_REG_ASSERTION` contains an object of type `ATTESTATION_ECDAA`
    1. If entry `ecdaaTrustAnchors` for the claimedAAGUID in the metadata [FIDOMetadataStatement] contains at least one element:
        1. For each of the `ecdaaTrustAnchors` entries, perform the ECDAA Verify operation as specified in [FIDOEcdaaAlgorithm].
            - If verification fails – continue with next `ecdaaTrustAnchors` entry
        2. If no ECDAA Verify operation succeeded – continue with next assertion
    2. Mark assertion as positively verified and the authenticator indeed is of model as indicated by the claimedAAGUID.
    3. If `Metadata(claimedAAID).ecdaaTrustAnchors` for this claimedAAGUID is empty - continue with next assertion
    4. Mark assertion as positively verified and the authenticator indeed is of model as indicated by the claimedAAGUID.
18. If `a.assertion.TAG_UAFV1_REG_ASSERTION` contains another `TAG_ATTESTATION` tag - verify the attestation by following appropriate processing rules applicable to that attestation. Currently this document defines the processing rules for Basic Attestation and direct anonymous attestation (ECDAA).
19. Extract `authenticatorData.attestedCredentialData.credentialPubKey` into PublicKey, `authenticatorData.attestedCredentialData.credentialID` into KeyID, `authenticatorData.counter` into SignCounter, `authenticatorData.attestedCredentialData.AAGUID` into AAGUID.
20. Set AuthenticatorVersion to 0 (as it is not included in the message).

4.3 Authentication Response Generation Rules for ASM

See [UAFASM] for details of the ASM API.

1. Locate the authenticator using `authenticatorIndex`. If the authenticator cannot be located, then fail with `UAF_ASM_STATUS_AUTHENTICATOR_DISCONNECTED`.
2. if this is a bound authenticator, verify `callerid` against the one stored at registration time and return `UAF_ASM_STATUS_ACCESS_DENIED` if it doesn't match.
3. Hash the provided `AuthenticateIn.finalChallenge` using the preferred authenticator-specific hash function (`FinalChallengeHash`).

   The authenticator's preferred hash function information MUST meet the algorithm defined in the `AuthenticatorInfo.authenticationAlgorithm` field.

4. Create an empty list `KeyIDRecords` of KeyID, related KeyHandle and related username
5. If `AuthenticateIn.keyIDs` is not empty,
    1. If this is a bound authenticator, then look up ASM's database with `AuthenticateIn.appID` and `AuthenticateIn.keyIDs` and matching entry into `KeyIDRecords`
        - Return `UAF_ASM_STATUS_KEY_DISAPPEARED_PERMANENTLY` if the related key disappeared permanently from the

authenticator.
        - Return `UAF_ASM_STATUS_ACCESS_DENIED` if no entry has been found.
    2. If this is a roaming authenticator, then for each entry in `AuthenticateIn.keyIDs` add an entry in `KeyIDRecords` with `entry.KeyID` and `entry.KeyHandle` set to the respective keyID in `AuthenticateIn.keyIDs`. Set `entry.userName` to empty.
6. If `AuthenticateIn.keyIDs` is empty, lookup all `KeyHandles` matching this request and add an entry in `KeyIDRecords` with `entry.KeyID` and `entry.KeyHandle` set to the respective `KeyHandles`. Set `entry.userName` the related userName.
7. If `KeyIDRecords` containes multiple entries, show the related distinct usernames and ask the user to choose a single username. Remember the `KeyHandle` and the related `KeyID` to this key.
8. If `AuthenticateIn.transaction` is NOT empty then select the entry `n` with the content type best matching the authenticator capabilities.
    1. if `AuthenticateIn.transaction[n].contentType` == "text/plain"

       then create a corresponding `txAuthSimple` extension in `extensionsCBOR`.

    2. if `AuthenticateIn.transaction[n].contentType` != "text/plain"

       then create a corresponding `txAuthGeneric` extension in `extensionsCBOR`.

9. for each extension included in `ASMRequest.exts`

   create a corresponding WebAuthn/FIDO2 extension (see [WebAuthn]) extension in `extensionsCBOR`. If no corrsponding WebAuthn/FIDO2 extension is specified, ignore this extension.

10. Call authenticatorGetAssertion (either via CTAP or via a platform proprietary API), send the require information and receive the expected `result` containing the error code of that operation.

    NOTE

    authenticatorGetAssertion has the following input parameters (see [FIDOCTAP]):

    1. rpId (required, String). Identity of the relying party.
    2. clientDataHash (required, byte array).
    3. allowList (optional, sequence of PublicKeyCredentialDescriptors).
    4. extensions (optional, CBOR map).
    5. options (optional, sequence of authenticator options, i.e. `up` for user presence and `uv` for user verification).
    6. pinAuth (optional, byte array).
    7. pinProtocol (optional, unsigned integer).

    The output parameters are (see [FIDOCTAP]):

    1. credential (optional, PublicKeyCredentialDescriptor).
    2. authData (required, byte array).
    3. signature (required, byte array).
    4. user (required, PublicKeyCredentialUserEntity).
    5. numberOfCredentials (optional, integer).

    Use the following values for the respective parameters:
    - Set `rpId` to the `ASMRequest.args.AppID`
    - Set `clientDataHash` to `FinalChallengeHash`
    - Set `allowList` to the `KeyHandle` remembered earlier
    - Set `extensions` to the CBOR map `extensionsCBOR`
    - Set `pinAuth` and `pinProtocol` to the respective values supported by this ASM (to the extent the underlying platform allows specifying these values).
    - Set `options` to an empty object and add items as follows
        1. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and `uvm.userVerificationMethod` includes one or more of the flags `USER_VERIFY_FINGERPRINT`, `USER_VERIFY_PASSCODE`, `USER_VERIFY_VOICEPRINT`,

USER_VERIFY_FACEPRINT, USER_VERIFY_LOCATION, USER_VERIFY_EYEPRINT, USER_VERIFY_PATTERN, or USER_VERIFY_HANDPRINT set options.uv to true and set options.up to true.
2. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and uvm.userVerificationMethod is equal to USER_VERIFY_CLIENTPIN set options.uv to true and set options.up to false. Remember to provide the clientPIN to the authenticator.
3. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and uvm.userVerificationMethod is equal to USER_VERIFY_PRESENCE set options.uv to false and set options.up to true.
4. If extension "UVM" (userVerificationMethod, see [UAFRegistry]) is present and uvm.userVerificationMethod is equal to USER_VERIFY_NONE set options.uv to false and set options.up to false.

> NOTE
>
> If the authenticator uses clientPin but the clientPin was not set (indicated by CTAP2_ERR_PIN_NOT_SET), the ASM should ask the user for the clientPin and provide it to the authenticator.

11. If result is not equal to CTAP2_OK and retry cannot fix the problem, then map the CTAP error code to a UAF ASM error code using the table in section 5. Mapping CTAP2 error codes to ASM error codes and return the resulting error code.
12. If the numberOfCredentials in the response is > 1, then follow the rules in section "Client Logic" [FIDOCTAP] to receive and process the remaining (numberOfCredentials-1) responses (see authenticatorGetNextAssertion in [FIDOCTAP]).
13. Create TAG_WAV1CBOR_AUTH_ASSERTION structure.
    1. Copy AAGUID (if known) into the respective TLV fields. Otherwise set the field to an empty value (zero length).

    > NOTE
    >
    > In the case of a platform authenticator, the AAGUID value can be remembered at registration time. In the case of a roaming authenticator, it might be possible to call authenticatorGetInfo [FIDOCTAP] which provides the AAGUID in the response.

    2. Copy the remembered KeyID into the respective TLV field.
    3. Copy result.authData into the value of the TAG_WAV1CBOR_SIGNED_DATA field.
    4. Copy result.signature into the value of the TAG_SIGNATURE field.
14. Create the AuthenticateOut object
    1. Set AuthenticateOut.assertionScheme to "WAV1CBOR"
    2. Encode the content of TAG_WAV1CBOR_AUTH_ASSERTION in base64url format and set as AuthenticateOut.assertion
15. set ASMResponse.responseData to AuthenticateOut object.
16. set ASMResponse.statusCode to the correct status code corresponding to the result received earlier.
17. set ASMResponse.exts to empty
18. Return ASMResponse object

4.4 Authentication Response Processing Rules for FIDO Server

Instead of skipping the assertion according to step 6.5. in section 3.5.7.5 [UAFProtocol], follow these rules:

1. if a.assertionScheme == "WAV1CBOR" AND a.assertion starts with a valid structure as defined in section 3.2 Authentication Assertion, then
    1. set tbsData to the data contained in a.assertion.tbsData.
    2. set authenticatorData to the CBOR object tbsData starts with. Use the "length" field of the CBOR object to determine its end.
    3. set clientDataHash to the remaining bytes of the tbsData (i.e. the bytes following the CBOR object).
    4. read claimedAAGUID from a.assertion.AAGUID (note that it might be empty).
    5. read claimedKeyID from a.assertion.KeyID.
    6. Locate UAuth.pub associated with (claimedAAGUID, claimedKeyID) in the user's record. If claimedAAGUID is empty, search for a matching claimedKeyID.

- If such record doesn't exist - continue with next assertion
- If multiple records match the search criteria - use the first one

7. if `claimedAAGUID` is empty, set it to the `AAGUID` stored along with `UAuth.pub`
8. Verify that `a.assertionScheme` matches `Metadata(claimedAAGUID).assertionScheme`
   - If it doesn't match - continue with next assertion
9. Verify whether the `claimedAAGUID` indeed matches the policy of the Authentication Request.
   - If it doesn't meet the policy – continue with next assertion
10. Check the Signature Counter `authenticatorData.SignCounter` and make sure it is either not supported by the authenticator (i.e. the value provided and the value stored in the user's record are both 0 or the value isKeyRestricted is set to 'false' in the related Metadata Statement) or it has been incremented (compared to the value stored in the user's record)
    - If it is greater than 0, but didn't increment - continue with next assertion (as this is a cloned authenticator or a cloned authenticator has been used previously).
11. Locate authenticator specific authentication algorithms from authenticator metadata (field `AuthenticationAlgs`)
12. If `fcp` is of type FinalChallengeParams, then hash `AuthenticationResponse.FinalChallengeParams` using the hashing algorithm suitable for this authenticator type. Look up the hash algorithm in authenticator Metadata, field `AuthenticationAlgs`. It is the hash algorithm associated with the first entry related to a constant with prefix ALG_SIGN.
    - `FCHash = hash(AuthenticationResponse.FinalChallengeParams)`
13. If `fcp` is of type CollectedClientData [UAFProtocol], then hash `AuthenticationResponse.fcParams` using hashing algorithm specified in `fcp.hashAlg`.
    - `FCHash = hash(AuthenticationResponse.fcParams)`
14. Make sure that `clientDataHash` == `FCHash`
    - If comparison fails – continue with next assertion
15. Extract the `up` and `uv` bits from `authenticatorData`. Verify whether these bits match the `UVM` extension sent in the request. Fail if the verification result is not acceptable.

    NOTE
    - `up`=false and `uv`=false means silent authentication (`USER_VERIFY_NONE`)
    - `up`=true and `uv`=false means user presence check only (`USER_VERIFY_PRESENCE`)
    - `up`=false and `uv`=true means user verification that doesn't provide user presence, e.g. client Pin or some other user verification method not necessarily implemented fully inside the authenticator boundary (`USER_VERIFY_CLIENTPIN`)
    - `up`=true and `uv`=true means user verification using a user verification method implemented inside the authenticator boundary (e.g. USER_VERIFY_FINGERPRINT, ...) or client Pin plus user presence check (`USER_VERIFY_CLIENTPIN`) AND `USER_VERIFY_PRESENCE` - depending on the authenticator capabilities as declared in the related Metadata Statement.

16. If a `UVM` extension is included in the response, extract this value and compare it verify whether it matches the extension from the request. Fail if the verification result is not acceptable.
17. If `authenticatorData` contains "txAuthSimple" (see section 10.2 [WebAuthn]) or "txAuthGeneric" (see section 10.3 [WebAuthn]) extension(s),

    NOTE

    The transaction/transaction hash included in this `AuthenticationResponse` must match the transaction content specified in the related `AuthenticationRequest`. As FIDO doesn't mandate any specific FIDO Server API, the transaction content could be cached by any relying party software component, e.g. the FIDO Server or the relying party Web Application.

    1. Make sure there is a transaction cached on Relying Party side.
       - If not – continue with next assertion
    2. Go over all cached forms of the transaction content (potentially multiple cached PNGs for the same transaction) and calculate their hashes using hashing algorithm suitable for this authenticator (same hash algorithm as used for

FinalChallenge).
    - For each `cachedTransaction` add `hash(cachedTransaction)` into `cachedTransactionHashList`
3. Make sure that the transaction ("txAuthSimple") or the transaction hash ("txAuthGeneric") included in the extension is in `cachedTransactionHashList`
    - If it's not in the list – continue with next assertion

18. Use the `UAuth.pub` key found in step 1.9 and the appropriate authentication algorithm to verify the signature `a.assertion.Signature` of the to-be-signed object `tbsData`.
    1. If signature verification fails – continue with next assertion
    2. Update `SignCounter` in user's record with `authenticatorData.SignCounter`.

NOTE

The values of `claimedAAGUID` and `claimedKeyID` are now confirmed since the public key we looked up using those values was the correct one.

5. Mapping CTAP2 error codes to ASM error codes

In many cases the status code returned via [FIDOCTAP] needs to be processed and handled by the ASM. If the communication to the authenticator via [FIDOCTAP] finally failed with an error, the following error code mapping rules apply:

CTAP2 Code	CTAP2 Name	ASM Error Name
0x00	CTAP1_ERR_SUCCESS, CTAP2_OK	UAF_ASM_STATUS_OK
0x01	CTAP1_ERR_INVALID_COMMAND	UAF_ASM_STATUS_ERROR
0x02	CTAP1_ERR_INVALID_PARAMETER	UAF_ASM_STATUS_ERROR
0x03	CTAP1_ERR_INVALID_LENGTH	UAF_ASM_STATUS_ERROR
0x04	CTAP1_ERR_INVALID_SEQ	UAF_ASM_STATUS_ERROR
0x05	CTAP1_ERR_TIMEOUT	UAF_ASM_STATUS_USER_NOT_RESPONSIVE
0x06	CTAP1_ERR_CHANNEL_BUSY	UAF_ASM_STATUS_ERROR
0x0A	CTAP1_ERR_LOCK_REQUIRED	UAF_ASM_STATUS_ERROR
0x0B	CTAP1_ERR_INVALID_CHANNEL	UAF_ASM_STATUS_ERROR
0x11	CTAP2_ERR_CBOR_UNEXPECTED_TYPE	UAF_ASM_STATUS_ERROR
0x12	CTAP2_ERR_INVALID_CBOR	UAF_ASM_STATUS_ERROR
0x14	CTAP2_ERR_MISSING_PARAMETER	UAF_ASM_STATUS_ERROR
0x15	CTAP2_ERR_LIMIT_EXCEEDED	UAF_ASM_STATUS_ERROR
0x16	CTAP2_ERR_UNSUPPORTED_EXTENSION	UAF_ASM_STATUS_ERROR
0x19	CTAP2_ERR_CREDENTIAL_EXCLUDED	UAF_ASM_STATUS_ERROR
0x21	CTAP2_ERR_PROCESSING	UAF_ASM_STATUS_ERROR
0x22	CTAP2_ERR_INVALID_CREDENTIAL	UAF_ASM_STATUS_ERROR
0x23	CTAP2_ERR_USER_ACTION_PENDING	UAF_ASM_STATUS_USER_NOT_RESPONSIVE
0x24	CTAP2_ERR_OPERATION_PENDING	UAF_ASM_STATUS_ERROR
0x25	CTAP2_ERR_NO_OPERATIONS	UAF_ASM_STATUS_ERROR

0x26	CTAP2_ERR_UNSUPPORTED_ALGORITHM	UAF_ASM_STATUS_ERROR
0x27	CTAP2_ERR_OPERATION_DENIED	UAF_ASM_STATUS_ACCESS_DENIED
0x28	CTAP2_ERR_KEY_STORE_FULL	UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES
0x2A	CTAP2_ERR_NO_OPERATION_PENDING	UAF_ASM_STATUS_ERROR
0x2B	CTAP2_ERR_UNSUPPORTED_OPTION	UAF_ASM_STATUS_ERROR
0x2C	CTAP2_ERR_INVALID_OPTION	UAF_ASM_STATUS_ERROR
0x2D	CTAP2_ERR_KEEPALIVE_CANCEL	UAF_ASM_STATUS_ERROR
0x2E	CTAP2_ERR_NO_CREDENTIALS	UAF_ASM_STATUS_ERROR
0x2F	CTAP2_ERR_USER_ACTION_TIMEOUT	UAF_ASM_STATUS_USER_NOT_RESPONSIVE
0x30	CTAP2_ERR_NOT_ALLOWED	UAF_ASM_STATUS_ERROR
0x31	CTAP2_ERR_PIN_INVALID	UAF_ASM_STATUS_ACCESS_DENIED
0x32	CTAP2_ERR_PIN_BLOCKED	UAF_ASM_STATUS_USER_LOCKOUT
0x33	CTAP2_ERR_PIN_AUTH_INVALID	UAF_ASM_STATUS_ACCESS_DENIED
0x34	CTAP2_ERR_PIN_AUTH_BLOCKED	UAF_ASM_STATUS_USER_LOCKOUT
0x35	CTAP2_ERR_PIN_NOT_SET	UAF_ASM_STATUS_USER_NOT_ENROLLED
0x36	CTAP2_ERR_PIN_REQUIRED	UAF_ASM_STATUS_ACCESS_DENIED
0x37	CTAP2_ERR_PIN_POLICY_VIOLATION	UAF_ASM_STATUS_ACCESS_DENIED
0x38	CTAP2_ERR_PIN_TOKEN_EXPIRED	UAF_ASM_STATUS_ACCESS_DENIED
0x39	CTAP2_ERR_REQUEST_TOO_LARGE	UAF_ASM_STATUS_INSUFFICIENT_AUTHENTICATOR_RESOURCES
0x3A	CTAP2_ERR_ACTION_TIMEOUT	UAF_ASM_STATUS_USER_NOT_RESPONSIVE
0x3B	CTAP2_ERR_UP_REQUIRED	UAF_ASM_STATUS_ACCESS_DENIED
0x7F	CTAP1_ERR_OTHER	UAF_ASM_STATUS_ERROR
0xDF	CTAP2_ERR_SPEC_LAST	UAF_ASM_STATUS_ERROR
0xE0	CTAP2_ERR_EXTENSION_FIRST	UAF_ASM_STATUS_ERROR
0xEF	CTAP2_ERR_EXTENSION_LAST	UAF_ASM_STATUS_ERROR
0xF0	CTAP2_ERR_VENDOR_FIRST	UAF_ASM_STATUS_ERROR
0xFF	CTAP2_ERR_VENDOR_LAST	UAF_ASM_STATUS_ERROR

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