Abstract

This document specifies a firmware update mechanism where the firmware image is encrypted. Firmware encryption uses the IETF SUIT manifest with key establishment provided by hybrid public-key encryption (HPKE) and AES Key Wrap (AES-KW). HPKE uses public key cryptography while AES-KW uses a pre-shared key-encryption key. Encryption of the firmware image is accomplished with conventional symmetric key cryptography.

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1. Introduction

Vulnerabilities with Internet of Things (IoT) devices have raised the need for a reliable and secure firmware update mechanism that is also suitable for constrained devices. To protect firmware images the SUIT manifest format was developed [I-D.ietf-suit-manifest]. The SUIT manifest provides a bundle of metadata about the firmware for an IoT device, where to find the firmware image, and the devices to which it applies.
The SUIT information model [RFC9124] details the information that has to be offered by the SUIT manifest format. In addition to offering protection against modification, which is provided by a digital signature or a message authentication code, the firmware image may also be afforded confidentiality using encryption.

Encryption prevents third parties, including attackers, from gaining access to the firmware binary. Hackers typically need intimate knowledge of the target firmware to mount their attacks. For example, return-oriented programming (ROP) requires access to the binary and encryption makes it much more difficult to write exploits.

The SUIT manifest provides the data needed for authorized recipients of the firmware image to decrypt it. The firmware image is encrypted using a symmetric key. This symmetric cryptographic key is established for encryption and decryption, and that key can be applied to a SUIT manifest, firmware images, or personalization data, depending on the encryption choices of the firmware author.

A symmetric key can be established using a variety of mechanisms; this document defines two approaches for use with the IETF SUIT manifest, namely:

* hybrid public-key encryption (HPKE), and
* AES Key Wrap (AES-KW) using a pre-shared key-encryption key (KEK).

These choices reduce the number of possible key establishment options and thereby help increase interoperability between different SUIT manifest parser implementations.

The document also contains a number of examples.

The main use case of this document is to encrypt firmware. However, SUIT manifests may require other payloads than firmware images to experience confidentiality protection using encryption, for example personalization data, configuration data, or machine learning models. While the term firmware is used throughout the document, plaintext other than firmware images may get encrypted using the described mechanism. Hence, the terms firmware (image) and plaintext are used interchangeably.
2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

This document assumes familiarity with the IETF SUIT manifest [I-D.ietf-suit-manifest], the SUIT information model [RFC9124] and the SUIT architecture [RFC9019].

The terms sender and recipient are defined in [RFC9180] and have the following meaning:

* Sender: Role of entity which sends an encrypted message.
* Recipient: Role of entity which receives an encrypted message.

Additionally, the following abbreviations are used in this document:

* Key Wrap (KW), defined in RFC 3394 [RFC3394] for use with AES.
* Key-encryption key (KEK), a term defined in RFC 4949 [RFC4949].
* Content-encryption key (CEK), a term defined in RFC 2630 [RFC2630].
* Hybrid Public Key Encryption (HPKE), defined in [RFC9180].

3. Architecture

[RFC9019] describes the architecture for distributing firmware images and manifests from the author to the firmware consumer. It does, however, not detail the use of encrypted firmware images.

This document enhances the SUIT architecture to include firmware encryption. Figure 1 shows the distribution system, which represents the firmware server and the device management infrastructure. The distribution system is aware of the individual devices to which a firmware update has to be delivered.
Firmware encryption requires the sender to know the firmware consumers and the respective credentials used by the key distribution mechanism. For AES-KW the KEK needs to be known and, in case of HPKE, the sender needs to be in possession of the public key of the recipient.

The firmware author may have knowledge about all devices that need to receive an encrypted firmware image but in most cases this is not likely. The distribution system certainly has the knowledge about the recipients to perform firmware encryption.

To offer confidentiality protection for firmware images two deployment variants need to be supported:

* The firmware author acts as the sender and the recipient is the firmware consumer (or the firmware consumers).

* The firmware author encrypts the firmware image with the distribution system as the initial recipient. Then, the distribution system decrypts and re-encrypts the firmware image towards the firmware consumer(s). Delegating the task of re-
encrypting the firmware image to the distribution system offers flexibility when the number of devices that need to receive encrypted firmware images changes dynamically or when updates to KEKs or recipient public keys are necessary. As a downside, the author needs to trust the distribution system with performing the re-encryption of the firmware image.

Irrespectively of the two variants, the key distribution data (in form of the COSE_Encrypt structure) is included in the SUIT envelope rather than in the SUIT manifest since the manifest will be digitally signed (or MACed) by the firmware author.

Since the SUIT envelope is not protected cryptographically an adversary could modify the COSE_Encrypt structure. For example, if the attacker alters the key distribution data then a recipient will decrypt the firmware image with an incorrect key. This will lead to expending energy and flash cycles until the failure is detected. To mitigate this attack, the optional suit-cek-verification parameter is added to the manifest. Since the manifest is protected by a digital signature (or a MAC), an adversary cannot successfully modify this value. This parameter allows the recipient to verify whether the CEK has successfully been derived.

Details about the changes to the envelope and the manifest can be found in the next section.

4. SUIT Envelope and SUIT Manifest

This specification introduces two extensions to the SUIT envelope and the manifest structure, as motivated in Section 3.

The SUIT envelope is enhanced with a key exchange payload, which is carried inside the suit-protection-wrappers parameter, see Figure 2. One or multiple SUIT_Encryption_Info payload(s) are carried within the suit-protection-wrappers parameter. The content of the SUIT_Encryption_Info payload is explained in Section 5 (for AES-KW) and in Section 6 (for HPKE). When the encryption capability is used, the suit-protection-wrappers parameter MUST be included in the envelope.
SUIT_Envelope_Tagged = $6.107(SUIT_Envelope)
SUIT_Envelope = {
    suit-authentication-wraper => bstr .cbor SUIT_Authentication,
    suit-manifest => bstr .cbor SUIT_Manifest,
    SUIT_Severable_Manifest_Members,
    suit-protection-wrappers => bstr .cbor {
        *(int/str) => [+ SUIT_Encryption_Info]
    }*
    SUIT_Integrated_Payload,
    SUIT_Integrated_Dependency,
    $$SUIT_Envelope_Extensions,
    *(int => bstr)
}

Figure 2: SUIT Envelope CDDL.

The manifest is extended with a CEK verification parameter (called suit-cek-verification), see Figure 3. This parameter is optional and is utilized in environments where battery exhaustion attacks are a concern. Details about the CEK verification can be found in Section 7.

SUIT_Manifest = {
    suit-manifest-version => 1,
    suit-manifest-sequence-number => uint,
    suit-common => bstr .cbor SUIT_Common,
    ? suit-reference-uri => tstr,
    SUIT_Severable_Members_Choice,
    SUIT_Unseverable_Members,
    $$SUIT_Manifest_Extensions,
}

SUIT_Parameters //= (suit-parameter-cek-verification => bstr)

Figure 3: SUIT Manifest CDDL.

5. AES Key Wrap

The AES Key Wrap (AES-KW) algorithm is described in RFC 3394 [RFC3394], and it can be used to encrypt a randomly generated content-encryption key (CEK) with a pre-shared key-encryption key (KEK). The COSE conventions for using AES-KW are specified in Section 12.2.1 of [RFC8152]. The encrypted CEK is carried in the COSE_recipient structure alongside the information needed for AES-KW. The COSE_recipient structure, which is a substructure of the COSE_Encrypt structure, contains the CEK encrypted by the KEK.
When the firmware image is encrypted for use by multiple recipients, there are three options. We use the following notation KEK(R1,S) is the KEK shared between recipient R1 and the sender S. Likewise, CEK(R1,S) is shared between R1 and S. If a single CEK or a single KEK is shared with all authorized recipients R by a given sender S in a certain context then we use CEK(_,S) or KEK(_,S), respectively. The notation ENC(plaintext, key) refers to the encryption of plaintext with a given key.

* If all authorized recipients have access to the KEK, a single COSE_recipient structure contains the encrypted CEK. This means KEK(*,S) ENC(CEK,KEK), and ENC(firmware,CEK).

* If recipients have different KEKs, then multiple COSE_recipient structures are included but only a single CEK is used. Each COSE_recipient structure contains the CEK encrypted with the KEKs appropriate for the recipient. In short, KEK_1(R1, S),..., KEK_n(Rn, S), ENC(CEK, KEK_i) for i=1 to n, and ENC(firmware,CEK). The benefit of this approach is that the firmware image is encrypted only once with a CEK while there is no sharing of the KEK across recipients. Hence, authorized recipients still use their individual KEKs to decrypt the CEK and to subsequently obtain the plaintext firmware.

* The third option is to use different CEKs encrypted with KEKs of the authorized recipients. Assume there are KEK_1(R1, S),..., KEK_n(Rn, S), and for i=1 to n the following computations need to be made: ENC(CEK_i, KEK_i) and ENC(firmware,CEK_i). This approach is appropriate when no benefits can be gained from encrypting and transmitting firmware images only once. For example, firmware images may contain information unique to a device instance.

Note that the AES-KW algorithm, as defined in Section 2.2.3.1 of [RFC3394], does not have public parameters that vary on a per-invocation basis. Hence, the protected structure in the COSE_recipient is a byte string of zero length.

The COSE_Encrypt conveys information for encrypting the firmware image, which includes information like the algorithm and the IV, even though the firmware image is not embedded in the COSE_Encrypt.ciphertext itself since it conveyed as detached content.

The CDDL for the COSE_Encrypt_Tagged structure is shown in Figure 4.
COSE_Encrypt_Tagged = #6.96(COSE_Encrypt)

SUIT_Encryption_Info = COSE_Encrypt_Tagged

COSE_Encrypt = [
    protected : bstr .cbor outer_header_map_protected,
    unprotected : outer_header_map_unprotected,
    ciphertext : null, ; because of detached ciphertext
    recipients : [ + COSE_recipient ]
]

outer_header_map_protected =
{
    1 => int, ; algorithm identifier
    * label =values ; extension point
}

outer_header_map_unprotected =
{
    5 => bstr, ; IV
    * label =values ; extension point
}

COSE_recipient = [
    protected : bstr .size 0,
    unprotected : recipient_header_map,
    ciphertext : bstr ; CEK encrypted with KEK
]

recipient_header_map =
{
    1 => int, ; algorithm identifier
    4 => bstr, ; key identifier
    * label =values ; extension point
}

The COSE specification requires a consistent byte stream for the authenticated data structure to be created, which is shown in Figure 5.

Enc_structure = [
    context : "Encrypt",
    protected : empty_or_serialized_map,
    external_aad : bstr
]
As shown in Figure 4, there are two protected fields: one protected field in the COSE_Encrypt structure and a second one in the COSE_recipient structure. The ‘protected’ field in the Enc_structure, see Figure 5, refers to the content of the protected field from the COSE_Encrypt structure.

The value of the external_aad MUST be set to null.

The following example illustrates the use of the AES-KW algorithm with AES-128.

We use the following parameters in this example:

* IV: 0x26, 0x68, 0x23, 0x06, 0xd4, 0xfb, 0x28, 0xca, 0x01, 0xb4, 0x3b, 0x80
* KEK: "aaaaaaaaaaaaaaaa"
* KID: "kid-1"
* Plaintext Firmware: "This is a real firmware image."
* Firmware (hex):
  5468697320697320612072656167652E

The COSE_Encrypt structure, in hex format, is (with a line break inserted):

D860843A10101A1054C26682306D4FB28CA01B43B80F68340A2012204456B69642D315818AF09622B4F40F17930129D18D0CEA46F159C49E7F6B644D

The resulting COSE_Encrypt structure in a diagnostic format is shown in Figure 6.
Figure 6: COSE_Encrypt Example for AES Key Wrap

The CEK, in hex format, was "4C805F1587D624ED5E0DBB7A7F7FA7EB" and the encrypted firmware (with a line feed added) was:

`A8B6E61EF17FBAD1F1BF3235B3C64C06098EA512223260
F9425105F67F0FB6C92248AE289A025258F06C2AD70415`

6. Hybrid Public-Key Encryption (HPKE)

Hybrid public-key encryption (HPKE) [RFC9180] is a scheme that provides public key encryption of arbitrary-sized plaintexts given a recipient’s public key.

For use with firmware encryption the scheme works as follows: HPKE, which internally utilizes a non-interactive ephemeral-static Diffie-Hellman exchange to derive a shared secret, is used to encrypt a CEK. This CEK is subsequently used to encrypt the firmware image. Hence, the plaintext passed to HPKE is the randomly generated CEK. The output of the HPKE SealBase function is therefore the encrypted CEK along with HPKE encapsulated key (i.e. the ephemeral ECDH public key).

Only the holder of recipient’s private key can decapsulate the CEK to decrypt the firmware. Key generation in HPKE is influenced by additional parameters, such as identity information.
This approach allows all recipients to use the same CEK to encrypt the firmware image, in case there are multiple recipients, to fulfill a requirement for the efficient distribution of firmware images using a multicast or broadcast protocol.

[I-D.ietf-cose-hpke] defines the use of HPKE with COSE and provides examples.

7. CEK Verification

The suit-cek-verification parameter contains a byte string resulting from the encryption of 8 bytes of 0xA5 using the CEK with a nonce of all zeros and empty additional data using the cipher algorithm and mode also used to encrypt the plaintext.

As explained in Section 3, the suit-cek-verification parameter is optional to implement and optional to use. When used, it reduces the risk of an battery exhaustion attack against the IoT device.

8. Ciphers without Integrity Protection

The ability to restart an interrupted firmware update is often a requirement for low-end IoT devices. To fulfill this requirement it is necessary to chunk a larger firmware image into blocks and to encrypt each block individually using a cipher that does not increase the size of the resulting ciphertext (i.e. by not adding an authentication tag after each encrypted block).

When the encrypted firmware image has been transferred to the device, it will typically be stored in a staging area. Then, the bootloader starts decrypting the downloaded image block-by-block and swaps it with the currently valid image. Note that the currently valid image is available in cleartext and hence it has to be re-encrypted before copying it to the staging area.

This approach of swapping the newly downloaded image with the previously valid image is often referred as A/B approach. A/B refers to the two storage areas, sometimes called slots, involved. Two slots are used to allow the update to be reversed in case the newly obtained firmware image fails to boot. This approach adds robustness to the firmware update procedure.

When an update gets aborted while the bootloader is decrypting the newly obtained image and swapping the blocks, the bootloader can restart where it left off. This technique again offers robustness.
To accomplish this functionality, ciphers without integrity protection are used to encrypt the firmware image. Integrity protection for the firmware image is, however, important and therefore the image digest defined in [I-D.ietf-suit-manifest] MUST be used.

This document registers several cipher algorithms for use with firmware encryption that do not offer integrity protection. These ciphers are registered within the COSE algorithm registry but are dedicated for this specific applications only. Hence, all algorithms listed in Figure 7 are not recommended for general use.

<table>
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<th>Name</th>
<th>Value</th>
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<th>Capabilities</th>
<th>Reference</th>
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<td>AES 256 CBC Mode</td>
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<td>AES 128 Counter Mode (CTR)</td>
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<tr>
<td>AES-256-CTR</td>
<td>38</td>
<td>AES 256 Counter Mode (CTR)</td>
<td>[ ]</td>
<td>[This Document]</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 7: Algorithms for the COSE Algorithm Registry

9. Complete Examples

[[Editor’s Note: Add examples for a complete manifest here (including a digital signature), multiple recipients, encryption of manifests (in comparison to firmware images).]]

10. Security Considerations

The algorithms described in this document assume that the party performing the firmware encryption

* shares a key-encryption key (KEK) with the firmware consumer (for use with the AES-Key Wrap scheme), or
* is in possession of the public key of the firmware consumer (for use with HPKE).

Both cases require some upfront communication interaction, which is not part of the SUIT manifest. This interaction is likely provided by an IoT device management solution, as described in [RFC9019].

For AES-Key Wrap to provide high security it is important that the KEK is of high entropy, and that implementations protect the KEK from disclosure. Compromise of the KEK may result in the disclosure of all key data protected with that KEK.

Since the CEK is randomly generated, it must be ensured that the guidelines for random number generations are followed, see [RFC8937].

In some cases third party companies analyse binaries for known security vulnerabilities. With encrypted firmware images this type of analysis is prevented. Consequently, these third party companies either need to be given access to the plaintext binary before encryption or they need to become authorized recipients of the encrypted firmware images. In either case, it is necessary to explicitly consider those third parties in the software supply chain when such a binary analysis is desired.

11. IANA Considerations

This document asks IANA to register new values into the COSE algorithm registry. The values are listed in Figure 7.

12. References

12.1. Normative References

[I-D.ietf-cose-hpke]


12.2. Informative References


Appendix A.  Acknowledgements

We would like to thank Henk Birkholz for his feedback on the CDDL description in this document. Additionally, we would like to thank Michael Richardson and Carsten Bormann for their review feedback. Finally, we would like to thank Dick Brooks for making us aware of the challenges firmware encryption imposes on binary analysis.

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A Concise Binary Object Representation (CBOR)-based Serialization Format for the Software Updates for Internet of Things (SUIT) Manifest
draft-ietf-suit-manifest-18

Abstract

This specification describes the format of a manifest. A manifest is a bundle of metadata about code/data obtained by a recipient (chiefly the firmware for an IoT device), where to find the that code/data, the devices to which it applies, and cryptographic information protecting the manifest. Software updates and Trusted Invocation both tend to use sequences of common operations, so the manifest encodes those sequences of operations, rather than declaring the metadata.

Status of This Memo

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1. Introduction

A firmware update mechanism is an essential security feature for IoT devices to deal with vulnerabilities. While the transport of firmware images to the devices themselves is important there are already various techniques available. Equally important is the inclusion of metadata about the conveyed firmware image (in the form of a manifest) and the use of a security wrapper to provide end-to-end security protection to detect modifications and (optionally) to make reverse engineering more difficult. End-to-end security allows the author, who builds the firmware image, to be sure that no other party (including potential adversaries) can install firmware updates on IoT devices without adequate privileges. For confidentiality protected firmware images it is additionally required to encrypt the firmware image. Starting security protection at the author is a risk mitigation technique so firmware images and manifests can be stored on untrusted repositories; it also reduces the scope of a compromise of any repository or intermediate system to be no worse than a denial of service.

A manifest is a bundle of metadata describing one or more code or data payloads and how to:

* Obtain any dependencies
* Obtain the payload(s)
* Install them
* Verify them
* Load them into memory
* Invoke them

This specification defines the SUIT manifest format and it is intended to meet several goals:

* Meet the requirements defined in [RFC9124].
* Simple to parse on a constrained node
* Simple to process on a constrained node
* Compact encoding
* Comprehensible by an intermediate system
* Expressive enough to enable advanced use cases on advanced nodes

* Extensible

The SUIT manifest can be used for a variety of purposes throughout its lifecycle, such as:

* a Firmware Author to reason about releasing a firmware.
* a Network Operator to reason about compatibility of a firmware.
* a Device Operator to reason about the impact of a firmware.
* the Device Operator to manage distribution of firmware to devices.
* a Plant Manager to reason about timing and acceptance of firmware updates.
* a device to reason about the authority & authenticity of a firmware prior to installation.
* a device to reason about the applicability of a firmware.
* a device to reason about the installation of a firmware.
* a device to reason about the authenticity & encoding of a firmware at boot.

Each of these uses happens at a different stage of the manifest lifecycle, so each has different requirements.

It is assumed that the reader is familiar with the high-level firmware update architecture [RFC9019] and the threats, requirements, and user stories in [RFC9124].

The design of this specification is based on an observation that the vast majority of operations that a device can perform during an update or Trusted Invocation are composed of a small group of operations:

* Copy some data from one place to another
* Transform some data
* Digest some data and compare to an expected value
* Compare some system parameters to an expected value
In this document, these operations are called commands. Commands are classed as either conditions or directives. Conditions have no side-effects, while directives do have side-effects. Conceptually, a sequence of commands is like a script but the language is tailored to software updates and Trusted Invocation.

The available commands support simple steps, such as copying a firmware image from one place to another, checking that a firmware image is correct, verifying that the specified firmware is the correct firmware for the device, or unpacking a firmware. By using these steps in different orders and changing the parameters they use, a broad range of use cases can be supported. The SUIT manifest uses this observation to optimize metadata for consumption by constrained devices.

While the SUIT manifest is informed by and optimized for firmware update and Trusted Invocation use cases, there is nothing in the SUIT Information Model ([RFC9124]) that restricts its use to only those use cases. Other use cases include the management of trusted applications (TAs) in a Trusted Execution Environment (TEE), as discussed in [I-D.ietf-teep-architecture].

2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Additionally, the following terminology is used throughout this document:

* SUIT: Software Update for the Internet of Things, also the IETF working group for this standard.
* Payload: A piece of information to be delivered. Typically Firmware for the purposes of SUIT.
* Resource: A piece of information that is used to construct a payload.
* Manifest: A manifest is a bundle of metadata about the firmware for an IoT device, where to find the firmware, and the devices to which it applies.
* Envelope: A container with the manifest, an authentication wrapper with cryptographic information protecting the manifest, authorization information, and severable elements.

* Update: One or more manifests that describe one or more payloads.

* Update Authority: The owner of a cryptographic key used to sign updates, trusted by Recipients.

* Recipient: The system, typically an IoT device, that receives and processes a manifest.

* Manifest Processor: A component of the Recipient that consumes Manifests and executes the commands in the Manifest.

* Component: An updatable logical block of the Firmware, Software, configuration, or data of the Recipient.

* Component Set: A group of interdependent Components that must be updated simultaneously.

* Command: A Condition or a Directive.

* Condition: A test for a property of the Recipient or its Components.


* Trusted Invocation: A process by which a system ensures that only trusted code is executed, for example secure boot or launching a Trusted Application.

* A/B images: Dividing a Recipient’s storage into two or more bootable images, at different offsets, such that the active image can write to the inactive image(s).

* Record: The result of a Command and any metadata about it.


* Procedure: The process of invoking one or more sequences of commands.

* Update Procedure: A procedure that updates a Recipient by fetching dependencies and images, and installing them.
* Invocation Procedure: A procedure in which a Recipient verifies dependencies and images, loading images, and invokes one or more image.

* Software: Instructions and data that allow a Recipient to perform a useful function.

* Firmware: Software that is typically changed infrequently, stored in nonvolatile memory, and small enough to apply to [RFC7228] Class 0-2 devices.

* Image: Information that a Recipient uses to perform its function, typically firmware/software, configuration, or resource data such as text or images. Also, a Payload, once installed is an Image.

* Slot: One of several possible storage locations for a given Component, typically used in A/B image systems

* Abort: An event in which the Manifest Processor immediately halts execution of the current Procedure. It creates a Record of an error condition.

3. How to use this Document

This specification covers five aspects of firmware update:

* Section 4 describes the device constraints, use cases, and design principles that informed the structure of the manifest.

* Section 5 gives a general overview of the metadata structure to inform the following sections

* Section 6 describes what actions a Manifest processor should take.

* Section 7 describes the process of creating a Manifest.

* Section 8 specifies the content of the Envelope and the Manifest.

To implement an updatable device, see Section 6 and Section 8. To implement a tool that generates updates, see Section 7 and Section 8.

The IANA consideration section, see Section 11, provides instructions to IANA to create several registries. This section also provides the CBOR labels for the structures defined in this document.
The complete CDDL description is provided in Appendix A, examples are given in Appendix B and a design rational is offered in Appendix C. Finally, Appendix D gives a summarize of the mandatory-to-implement features of this specification.

This specification covers the core features of SUIT. Additional specifications describe functionality of advanced use cases, such as:

* Firmware Encryption is covered in [I-D.ietf-suit-firmware-encryption]
* Update Management is covered in [I-D.ietf-suit-update-management]
* Features, such as dependencies, key delegation, multiple processors, required by the use of multiple trust domains are covered in [I-D.ietf-suit-trust-domains]
* Secure reporting of the update status is covered in [I-D.ietf-suit-report]
* Compression of firmware images

4. Background

Distributing software updates to diverse devices with diverse trust anchors in a coordinated system presents unique challenges. Devices have a broad set of constraints, requiring different metadata to make appropriate decisions. There may be many actors in production IoT systems, each of whom has some authority. Distributing firmware in such a multi-party environment presents additional challenges. Each party requires a different subset of data. Some data may not be accessible to all parties. Multiple signatures may be required from parties with different authorities. This topic is covered in more depth in [RFC9019]. The security aspects are described in [RFC9124].

4.1. IoT Firmware Update Constraints

The various constraints of IoT devices and the range of use cases that need to be supported create a broad set of requirements. For example, devices with:

* limited processing power and storage may require a simple representation of metadata.
* bandwidth constraints may require firmware compression or partial update support.
* bootloader complexity constraints may require simple selection between two bootable images.

* small internal storage may require external storage support.

* multiple microcontrollers may require coordinated update of all applications.

* large storage and complex functionality may require parallel update of many software components.

* extra information may need to be conveyed in the manifest in the earlier stages of the device lifecycle before those data items are stripped when the manifest is delivered to a constrained device.

Supporting the requirements introduced by the constraints on IoT devices requires the flexibility to represent a diverse set of possible metadata, but also requires that the encoding is kept simple.

4.2. SUIT Workflow Model

There are several fundamental assumptions that inform the model of Update Procedure workflow:

* Compatibility must be checked before any other operation is performed.

* In some applications, payloads must be fetched and validated prior to installation.

There are several fundamental assumptions that inform the model of the Invocation Procedure workflow:

* Compatibility must be checked before any other operation is performed.

* All payloads must be validated prior to loading.

* All loaded images must be validated prior to execution.

Based on these assumptions, the manifest is structured to work with a pull parser, where each section of the manifest is used in sequence. The expected workflow for a Recipient installing an update can be broken down into five steps:

1. Verify the signature of the manifest.
2. Verify the applicability of the manifest.

3. Fetch payload(s).

4. Install payload(s).

When installation is complete, similar information can be used for validating and running images in a further three steps:

1. Verify image(s).

2. Load image(s).

3. Run image(s).

If verification and running is implemented in a bootloader, then the bootloader MUST also verify the signature of the manifest and the applicability of the manifest in order to implement secure boot workflows. The bootloader may add its own authentication, e.g. a Message Authentication Code (MAC), to the manifest in order to prevent further verifications.

5. Metadata Structure Overview

This section provides a high level overview of the manifest structure. The full description of the manifest structure is in Section 8.4.

The manifest is structured from several key components:

1. The Envelope (see Section 5.1) contains the Authentication Block, the Manifest, any Severable Elements, and any Integrated Payloads.

2. The Authentication Block (see Section 5.2) contains a list of signatures or MACs of the manifest.

3. The Manifest (see Section 5.3) contains all critical, non-severable metadata that the Recipient requires. It is further broken down into:

   1. Critical metadata, such as sequence number.

   2. Common metadata, such as affected components.

   3. Command sequences, directing the Recipient how to install and use the payload(s).
4. Integrity check values for severable elements.

4. Severable elements (see Section 5.4).

5. Integrated payloads (see Section 5.5).

The diagram below illustrates the hierarchy of the Envelope.

```
+-------------------------+
| Envelope                |
+-------------------------+
    +------------------------+
    | Authentication Block   |
    +------------------------+
    | Manifest               |
    | Severable Elements     |
    +------------------------+
    | Human-Readable Text     |
    | Integrated Payloads    |
    +------------------------+

+------------------------+
| Common Structure       |
+------------------------+
    +------------------------+
    | Components IDs         |
    | Common Command Sequence|
    +------------------------+

5.1. Envelope

The SUIT Envelope is a container that encloses the Authentication Block, the Manifest, any Severable Elements, and any integrated payloads. The Envelope is used instead of conventional cryptographic envelopes, such as COSE_Envelope because it allows modular processing, severing of elements, and integrated payloads in a way that would add substantial complexity with existing solutions. See Appendix C.1 for a description of the reasoning for this.

See Section 8.2 for more detail.
5.2. Authentication Block

The Authentication Block contains a bstr-wrapped SUIT Digest Container, see Section 10, and one or more [RFC8152] CBOR Object Signing and Encryption (COSE) authentication blocks. These blocks are one of:

* COSE_Sign_Tagged
* COSE_Sign1_Tagged
* COSE_Mac_Tagged
* COSE_Mac0_Tagged

Each of these objects is used in detached payload mode. The payload is the bstr-wrapped SUIT_Digest.

See Section 8.3 for more detail.

5.3. Manifest

The Manifest contains most metadata about one or more images. The Manifest is divided into Critical Metadata, Common Metadata, Command Sequences, and Integrity Check Values.

See Section 8.4 for more detail.

5.3.1. Critical Metadata

Some metadata needs to be accessed before the manifest is processed. This metadata can be used to determine which manifest is newest and whether the structure version is supported. It also MAY provide a URI for obtaining a canonical copy of the manifest and Envelope.

See Section 8.4.1, Section 8.4.2, and Section 8.4.3 for more detail.

5.3.2. Common

Some metadata is used repeatedly and in more than one command sequence. In order to reduce the size of the manifest, this metadata is collected into the Common section. Common is composed of two parts: a list of components referenced by the manifest, and a command sequence to execute prior to each other command sequence. The common command sequence is typically used to set commonly used values and perform compatibility checks. The common command sequence MUST NOT have any side-effects outside of setting parameter values.
See Section 8.4.5 for more detail.

5.3.3. Command Sequences

Command sequences provide the instructions that a Recipient requires in order to install or use an image. These sequences tell a device to set parameter values, test system parameters, copy data from one place to another, transform data, digest data, and run code.

Command sequences are broken up into three groups: Common Command Sequence (see Section 5.3.2), update commands, and secure boot commands.

Update Command Sequences are: Payload Fetch, and Payload Installation. An Update Procedure is the complete set of each Update Command Sequence, each preceded by the Common Command Sequence.

Invocation Command Sequences are: System Validation, Image Loading, and Image Invocation. An Invocation Procedure is the complete set of each Invocation Command Sequence, each preceded by the Common Command Sequence.

Command Sequences are grouped into these sets to ensure that there is common coordination between dependencies and dependents on when to execute each command (dependencies are not defined in this specification).

See Section 8.4.6 for more detail.

5.3.4. Integrity Check Values

To enable Section 5.4, there needs to be a mechanism to verify integrity of any metadata outside the manifest. Integrity Check Values are used to verify the integrity of metadata that is not contained in the manifest. This MAY include Severable Command Sequences, or Text data. Integrated Payloads are integrity-checked using Command Sequences, so they do not have Integrity Check Values present in the Manifest.

See Section 8.4.11 for more detail.

5.3.5. Human-Readable Text

Text is typically a Severable Element (Section 5.4). It contains all the text that describes the update. Because text is explicitly for human consumption, it is all grouped together so that it can be Severed easily. The text section has space both for describing the manifest as a whole and for describing each individual component.
See Section 8.4.4 for more detail.

5.4. Severable Elements

Severable Elements are elements of the Envelope (Section 5.1) that have Integrity Check Values (Section 5.3.4) in the Manifest (Section 5.3).

Because of this organisation, these elements can be discarded or "Severed" from the Envelope without changing the signature of the Manifest. This allows savings based on the size of the Envelope in several scenarios, for example:

* A management system severs the Text sections before sending an Envelope to a constrained Recipient, which saves Recipient bandwidth.

* A Recipient severs the Installation section after installing the Update, which saves storage space.

See Section 8.5 for more detail.

5.5. Integrated Payloads

In some cases, it is beneficial to include a payload in the Envelope of a manifest. For example:

* When an update is delivered via a comparatively unconstrained medium, such as a removable mass storage device, it may be beneficial to bundle updates into single files.

* When a manifest transports a small payload, such as an encrypted key, that payload may be placed in the manifest’s envelope.

See Section 7.5 for more detail.

6. Manifest Processor Behavior

This section describes the behavior of the manifest processor and focuses primarily on interpreting commands in the manifest. However, there are several other important behaviors of the manifest processor: encoding version detection, rollback protection, and authenticity verification are chief among these.
6.1. Manifest Processor Setup

Prior to executing any command sequence, the manifest processor or its host application MUST inspect the manifest version field and fail when it encounters an unsupported encoding version. Next, the manifest processor or its host application MUST extract the manifest sequence number and perform a rollback check using this sequence number. The exact logic of rollback protection may vary by application, but it has the following properties:

* Whenever the manifest processor can choose between several manifests, it MUST select the latest valid, authentic manifest.

* If the latest valid, authentic manifest fails, it MAY select the next latest valid, authentic manifest, according to application-specific policy.

Here, valid means that a manifest has a supported encoding version and it has not been excluded for other reasons. Reasons for excluding typically involve first executing the manifest and may include:

* Test failed (e.g. Vendor ID/Class ID).

* Unsupported command encountered.

* Unsupported parameter encountered.

* Unsupported Component Identifier encountered.

* Payload not available.

* Application crashed when executed.

* Watchdog timeout occurred.

* Payload verification failed.

* Missing required component from a Component Set.

* Required parameter not supplied.

These failure reasons MAY be combined with retry mechanisms prior to marking a manifest as invalid.

Selecting an older manifest in the event of failure of the latest valid manifest is a robustness mechanism that is necessary for supporting the requirements in [RFC9019], section 3.5. It may not be
appropriate for all applications. In particular Trusted Execution Environments MAY require a failure to invoke a new installation, rather than a rollback approach. See [RFC9124], Section 4.2.1 for more discussion on the security considerations that apply to rollback.

Following these initial tests, the manifest processor clears all parameter storage. This ensures that the manifest processor begins without any leaked data.

6.2. Required Checks

The RECOMMENDED process is to verify the signature of the manifest prior to parsing/executing any section of the manifest. This guards the parser against arbitrary input by unauthenticated third parties, but it costs extra energy when a Recipient receives an incompatible manifest.

When validating authenticity of manifests, the manifest processor MAY use an ACL (see Section 9) to determine the extent of the rights conferred by that authenticity.

Once a valid, authentic manifest has been selected, the manifest processor MUST examine the component list and verify that its maximum number of components is not exceeded and that each listed component is supported.

For each listed component, the manifest processor MUST provide storage for the supported parameters. If the manifest processor does not have sufficient temporary storage to process the parameters for all components, it MAY process components serially for each command sequence. See Section 6.6 for more details.

The manifest processor SHOULD check that the common sequence contains at least Check Vendor Identifier command and at least one Check Class Identifier command.

Because the common sequence contains Check Vendor Identifier and Check Class Identifier command(s), no custom commands are permitted in the common sequence. This ensures that any custom commands are only executed by devices that understand them.

If the manifest contains more than one component, each command sequence MUST begin with a Set Component Index.

If a Recipient supports groups of interdependent components (a Component Set), then it SHOULD verify that all Components in the Component Set are specified by one update, that is the manifest:
1. has sufficient permissions imparted by its signatures

2. specifies a digest and a payload for every Component in the Component Set.

6.2.1. Minimizing Signature Verifications

Signature verification can be energy and time expensive on a constrained device. MAC verification is typically unaffected by these concerns. A Recipient MAY choose to parse and execute only the SUIT_Common section of the manifest prior to signature verification, if all of the below apply:

* The Authentication Block contains a COSE_Sign_Tagged or COSE_Sign1_Tagged

* The Recipient receives manifests over an unauthenticated channel, exposing it to more inauthentic or incompatible manifests, and

* The Recipient has a power budget that makes signature verification undesirable

When executing Common prior to authenticity validation, the Manifest Processor MUST first evaluate the integrity of the manifest using the SUIT_Digest present in the authentication block.

The guidelines in Creating Manifests (Section 7) require that the common section contains the applicability checks, so this section is sufficient for applicability verification. The parser MUST restrict acceptable commands to conditions and the following directives: Override Parameters, Set Parameters, Try Each, and Run Sequence ONLY. The manifest parser MUST NOT execute any command with side-effects outside the parser (for example, Run, Copy, Swap, or Fetch commands) prior to authentication and any such command MUST Abort. The Common Sequence MUST be executed again, in its entirety, after authenticity validation.

A Recipient MAY rely on network infrastructure to filter inapplicable manifests.

6.3. Interpreter Fundamental Properties

The interpreter has a small set of design goals:

1. Executing an update MUST either result in an error, or a verifiably correct system state.
2. Executing a Trusted Invocation MUST either result in an error, or an invoked image.

3. Executing the same manifest on multiple Recipients MUST result in the same system state.

NOTE: when using A/B images, the manifest functions as two (or more) logical manifests, each of which applies to a system in a particular starting state. With that provision, design goal 3 holds.

6.3.1. Resilience to Disruption

As required in Section 3 of RFC9019 and as an extension of design goal 1, devices must remain operable after a disruption, such as a power failure or network interruption, interrupts the update process.

The manifest processor must be resilient to these faults. In order to enable this resilience, systems implementing the manifest processor MUST make the following guarantees:

Either: 1. A fallback/recovery image is provided so that a disrupted system can apply the SUIT Manifest again. 2. Manifests are constructed so that repeated partial invocations of any manifest sequence always results in a correct system configuration. 3. A journal of manifest operations is stored in nonvolatile memory so that a repeated invocation does not alter nonvolatile memory up until the point of the previous failure. The journal enables the parser to recreate the processor state just prior to the disruption. This journal can be, for example, a SUIT Report. This report can be used to resume processing of the manifest from the point of failure.

AND

1. Where a command is not repeatable because of the way in which it alters system state (e.g. swapping images or in-place delta) it MUST be resumable or revertible. This applies to commands that modify at least one source component as well as the destination component.

6.4. Abstract Machine Description

The heart of the manifest is the list of commands, which are processed by a Manifest Processor--a form of interpreter. This Manifest Processor can be modeled as a simple abstract machine. This machine consists of several data storage locations that are modified by commands.
There are two types of commands, namely those that modify state (directives) and those that perform tests (conditions). Parameters are used as the inputs to commands. Some directives offer control flow operations. Directives target a specific component. A component is a unit of code or data that can be targeted by an update. Components are identified by Component Identifiers, but referenced in commands by Component Index; Component Identifiers are arrays of binary strings and a Component Index is an index into the array of Component Identifiers.

Conditions MUST NOT have any side-effects other than informing the interpreter of success or failure. The Interpreter does not Abort if the Soft Failure flag (Section 8.4.8.14) is set when a Condition reports failure.

Directives MAY have side-effects in the parameter table, the interpreter state, or the current component. The Interpreter MUST Abort if a Directive reports failure regardless of the Soft Failure flag.

To simplify the logic describing the command semantics, the object "current" is used. It represents the component identified by the Component Index:

```
current := components\[component-index\]
```

As a result, Set Component Index is described as current := components[arg].

The following table describes the behavior of each command. "params" represents the parameters for the current component. Most commands operate on a component.

<table>
<thead>
<tr>
<th>Command Name</th>
<th>Semantic of the Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check Vendor Identifier</td>
<td>assert(binary-match(current, current.params[vendor-id]))</td>
</tr>
<tr>
<td>Check Class Identifier</td>
<td>assert(binary-match(current, current.params[class-id]))</td>
</tr>
<tr>
<td>Verify Image</td>
<td>assert(binary-match(digest(current), current.params[digest]))</td>
</tr>
<tr>
<td>Set Component Index</td>
<td>current := components[arg]</td>
</tr>
<tr>
<td>Override Parameters</td>
<td>current.params[k] := v for-each k,v</td>
</tr>
</tbody>
</table>
Table 1

6.5. Special Cases of Component Index

Component Index can take on one of three types:

1. Integer
2. Array of integers
3. True
Integers MUST always be supported by Set Component Index. Arrays of integers MUST be supported by Set Component Index if the Recipient supports 3 or more components. True MUST be supported by Set Component Index if the Recipient supports 2 or more components. Each of these operates on the list of components declared in the manifest.

Integer indices are the default case as described in the previous section. An array of integers represents a list of the components (Set Component Index) to which each subsequent command applies. The value True replaces the list of component indices with the full list of components, as defined in the manifest.

When a command is executed, it either 1. operates on the component identified by the component index if that index is an integer, or 2. it operates on each component identified by an array of indicies, or 3. it operates on every component if the index is the boolean True. This is described by the following pseudocode:

```
if component-index is true:
    current-list = components
else if component-index is array:
    current-list = [ components[idx] for idx in component-index ]
else:
    current-list = [ components[component-index] ]
for current in current-list:
    cmd(current)
```

Try Each and Run Sequence are affected in the same way as other commands: they are invoked once for each possible Component. This means that the sequences that are arguments to Try Each and Run Sequence are NOT invoked with Component Index = True, nor are they invoked with array indices. They are only invoked with integer indices. The interpreter loops over the whole sequence, setting the Component Index to each index in turn.

6.6. Serialized Processing Interpreter

In highly constrained devices, where storage for parameters is limited, the manifest processor MAY handle one component at a time, traversing the manifest tree once for each listed component. In this mode, the interpreter ignores any commands executed while the component index is not the current component. This reduces the overall volatile storage required to process the update so that the only limit on number of components is the size of the manifest. However, this approach requires additional processing power.
In order to operate in this mode, the manifest processor loops on each section for every supported component, simply ignoring commands when the current component is not selected.

When a serialized Manifest Processor encounters a component index of True, it does not ignore any commands. It applies them to the current component on each iteration.

6.7. Parallel Processing Interpreter

Advanced Recipients MAY make use of the Strict Order parameter and enable parallel processing of some Command Sequences, or it may reorder some Command Sequences. To perform parallel processing, once the Strict Order parameter is set to False, the Recipient may issue each or every command concurrently until the Strict Order parameter is returned to True or the Command Sequence ends. Then, it waits for all issued commands to complete before continuing processing of commands. To perform out-of-order processing, a similar approach is used, except the Recipient consumes all commands after the Strict Order parameter is set to False, then it sorts these commands into its preferred order, invokes them all, then continues processing.

When the manifest processor encounters any of these scenarios the parallel processing MUST halt until all issued commands have completed:

* Set Parameters.
* Override Parameters.
* Set Strict Order = True.
* Set Component Index.

To perform more useful parallel operations, a manifest author may collect sequences of commands in a Run Sequence command. Then, each of these sequences MAY be run in parallel. Each sequence defaults to Strict Order = True. To isolate each sequence from each other sequence, each sequence MUST begin with a Set Component Index directive with the following exception: when the index is either True or an array of indices, the Set Component Index is implied. Any further Set Component Index directives MUST cause an Abort. This allows the interpreter that issues Run Sequence commands to check that the first element is correct, then issue the sequence to a parallel execution context to handle the remainder of the sequence.
7. Creating Manifests

Manifests are created using tools for constructing COSE structures, calculating cryptographic values and compiling desired system state into a sequence of operations required to achieve that state. The process of constructing COSE structures and the calculation of cryptographic values is covered in [RFC8152].

Compiling desired system state into a sequence of operations can be accomplished in many ways. Several templates are provided below to cover common use-cases. These templates can be combined to produce more complex behavior.

The author MUST ensure that all parameters consumed by a command are set prior to invoking that command. Where Component Index = True, this means that the parameters consumed by each command MUST have been set for each Component.

This section details a set of templates for creating manifests. These templates explain which parameters, commands, and orders of commands are necessary to achieve a stated goal.

NOTE: On systems that support only a single component, Set Component Index has no effect and can be omitted.

NOTE: *A digest MUST always be set using Override Parameters.*

7.1. Compatibility Check Template

The goal of the compatibility check template ensure that Recipients only install compatible images.

In this template all information is contained in the common sequence and the following sequence of commands is used:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for Vendor ID and Class ID (see Section 8.4.8)
* Check Vendor Identifier condition (see Section 8.4.8.2)
* Check Class Identifier condition (see Section 8.4.8.2)
7.2. Trusted Invocation Template

The goal of the Trusted Invocation template is to ensure that only authorized code is invoked; such as in Secure Boot or when a Trusted Application is loaded into a TEE.

The following commands are placed into the common sequence:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for Image Digest and Image Size (see Section 8.4.8)

The system validation sequence contains the following commands:

* Set Component Index directive (see Section 8.4.10.1)
* Check Image Match condition (see Section 8.4.9.2)

Then, the run sequence contains the following commands:

* Set Component Index directive (see Section 8.4.10.1)
* Run directive (see Section 8.4.10.7)

7.3. Component Download Template

The goal of the Component Download template is to acquire and store an image.

The following commands are placed into the common sequence:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for Image Digest and Image Size (see Section 8.4.8)

Then, the install sequence contains the following commands:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for URI (see Section 8.4.8.9)
* Fetch directive (see Section 8.4.10.4)
* Check Image Match condition (see Section 8.4.9.2)
The Fetch directive needs the URI parameter to be set to determine where the image is retrieved from. Additionally, the destination of where the component shall be stored has to be configured. The URI is configured via the Set Parameters directive while the destination is configured via the Set Component Index directive.

7.4. Install Template

The goal of the Install template is to use an image already stored in an identified component to copy into a second component.

This template is typically used with the Component Download template, however a modification to that template is required: the Component Download operations are moved from the Payload Install sequence to the Payload Fetch sequence.

Then, the install sequence contains the following commands:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for Source Component (see Section 8.4.8.10)
* Copy directive (see Section 8.4.10.5)
* Check Image Match condition (see Section 8.4.9.2)

7.5. Integrated Payload Template

The goal of the Integrated Payload template is to install a payload that is included in the manifest envelope. It is identical to the Component Download template (Section 7.3).

An implementer MAY choose to place a payload in the envelope of a manifest. The payload envelope key MUST be a string. The payload MUST be serialized in a bstr element.

The URI for a payload enclosed in this way MAY be expressed as a fragment-only reference, as defined in [RFC3986], Section 4.4.

A distributor MAY choose to pre-fetch a payload and add it to the manifest envelope, using the URI as the key.

7.6. Load from Nonvolatile Storage Template

The goal of the Load from Nonvolatile Storage template is to load an image from a non-volatile component into a volatile component, for example loading a firmware image from external Flash into RAM.
The following commands are placed into the load sequence:

* Set Component Index directive (see Section 8.4.10.1)
* Override Parameters directive (see Section 8.4.10.3) for Source Component (see Section 8.4.8)
* Copy directive (see Section 8.4.10.5)

As outlined in Section 6.4, the Copy directive needs a source and a destination to be configured. The source is configured via Component Index (with the Set Parameters directive) and the destination is configured via the Set Component Index directive.

7.7. A/B Image Template

The goal of the A/B Image Template is to acquire, validate, and invoke one of two images, based on a test.

The following commands are placed in the common block:

* Set Component Index directive (see Section 8.4.10.1)
* Try Each
  - First Sequence:
    o Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot A
    o Check Slot Condition (see Section 8.4.9.3)
    o Override Parameters directive (see Section 8.4.10.3) for Image Digest A and Image Size A (see Section 8.4.8)
  - Second Sequence:
    o Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot B
    o Check Slot Condition (see Section 8.4.9.3)
    o Override Parameters directive (see Section 8.4.10.3) for Image Digest B and Image Size B (see Section 8.4.8)

The following commands are placed in the fetch block or install block

* Set Component Index directive (see Section 8.4.10.1)
* Try Each

- First Sequence:
  - Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot A
  - Check Slot Condition (see Section 8.4.9.3)
  - Set Parameters directive (see Section 8.4.10.3) for URI A (see Section 8.4.8)

- Second Sequence:
  - Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot B
  - Check Slot Condition (see Section 8.4.9.3)
  - Set Parameters directive (see Section 8.4.10.3) for URI B (see Section 8.4.8)

* Fetch

If Trusted Invocation (Section 7.2) is used, only the run sequence is added to this template, since the common sequence is populated by this template:

* Set Component Index directive (see Section 8.4.10.1)

* Try Each

- First Sequence:
  - Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot A
  - Check Slot Condition (see Section 8.4.9.3)

- Second Sequence:
  - Override Parameters directive (see Section 8.4.10.3, Section 8.4.8) for Slot B
  - Check Slot Condition (see Section 8.4.9.3)

* Run
NOTE: Any test can be used to select between images, Check Slot Condition is used in this template because it is a typical test for execute-in-place devices.

8. Metadata Structure

The metadata for SUIT updates is composed of several primary constituent parts: the Envelope, Authentication Information, Manifest, and Severable Elements.

For a diagram of the metadata structure, see Section 5.

8.1. Encoding Considerations

The map indices in the envelope encoding are reset to 1 for each map within the structure. This is to keep the indices as small as possible. The goal is to keep the index objects to single bytes (CBOR positive integers 1-23).

Wherever enumerations are used, they are started at 1. This allows detection of several common software errors that are caused by uninitialized variables. Positive numbers in enumerations are reserved for IANA registration. Negative numbers are used to identify application-specific values, as described in Section 11.

All elements of the envelope must be wrapped in a bstr to minimize the complexity of the code that evaluates the cryptographic integrity of the element and to ensure correct serialization for integrity and authenticity checks.

All CBOR maps in the Manifest and manifest envelope MUST be encoded with the canonical CBOR ordering as defined in [RFC8949].

8.2. Envelope

The Envelope contains each of the other primary constituent parts of the SUIT metadata. It allows for modular processing of the manifest by ordering components in the expected order of processing.

The Envelope is encoded as a CBOR Map. Each element of the Envelope is enclosed in a bstr, which allows computation of a message digest against known bounds.
8.3. Authenticated Manifests

The suit-authentication-wrapper contains a SUIT Digest Container (see Section 10) and one or more SUIT Authentication Blocks. The SUIT_Digest carries the result of computing the indicated hash algorithm over the suit-manifest element. A signing application MUST verify the suit-manifest element against the SUIT_Digest prior to signing. A SUIT Authentication Block is implemented as COSE_Mac_Tagged, COSE_Mac0_Tagged, COSE_Sign_Tagged or COSE_Sign1_Tagged structures with detached payloads, as described in RFC 8152 [RFC8152].

For COSE_Sign and COSE_Sign1 a special signature structure (called Sig_structure) has to be created onto which the selected digital signature algorithm is applied to, see Section 4.4 of [RFC8152] for details. This specification requires Sig_structure to be populated as follows: * The external_aad field MUST be set to a zero-length binary string (i.e. there is no external additional authenticated data). * The payload field contains the SUIT_Digest wrapped in a bstr, as per the requirements in Section 4.4 of RFC 8152. All other fields in the Sig_structure are populated as described in Section 4.4 of [RFC8152].

Likewise, Section 6.3 of [RFC8152] describes the details for computing a MAC and the fields of the MAC_structure need to be populated. The rules for external_aad and the payload fields described in the paragraph above also apply to this structure.

The suit-authentication-wrapper MUST come before the suit-manifest element, regardless of canonical encoding of CBOR.

A SUIT_Envelope that has not had authentication information added MUST still contain the suit-authentication-wrapper element, but the content MUST be a list containing only the SUIT_Digest.

The algorithms used in SUIT_Authentication are defined by the profiles declared in [I-D.moran-suit-mti].

8.4. Manifest

The manifest contains:

* a version number (see Section 8.4.1)
* a sequence number (see Section 8.4.2)
* a reference URI (see Section 8.4.3)
* a common structure with information that is shared between command sequences (see Section 8.4.5)

* one or more lists of commands that the Recipient should perform (see Section 8.4.6)

* a reference to the full manifest (see Section 8.4.3)

* human-readable text describing the manifest found in the SUIT_Envelope (see Section 8.4.4)

The Text section, or any Command Sequence of the Update Procedure (Image Fetch, Image Installation) can be either a CBOR structure or a SUIT_Digest. In each of these cases, the SUIT_Digest provides for a severable element. Severable elements are RECOMMENDED to implement. In particular, the human-readable text SHOULD be severable, since most useful text elements occupy more space than a SUIT_Digest, but are not needed by the Recipient. Because SUIT_Digest is a CBOR Array and each severable element is a CBOR bstr, it is straight-forward for a Recipient to determine whether an element has been severed. The key used for a severable element is the same in the SUIT_Manifest and in the SUIT_Envelope so that a Recipient can easily identify the correct data in the envelope. See Section 8.4.11 for more detail.

8.4.1. suit-manifest-version

The suit-manifest-version indicates the version of serialization used to encode the manifest. Version 1 is the version described in this document. suit-manifest-version is REQUIRED to implement.

8.4.2. suit-manifest-sequence-number

The suit-manifest-sequence-number is a monotonically increasing anti-rollback counter. Each Recipient MUST reject any manifest that has a sequence number lower than its current sequence number. For convenience, an implementer MAY use a UTC timestamp in seconds as the sequence number. suit-manifest-sequence-number is REQUIRED to implement.

8.4.3. suit-reference-uri

suit-reference-uri is a text string that encodes a URI where a full version of this manifest can be found. This is convenient for allowing management systems to show the severed elements of a manifest when this URI is reported by a Recipient after installation.
8.4.4. suit-text

suit-text SHOULD be a severable element. suit-text is a map containing two different types of pair:

* integer => text

* SUIT_Component_Identifier => map

Each SUIT_Component_Identifier => map entry contains a map of integer => text values. All SUIT_Component_Identifiers present in suit-text MUST also be present in suit-common (Section 8.4.5).

suit-text contains all the human-readable information that describes any and all parts of the manifest, its payload(s) and its resource(s). The text section is typically severable, allowing manifests to be distributed without the text, since end-nodes do not require text. The meaning of each field is described below.

Each section MAY be present. If present, each section MUST be as described. Negative integer IDs are reserved for application-specific text values.

The following table describes the text fields available in suit-text:

<table>
<thead>
<tr>
<th>CDDL Structure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>suit-text-manifest-description</td>
<td>Free text description of the manifest</td>
</tr>
<tr>
<td>suit-text-update-description</td>
<td>Free text description of the update</td>
</tr>
<tr>
<td>suit-text-manifest-json-source</td>
<td>The JSON-formatted document that was used to create the manifest</td>
</tr>
<tr>
<td>suit-text-manifest-yaml-source</td>
<td>The YAML ([YAML])-formatted document that was used to create the manifest</td>
</tr>
</tbody>
</table>

Table 2

The following table describes the text fields available in each map identified by a SUIT_Component_Identifier.
suit-text is OPTIONAL to implement.

8.4.5. suit-common

suit-common encodes all the information that is shared between each of the command sequences, including: suit-components, and suit-common-sequence. suit-common is REQUIRED to implement.

suit-components is a list of SUIT_Component_Identifier (Section 8.4.5.1) blocks that specify the component identifiers that will be affected by the content of the current manifest. suit-components is REQUIRED to implement.

suit-common-sequence is a SUIT_Command_Sequence to execute prior to executing any other command sequence. Typical actions in suit-common-sequence include setting expected Recipient identity and image digests when they are conditional (see Section 8.4.10.2 and Section 7.7 for more information on conditional sequences). suit-common-sequence is RECOMMENDED to implement. It is REQUIRED if the optimizations described in Section 6.2.1 will be used. Whenever a parameter or Try Each command is required by more than one Command Sequence, placing that parameter or command in suit-common-sequence results in a smaller encoding.
8.4.5.1. SUIT_Component_Identifier

A component is a unit of code or data that can be targeted by an update. To facilitate composite devices, components are identified by a list of CBOR byte strings, which allows construction of hierarchical component structures. Components are identified by Component Identifiers, but referenced in commands by Component Index; Component Identifiers are arrays of binary strings and a Component Index is an index into the array of Component Identifiers.

A Component Identifier can be trivial, such as the simple array [h’00’]. It can also represent a filesystem path by encoding each segment of the path as an element in the list. For example, the path "/usr/bin/env" would encode to [‘usr’,’bin’,’env’].

This hierarchical construction allows a component identifier to identify any part of a complex, multi-component system.

8.4.6. SUIT_Command_Sequence

A SUIT_Command_Sequence defines a series of actions that the Recipient MUST take to accomplish a particular goal. These goals are defined in the manifest and include:

1. Payload Fetch: suit-payload-fetch is a SUIT_Command_Sequence to execute in order to obtain a payload. Some manifests may include these actions in the suit-install section instead if they operate in a streaming installation mode. This is particularly relevant for constrained devices without any temporary storage for staging the update. suit-payload-fetch is OPTIONAL to implement.

2. Payload Installation: suit-install is a SUIT_Command_Sequence to execute in order to install a payload. Typical actions include verifying a payload stored in temporary storage, copying a staged payload from temporary storage, and unpacking a payload. suit-install is OPTIONAL to implement.

3. Image Validation: suit-validate is a SUIT_Command_Sequence to execute in order to validate that the result of applying the update is correct. Typical actions involve image validation. suit-validate is REQUIRED to implement.

4. Image Loading: suit-load is a SUIT_Command_Sequence to execute in order to prepare a payload for execution. Typical actions include copying an image from permanent storage into RAM, optionally including actions such as decryption or decompression. suit-load is OPTIONAL to implement.
5. Run or Boot: suit-run is a SUIT_Command_Sequence to execute in order to run an image. suit-run typically contains a single instruction: the "run" directive. suit-run is OPTIONAL to implement.

Goals 1,2 form the Update Procedure. Goals 4,5,6 form the Invocation Procedure.

Each Command Sequence follows exactly the same structure to ensure that the parser is as simple as possible.

Lists of commands are constructed from two kinds of element:
1. Conditions that MUST be true and any failure is treated as a failure of the update/load/invocation
2. Directives that MUST be executed.

Each condition is composed of:
1. A command code identifier
2. A SUIT_Reporting_Policy (Section 8.4.7)

Each directive is composed of:
1. A command code identifier
2. An argument block or a SUIT_Reporting_Policy (Section 8.4.7)

Argument blocks are consumed only by flow-control directives:
* Set Component Index
* Set/Override Parameters
* Try Each
* Run Sequence

Reporting policies provide a hint to the manifest processor of whether to add the success or failure of a command to any report that it generates.
Many conditions and directives apply to a given component, and these generally grouped together. Therefore, a special command to set the current component index is provided. This index is a numeric index into the Component Identifier table defined at the beginning of the manifest.

To facilitate optional conditions, a special directive, suit-directive-try-each (Section 8.4.10.2), is provided. It runs several new lists of conditions/directives, one after another, that are contained as an argument to the directive. By default, it assumes that a failure of a condition should not indicate a failure of the update/invocation, but a parameter is provided to override this behavior. See suit-parameter-soft-failure (Section 8.4.8.14).

8.4.7. Reporting Policy

To facilitate construction of Reports that describe the success or failure of a given Procedure, each command is given a Reporting Policy. This is an integer bitfield that follows the command and indicates what the Recipient should do with the Record of executing the command. The options are summarized in the table below.

<table>
<thead>
<tr>
<th>Policy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>suit-send-record-on-success</td>
<td>Record when the command succeeds</td>
</tr>
<tr>
<td>suit-send-record-on-failure</td>
<td>Record when the command fails</td>
</tr>
<tr>
<td>suit-send-sysinfo-success</td>
<td>Add system information when the command succeeds</td>
</tr>
<tr>
<td>suit-send-sysinfo-failure</td>
<td>Add system information when the command fails</td>
</tr>
</tbody>
</table>

Table 4

Any or all of these policies may be enabled at once.

At the completion of each command, a Manifest Processor MAY forward information about the command to a Reporting Engine, which is responsible for reporting boot or update status to a third party. The Reporting Engine is entirely implementation-defined, the reporting policy simply facilitates the Reporting Engine’s interface to the SUIT Manifest Processor.

The information elements provided to the Reporting Engine are:
* The reporting policy
* The result of the command
* The values of parameters consumed by the command
* The system information consumed by the command

Together, these elements are called a Record. A group of Records is a Report.

If the component index is set to True or an array when a command is executed with a non-zero reporting policy, then the Reporting Engine MUST receive one Record for each Component, in the order expressed in the Components list or the component index array.

This specification does not define a particular format of Records or Reports. This specification only defines hints to the Reporting Engine for which Records it should aggregate into the Report. The Reporting Engine MAY choose to ignore these hints and apply its own policy instead.

When used in a Invocation Procedure, the report MAY form the basis of an attestation report. When used in an Update Process, the report MAY form the basis for one or more log entries.

8.4.8. SUIT_Parameters

Many conditions and directives require additional information. That information is contained within parameters that can be set in a consistent way. This allows reuse of parameters between commands, thus reducing manifest size.

Most parameters are scoped to a specific component. This means that setting a parameter for one component has no effect on the parameters of any other component. The only exceptions to this are two Manifest Processor parameters: Strict Order and Soft Failure.

The defined manifest parameters are described below.
<table>
<thead>
<tr>
<th>Name</th>
<th>CDDL Structure</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor ID</td>
<td>suit-parameter-vendor-identifier</td>
<td>Section 8.4.8.3</td>
</tr>
<tr>
<td>Class ID</td>
<td>suit-parameter-class-identifier</td>
<td>Section 8.4.8.4</td>
</tr>
<tr>
<td>Device ID</td>
<td>suit-parameter-device-identifier</td>
<td>Section 8.4.8.5</td>
</tr>
<tr>
<td>Image Digest</td>
<td>suit-parameter-image-digest</td>
<td>Section 8.4.8.6</td>
</tr>
<tr>
<td>Image Size</td>
<td>suit-parameter-image-size</td>
<td>Section 8.4.8.7</td>
</tr>
<tr>
<td>Component Slot</td>
<td>suit-parameter-component-slot</td>
<td>Section 8.4.8.8</td>
</tr>
<tr>
<td>URI</td>
<td>suit-parameter-uri</td>
<td>Section 8.4.8.9</td>
</tr>
<tr>
<td>Source Component</td>
<td>suit-parameter-source-component</td>
<td>Section 8.4.8.10</td>
</tr>
<tr>
<td>Run Args</td>
<td>suit-parameter-run-args</td>
<td>Section 8.4.8.11</td>
</tr>
<tr>
<td>Fetch Arguments</td>
<td>suit-parameter-fetch-arguments</td>
<td>Section 8.4.8.12</td>
</tr>
<tr>
<td>Strict Order</td>
<td>suit-parameter-strict-order</td>
<td>Section 8.4.8.13</td>
</tr>
<tr>
<td>Soft Failure</td>
<td>suit-parameter-soft-failure</td>
<td>Section 8.4.8.14</td>
</tr>
<tr>
<td>Custom</td>
<td>suit-parameter-custom</td>
<td>Section 8.4.8.15</td>
</tr>
</tbody>
</table>

Table 5

CBOR-encoded object parameters are still wrapped in a bstr. This is because it allows a parser that is aggregating parameters to reference the object with a single pointer and traverse it without understanding the contents. This is important for modularization and division of responsibility within a pull parser. The same consideration does not apply to Directives because those elements are invoked with their arguments immediately.
8.4.8.1. CBOR PEN UUID Namespace Identifier

The CBOR PEN UUID Namespace Identifier is constructed as follows:

It uses the OID Namespace as a starting point, then uses the CBOR absolute OID encoding for the IANA PEN OID (1.3.6.1.4.1):

D8 6F       # tag(111)
45         # bytes(5)

# Absolute OID encoding of IANA Private Enterprise Number:
# 1.3. 6. 1. 4. 1
2B 06 01 04 01 # X.690 Clause 8.19

Computing a type 5 UUID from these produces:

NAMESPACE_CBOR_PEN = UUID5(NAMESPACE_OID, h’D86F452B06010401’)
NAMESPACE_CBOR_PEN = 47fbdabb-f2e4-55f0-bb39-3620c2f6df4e

8.4.8.2. Constructing UUIDs

Several conditions use identifiers to determine whether a manifest matches a given Recipient or not. These identifiers are defined to be RFC 4122 [RFC4122] UUIDs. These UUIDs are not human-readable and are therefore used for machine-based processing only.

A Recipient MAY match any number of UUIDs for vendor or class identifier. This may be relevant to physical or software modules. For example, a Recipient that has an OS and one or more applications might list one Vendor ID for the OS and one or more additional Vendor IDs for the applications. This Recipient might also have a Class ID that must be matched for the OS and one or more Class IDs for the applications.

Identifiers are used for compatibility checks. They MUST NOT be used as assertions of identity. They are evaluated by identifier conditions (Section 8.4.9.1).

A more complete example: Imagine a device has the following physical components: 1. A host MCU 2. A WiFi module

This same device has three software modules: 1. An operating system 2. A WiFi module interface driver 3. An application

Suppose that the WiFi module’s firmware has a proprietary update mechanism and doesn’t support manifest processing. This device can report four class IDs:

1. Hardware model/revision
2. OS

3. WiFi module model/revision

4. Application

This allows the OS, WiFi module, and application to be updated independently. To combat possible incompatibilities, the OS class ID can be changed each time the OS has a change to its API.

This approach allows a vendor to target, for example, all devices with a particular WiFi module with an update, which is a very powerful mechanism, particularly when used for security updates.

UUIDs MUST be created according to RFC 4122 [RFC4122]. UUIDs SHOULD use versions 3, 4, or 5, as described in RFC4122. Versions 1 and 2 do not provide a tangible benefit over version 4 for this application.

The RECOMMENDED method to create a vendor ID is:

Vendor ID = UUID5(DNS_PREFIX, vendor domain name)

If the Vendor ID is a UUID, the RECOMMENDED method to create a Class ID is:

Class ID = UUID5(Vendor ID, Class-Specific-Information)

If the Vendor ID is a CBOR PEN (see Section 8.4.8.3), the RECOMMENDED method to create a Class ID is:

Class ID = UUID5(
    UUID5(NAMESPACE_CBOR_PEN, CBOR_PEN),
    Class-Specific-Information)

Class-specific-information is composed of a variety of data, for example:

* Model number.
* Hardware revision.
* Bootloader version (for immutable bootloaders).

8.4.8.3. suit-parameter-vendor-identifier

suit-parameter-vendor-identifier may be presented in one of two ways:
* A Private Enterprise Number

* A byte string containing a UUID ([RFC4122])

Private Enterprise Numbers are encoded as a relative OID, according to the definition in [I-D.ietf-cbor-tags-oid]. All PENs are relative to the IANA PEN: 1.3.6.1.4.1.

8.4.8.4. suit-parameter-class-identifier

A RFC 4122 UUID representing the class of the device or component. The UUID is encoded as a 16 byte bstr, containing the raw bytes of the UUID. It MUST be constructed as described in Section 8.4.8.2

8.4.8.5. suit-parameter-device-identifier

A RFC 4122 UUID representing the specific device or component. The UUID is encoded as a 16 byte bstr, containing the raw bytes of the UUID. It MUST be constructed as described in Section 8.4.8.2

8.4.8.6. suit-parameter-image-digest

A fingerprint computed over the component itself, encoded in the SUIT_Digest Section 10 structure. The SUIT_Digest is wrapped in a bstr, as required in Section 8.4.8.

8.4.8.7. suit-parameter-image-size

The size of the firmware image in bytes. This size is encoded as a positive integer.

8.4.8.8. suit-parameter-component-slot

This parameter sets the slot index of a component. Some components support multiple possible Slots (offsets into a storage area). This parameter describes the intended Slot to use, identified by its index into the component’s storage area. This slot MUST be encoded as a positive integer.

8.4.8.9. suit-parameter-uri

A URI Reference ([RFC3986]) from which to fetch a resource, encoded as a text string. CBOR Tag 32 is not used because the meaning of the text string is unambiguous in this context.
8.4.8.10. suit-parameter-source-component

This parameter sets the source component to be used with either suit-directive-copy (Section 8.4.10.5) or with suit-directive-swap (Section 8.4.10.6). The current Component, as set by suit-directive-set-component-index defines the destination, and suit-parameter-source-component defines the source.

8.4.8.11. suit-parameter-run-args

This parameter contains an encoded set of arguments for suit-directive-run (Section 8.4.10.6). The arguments MUST be provided as an implementation-defined bstr.

8.4.8.12. suit-parameter-fetch-arguments

An implementation-defined set of arguments to suit-directive-fetch (Section 8.4.10.4). Arguments are encoded in a bstr.

8.4.8.13. suit-parameter-strict-order

The Strict Order Parameter allows a manifest to govern when directives can be executed out-of-order. This allows for systems that have a sensitivity to order of updates to choose the order in which they are executed. It also allows for more advanced systems to parallelize their handling of updates. Strict Order defaults to True. It MAY be set to False when the order of operations does not matter. When arriving at the end of a command sequence, ALL commands MUST have completed, regardless of the state of SUIT_Parameter_Strict_Order. If SUIT_Parameter_Strict_Order is returned to True, ALL preceding commands MUST complete before the next command is executed.

See Section 6.7 for behavioral description of Strict Order.

8.4.8.14. suit-parameter-soft-failure

When executing a command sequence inside suit-directive-try-each (Section 8.4.10.2) or suit-directive-run-sequence (Section 8.4.10.7) and a condition failure occurs, the manifest processor aborts the sequence. For suit-directive-try-each, if Soft Failure is True, the next sequence in Try Each is invoked, otherwise suit-directive-try-each fails with the condition failure code. In suit-directive-run-sequence, if Soft Failure is True the suit-directive-run-sequence simply halts with no side-effects and the Manifest Processor continues with the following command, otherwise, the suit-directive-run-sequence fails with the condition failure code.
suit-parameter-soft-failure is scoped to the enclosing SUIT_Command_Sequence. Its value is discarded when SUIT_Command_Sequence terminates. It MUST NOT be set outside of suit-directive-try-each or suit-directive-run-sequence.

When suit-directive-try-each is invoked, Soft Failure defaults to True. An Update Author may choose to set Soft Failure to False if they require a failed condition in a sequence to force an Abort.

When suit-directive-run-sequence is invoked, Soft Failure defaults to False. An Update Author may choose to make failures soft within a suit-directive-run-sequence.

8.4.8.15. suit-parameter-custom

This parameter is an extension point for any proprietary, application specific conditions and directives. It MUST NOT be used in the common sequence. This effectively scopes each custom command to a particular Vendor Identifier/Class Identifier pair.

8.4.9. SUIT_Condition

Conditions are used to define mandatory properties of a system in order for an update to be applied. They can be pre-conditions or post-conditions of any directive or series of directives, depending on where they are placed in the list. All Conditions specify a Reporting Policy as described Section 8.4.7. Conditions include:
The abstract description of these conditions is defined in Section 6.4.

Conditions compare parameters against properties of the system. These properties may be asserted in many different ways, including:

- Calculation on-demand
- Volatile definition in memory
- Static definition within the manifest processor
- Storage in known location within an image
- Storage within a key storage system
- Storage in One-Time-Programmable memory
- Inclusion in mask ROM
- Inclusion as a register in hardware

Some of these assertion methods are global in scope, such as a hardware register, some are scoped to an individual component, such as storage at a known location in an image, and some assertion methods can be either global or component-scope, based on implementation.

Each condition MUST report a result code on completion. If a condition reports failure, then the current sequence of commands MUST terminate. A subsequent command or command sequence MAY continue executing if suit-parameter-soft-failure (Section 8.4.8.14) is set. If a condition requires additional information, this MUST be specified in one or more parameters before the condition is executed.
If a Recipient attempts to process a condition that expects additional information and that information has not been set, it MUST report a failure. If a Recipient encounters an unknown condition, it MUST report a failure.

Condition labels in the positive number range are reserved for IANA registration while those in the negative range are custom conditions reserved for proprietary definition by the author of a manifest processor. See Section 11 for more details.

8.4.9.1. suit-condition-vendor-identifier, suit-condition-class-identifier, and suit-condition-device-identifier

There are three identifier-based conditions: suit-condition-vendor-identifier, suit-condition-class-identifier, and suit-condition-device-identifier. Each of these conditions match a RFC 4122 [RFC4122] UUID that MUST have already been set as a parameter. The installing Recipient MUST match the specified UUID in order to consider the manifest valid. These identifiers are scoped by component in the manifest. Each component MAY match more than one identifier. Care is needed to ensure that manifests correctly identify their targets using these conditions. Using only a generic class ID for a device-specific firmware could result in matching devices that are not compatible.

The Recipient uses the ID parameter that has already been set using the Set Parameters directive. If no ID has been set, this condition fails. suit-condition-class-identifier and suit-condition-vendor-identifier are REQUIRED to implement. suit-condition-device-identifier is OPTIONAL to implement.

Each identifier condition compares the corresponding identifier parameter to a parameter asserted to the Manifest Processor by the Recipient. Identifiers MUST be known to the Manifest Processor in order to evaluate compatibility.

8.4.9.2. suit-condition-image-match

Verify that the current component matches the suit-parameter-image-digest (Section 8.4.8.6) for the current component. The digest is verified against the digest specified in the Component’s parameters list. If no digest is specified, the condition fails. suit-condition-image-match is REQUIRED to implement.
8.4.9.3. suit-condition-component-slot

Verify that the slot index of the current component matches the slot index set in suit-parameter-component-slot (Section 8.4.8.8). This condition allows a manifest to select between several images to match a target slot.

8.4.9.4. suit-condition-abort

Unconditionally fail. This operation is typically used in conjunction with suit-directive-try-each (Section 8.4.10.2).

8.4.9.5. suit-condition-custom

suit-condition-custom describes any proprietary, application specific condition. This is encoded as a negative integer, chosen by the firmware developer. If additional information must be provided to the condition, it should be encoded in a custom parameter (a nint) as described in Section 8.4.8. SUIT_Condition_Custom is OPTIONAL to implement.

8.4.10. SUIT_Directive

Directives are used to define the behavior of the recipient. Directives include:
<table>
<thead>
<tr>
<th>Name</th>
<th>CDDL Structure</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set Component Index</td>
<td>suit-directive-set-component-index</td>
<td>Section 8.4.10.1</td>
</tr>
<tr>
<td>Try Each</td>
<td>suit-directive-try-each</td>
<td>Section 8.4.10.2</td>
</tr>
<tr>
<td>Override Parameters</td>
<td>suit-directive-override-parameters</td>
<td>Section 8.4.10.3</td>
</tr>
<tr>
<td>Fetch</td>
<td>suit-directive-fetch</td>
<td>Section 8.4.10.4</td>
</tr>
<tr>
<td>Copy</td>
<td>suit-directive-copy</td>
<td>Section 8.4.10.5</td>
</tr>
<tr>
<td>Run</td>
<td>suit-directive-run</td>
<td>Section 8.4.10.6</td>
</tr>
<tr>
<td>Run Sequence</td>
<td>suit-directive-run-sequence</td>
<td>Section 8.4.10.7</td>
</tr>
<tr>
<td>Swap</td>
<td>suit-directive-swap</td>
<td>Section 8.4.10.8</td>
</tr>
</tbody>
</table>

Table 7

The abstract description of these commands is defined in Section 6.4.

When a Recipient executes a Directive, it MUST report a result code. If the Directive reports failure, then the current Command Sequence MUST be terminated.

8.4.10.1. suit-directive-set-component-index

Set Component Index defines the component to which successive directives and conditions will apply. The supplied argument MUST be one of three types:

1. An unsigned integer (REQUIRED to implement in parser)
2. A boolean (REQUIRED to implement in parser ONLY IF 2 or more components supported)
3. An array of unsigned integers (REQUIRED to implement in parser
    ONLY IF 3 or more components supported)

If the following commands apply to ONE component, an unsigned integer
index into the component list is used. If the following commands
apply to ALL components, then the boolean value "True" is used
instead of an index. If the following commands apply to more than
one, but not all components, then an array of unsigned integer
indices into the component list is used. See Section 6.5 for more
details.

If component index is set to True when a command is invoked, then the
command applies to all components, in the order they appear in suit-
common-components. When the Manifest Processor invokes a command
while the component index is set to True, it must execute the command
once for each possible component index, ensuring that the command
receives the parameters corresponding to that component index.

8.4.10.2. suit-directive-try-each

This command runs several SUIT_Command_Sequence instances, one after
another, in a strict order. Use this command to implement a "try/
catch-try/catch" sequence. Manifest processors MAY implement this
command.

suit-parameter-soft-failure (Section 8.4.8.14) is initialized to True
at the beginning of each sequence. If one sequence aborts due to a
condition failure, the next is started. If no sequence completes
without condition failure, then suit-directive-try-each returns an
error. If a particular application calls for all sequences to fail
and still continue, then an empty sequence (nil) can be added to the
Try Each Argument.

The argument to suit-directive-try-each is a list of
SUIT_Command_Sequence. suit-directive-try-each does not specify a
reporting policy.

8.4.10.3. suit-directive-override-parameters

suit-directive-override-parameters replaces any listed parameters
that are already set with the values that are provided in its
argument. This allows a manifest to prevent replacement of critical
parameters.

Available parameters are defined in Section 8.4.8.

suit-directive-override-parameters does not specify a reporting
policy.
8.4.10.4. suit-directive-fetch

suit-directive-fetch instructs the manifest processor to obtain one or more manifests or payloads, as specified by the manifest index and component index, respectively.

suit-directive-fetch can target one or more payloads. suit-directive-fetch retrieves each component listed in component-index. If component-index is True, instead of an integer, then all current manifest components are fetched. If component-index is an array, then all listed components are fetched.

suit-directive-fetch typically takes no arguments unless one is needed to modify fetch behavior. If an argument is needed, it must be wrapped in a bstr and set in suit-parameter-fetch-arguments.

suit-directive-fetch reads the URI parameter to find the source of the fetch it performs.

8.4.10.5. suit-directive-copy

suit-directive-copy instructs the manifest processor to obtain one or more payloads, as specified by the component index. As described in Section 6.5 component index may be a single integer, a list of integers, or True. suit-directive-copy retrieves each component specified by the current component-index, respectively.

suit-directive-copy reads its source from suit-parameter-source-component (Section 8.4.8.10).

If either the source component parameter or the source component itself is absent, this command fails.

8.4.10.6. suit-directive-run

suit-directive-run directs the manifest processor to transfer execution to the current Component Index. When this is invoked, the manifest processor MAY be unloaded and execution continues in the Component Index. Arguments are provided to suit-directive-run through suit-parameter-run-arguments (Section 8.4.8.11) and are forwarded to the executable code located in Component Index in an application-specific way. For example, this could form the Linux Kernel Command Line if booting a Linux device.
If the executable code at Component Index is constructed in such a way that it does not unload the manifest processor, then the manifest processor may resume execution after the executable completes. This allows the manifest processor to invoke suitable helpers and to verify them with image conditions.

8.4.10.7. suit-directive-run-sequence

To enable conditional commands, and to allow several strictly ordered sequences to be executed out-of-order, suit-directive-run-sequence allows the manifest processor to execute its argument as a SUIT_Command_Sequence. The argument must be wrapped in a bstr.

When a sequence is executed, any failure of a condition causes immediate termination of the sequence.

When suit-directive-run-sequence completes, it forwards the last status code that occurred in the sequence. If the Soft Failure parameter is true, then suit-directive-run-sequence only fails when a directive in the argument sequence fails.

suit-parameter-soft-failure (Section 8.4.8.14) defaults to False when suit-directive-run-sequence begins. Its value is discarded when suit-directive-run-sequence terminates.

8.4.10.8. suit-directive-swap

suit-directive-swap instructs the manifest processor to move the source to the destination and the destination to the source simultaneously. Swap has nearly identical semantics to suit-directive-copy except that suit-directive-swap replaces the source with the current contents of the destination in an application-defined way. As with suit-directive-copy, if the source component is missing, this command fails.

If SUIT_Parameter_Compression_Info or SUIT_Parameter_Encryption_Info are present, they MUST be handled in a symmetric way, so that the source is decompressed into the destination and the destination is compressed into the source. The source is decrypted into the destination and the destination is encrypted into the source. suit-directive-swap is OPTIONAL to implement.
8.4.11. Integrity Check Values

When the Text section or any Command Sequence of the Update Procedure is made severable, it is moved to the Envelope and replaced with a SUIT_Digest. The SUIT_Digest is computed over the entire bstr enclosing the Manifest element that has been moved to the Envelope. Each element that is made severable from the Manifest is placed in the Envelope. The keys for the envelope elements have the same values as the keys for the manifest elements.

Each Integrity Check Value covers the corresponding Envelope Element as described in Section 8.5.

8.5. Severable Elements

Because the manifest can be used by different actors at different times, some parts of the manifest can be removed or "Severed" without affecting later stages of the lifecycle. Severing of information is achieved by separating that information from the signed container so that removing it does not affect the signature. This means that ensuring integrity of severable parts of the manifest is a requirement for the signed portion of the manifest. Severing some parts makes it possible to discard parts of the manifest that are no longer necessary. This is important because it allows the storage used by the manifest to be greatly reduced. For example, no text size limits are needed if text is removed from the manifest prior to delivery to a constrained device.

Elements are made severable by removing them from the manifest, encoding them in a bstr, and placing a SUIT_Digest of the bstr in the manifest so that they can still be authenticated. The SUIT_Digest typically consumes 4 bytes more than the size of the raw digest, therefore elements smaller than \((\text{Digest Bits})/8 + 4\) SHOULD NOT be severable. Elements larger than \((\text{Digest Bits})/8 + 4\) MAY be severable, while elements that are much larger than \((\text{Digest Bits})/8 + 4\) SHOULD be severable.

Because of this, all command sequences in the manifest are encoded in a bstr so that there is a single code path needed for all command sequences.

9. Access Control Lists

To manage permissions in the manifest, there are three models that can be used.
First, the simplest model requires that all manifests are authenticated by a single trusted key. This mode has the advantage that only a root manifest needs to be authenticated, since all of its dependencies have digests included in the root manifest.

This simplest model can be extended by adding key delegation without much increase in complexity.

A second model requires an ACL to be presented to the Recipient, authenticated by a trusted party or stored on the Recipient. This ACL grants access rights for specific component IDs or Component Identifier prefixes to the listed identities or identity groups. Any identity can verify an image digest, but fetching into or fetching from a Component Identifier requires approval from the ACL.

A third model allows a Recipient to provide even more fine-grained controls: The ACL lists the Component Identifier or Component Identifier prefix that an identity can use, and also lists the commands and parameters that the identity can use in combination with that Component Identifier.

10. SUIT Digest Container

The SUIT digest is a CBOR List containing two elements: an algorithm identifier and a bstr containing the bytes of the digest. Some forms of digest may require additional parameters. These can be added following the digest.

The values of the algorithm identifier are defined by [I-D.ietf-cose-hash-algs]. The following algorithms MUST be implemented by all Manifest Processors:

* SHA-256 (-16)

The following algorithms MAY be implemented in a Manifest Processor:

* SHAKE128 (-18)
* SHA-384 (-43)
* SHA-512 (-44)
* SHAKE256 (-45)

11. IANA Considerations

IANA is requested to:
* allocate CBOR tag 107 in the CBOR Tags registry for the SUIT Envelope.

* allocate CBOR tag 1070 in the CBOR Tags registry for the SUIT Manifest.

* allocate media type application/suit-envelope in the Media Types registry.

* setup several registries as described below.

IANA is requested to setup a registry for SUIT manifests. Several registries defined in the subsections below need to be created.

For each registry, values 0-23 are Standards Action, 24-255 are IETF Review, 256-65535 are Expert Review, and 65536 or greater are First Come First Served.

Negative values -23 to 0 are Experimental Use, -24 and lower are Private Use.

11.1. SUIT Commands

<table>
<thead>
<tr>
<th>Label</th>
<th>Name</th>
<th>Reference</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>Class Identifier</td>
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<td>3</td>
<td>Image Match</td>
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<td>Reserved</td>
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<tr>
<td>14</td>
<td>Abort</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Try Each</td>
<td>Section 8.4.10.2</td>
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</tr>
<tr>
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11.2. SUIT Parameters

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<td>3</td>
<td>Image Digest</td>
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<td>Device Identifier</td>
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<td>30</td>
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<td>Swap</td>
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</tr>
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<td>32</td>
<td>Run Sequence</td>
<td>Section 8.4.10.7</td>
</tr>
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<td>33</td>
<td>Reserved</td>
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</tr>
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<td>nint</td>
<td>Custom Condition</td>
<td>Section 8.4.9.5</td>
</tr>
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### Table 9

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<td>Update Description</td>
<td>Section 8.4.4</td>
</tr>
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</table>

11.3. SUIT Text Values
11.4. SUIT Component Text Values

<table>
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<th>Reference</th>
</tr>
</thead>
<tbody>
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<td>Vendor Name</td>
<td>Section 8.4.4</td>
</tr>
<tr>
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<td>Model Name</td>
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<td>3</td>
<td>Vendor Domain</td>
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<td>Component Description</td>
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<td>Component Version</td>
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<td>Component Version Required</td>
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<tr>
<td>nint</td>
<td>Custom</td>
<td>Section 8.4.4</td>
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</tbody>
</table>

Table 10

12. Security Considerations

This document is about a manifest format protecting and describing how to retrieve, install, and invoke firmware images and as such it is part of a larger solution for delivering firmware updates to IoT devices. A detailed security treatment can be found in the architecture [RFC9019] and in the information model [RFC9124] documents.

13. Acknowledgements

We would like to thank the following persons for their support in designing this mechanism:

* Milosch Meriac
14. References

14.1. Normative References

[I-D.moran-suit-mti]


<https://www.rfc-editor.org/info/rfc8152>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, 


14.2. Informative References

[I-D.ietf-cbor-tags-oid] Bormann, C., "Concise Binary Object Representation (CBOR) Tags for Object Identifiers", Work in Progress, Internet-Draft, draft-ietf-cbor-tags-oid-08, 21 May 2021, 

[I-D.ietf-suit-firmware-encryption]

[I-D.ietf-suit-report]

[I-D.ietf-suit-trust-domains]

[I-D.ietf-suit-update-management]

[I-D.ietf-teep-architecture]


Appendix A.  Full CDDL

In order to create a valid SUIT Manifest document the structure of the corresponding CBOR message MUST adhere to the following CDDL data definition.

To be valid, the following CDDL MUST have the COSE CDDL appended to it. The COSE CDDL can be obtained by following the directions in [RFC8152], Section 1.3.

SUIT_Envelope_Tagged = #6.107(SUIT_Envelope)
SUIT_Envelope = {
    suit-authentication-wrapper => bstr .cbor SUIT_Authentication,
    suit-manifest => bstr .cbor SUIT_Manifest,
    SUIT_Severable_Manifest_Members,
    * SUIT_Integrated_Payload,
    * $$SUIT_Envelope_Extensions,
}

SUIT_Authentication = [
    bstr .cbor SUIT_Digest,
    * bstr .cbor SUIT_Authentication_Block
]

SUIT_Digest = [
    suit-digest-algorithm-id : suit-cose-hash-algs,
    suit-digest-bytes : bstr,
    * $$SUIT_Digest-extensions
]

SUIT_Authentication_Block /= COSE_Mac_Tagged
SUIT_Authentication_Block /= COSE_Sign_Tagged
SUIT_Authentication_Block /= COSE_Mac0_Tagged
SUIT_Authentication_Block /= COSE_Sign1_Tagged

SUIT_Severable_Manifest_Members = (
    ? suit-payload-fetch => bstr .cbor SUIT_Command_Sequence,
    ? suit-install => bstr .cbor SUIT_Command_Sequence,
    ? suit-text => bstr .cbor SUIT_Text_Map,
    * $$SUIT_severable-members-extensions,
)

SUIT_Integrated_Payload = (suit-integrated-payload-key => bstr)
suit-integrated-payload-key = tstr

SUIT_Manifest_Tagged = #6.1070(SUIT_Manifest)
SUIT_Manifest = {

suit-manifest-version => 1,
suit-manifest-sequence-number => uint,
suit-common => bstr .cbor SUIT_Common,
? suit-reference-uri => tstr,
SUIT_Unseverable_Members,
SUIT_Severable_Members_Choice,
* $$SUIT_Manifest_Extensions,
}

SUIT_Unseverable_Members = {

? suit-validate => bstr .cbor SUIT_Command_Sequence,
? suit-load => bstr .cbor SUIT_Command_Sequence,
? suit-run => bstr .cbor SUIT_Command_Sequence,
* $$unseverable-manifest-member-extensions,
}

SUIT_Severable_Members_Choice = {

? suit-payload-fetch => SUIT_Digest / bstr .cbor SUIT_Command_Sequence,
? suit-install => SUIT_Digest / bstr .cbor SUIT_Command_Sequence,
? suit-text => SUIT_Digest / bstr .cbor SUIT_Text_Map,
* $$severable-manifest-members-choice-extensions
}

SUIT_Common = {

? suit-components => SUIT_Components,
? suit-common-sequence => bstr .cbor SUIT_Common_Sequence,
* $$SUIT_Common-extensions,
}

SUIT_Components = [ + SUIT_Component_Identifier ]

SUIT_Dependency = {

suit-dependency-digest => SUIT_Digest,
? suit-dependency-prefix => SUIT_Component_Identifier,
* $$SUIT_Dependency-extensions,
}

;REQUIRED to implement:
suit-cose-hash-algs /= cose-alg-sha-256

;OPTIONAL to implement:
suit-cose-hash-algs /= cose-alg-shake128
suit-cose-hash-algs /= cose-alg-sha-384
suit-cose-hash-algs /= cose-alg-sha-512
suit-cose-hash-algs /= cose-alg-shake256

SUIT_Component_Identifier = [* bstr]
SUIT_Common_Sequence = [
    + ( SUIT_Condition // SUIT_Common_Commands )
]

SUIT_Common_Commands //== (suit-directive-set-component-index, IndexArg)
SUIT_Common_Commands //= (suit-directive-run-sequence,
    bstr .cbor SUIT_Common_Sequence)
SUIT_Common_Commands //= (suit-directive-try-each,
    SUIT_Directive_Try_Each_Argument_Common)
SUIT_Common_Commands //= (suit-directive-override-parameters,
    (+ SUIT_Parameters))

IndexArg /= uint
IndexArg /= bool
IndexArg /= [+uint]

SUIT_Directive_Try_Each_Argument_Common = [
    2* bstr .cbor SUIT_Common_Sequence,
    ?nil
]

SUIT_Command_Sequence = [ + ();
    SUIT_Condition // SUIT_Directive // SUIT_Command_Custom
"
]

SUIT_Command_Custom = (suit-command-custom, bstr/tstr/int/nil)
SUIT_Condition //= (suit-condition-vendor-identifier, SUIT_Rep_Policy)
SUIT_Condition //= (suit-condition-class-identifier, SUIT_Rep_Policy)
SUIT_Condition //= (suit-condition-device-identifier, SUIT_Rep_Policy)
SUIT_Condition //= (suit-condition-image-match, SUIT_Rep_Policy)
SUIT_Condition //= (suit-condition-component-slot, SUIT_Rep_Policy)
SUIT_Condition //= (suit-condition-abort, SUIT_Rep_Policy)

SUIT_Directive //= (suit-directive-set-component-index, IndexArg)
SUIT_Directive //= (suit-directive-run-sequence,
    bstr .cbor SUIT_Command_Sequence)
SUIT_Directive //= (suit-directive-try-each,
    SUIT_Directive_Try_Each_Argument)
SUIT_Directive //= (suit-directive-override-parameters,
    (+ SUIT_Parameters))
SUIT_Directive //= (suit-directive-fetch, SUIT_Rep_Policy)
SUIT_Directive //= (suit-directive-copy, SUIT_Rep_Policy)
SUIT_Directive //= (suit-directive-swap, SUIT_Rep_Policy)
SUIT_Directive //= (suit-directive-run, SUIT_Rep_Policy)

SUIT_Directive_Try_Each_Argument = [
    2* bstr .cbor SUIT_Command_Sequence,
nil

SUIT_Rep_Policy = uint .bits suit-reporting-bits

suit-reporting-bits = &(
    suit-send-record-success : 0,
    suit-send-record-failure : 1,
    suit-send-sysinfo-success : 2,
    suit-send-sysinfo-failure : 3
)

SUIT_Parameters //= (suit-parameter-vendor-identifier =>
    (RFC4122_UUID / cbor-pen))
    cbor-pen = #6.112(bstr)

SUIT_Parameters //= (suit-parameter-class-identifier => RFC4122_UUID)
SUIT_Parameters //= (suit-parameter-image-digest => bstr .cbor SUIT_Digest)
SUIT_Parameters //= (suit-parameter-image-size => uint)
SUIT_Parameters //= (suit-parameter-component-slot => uint)

SUIT_Parameters //= (suit-parameter-uri => tstr)
SUIT_Parameters //= (suit-parameter-source-component => uint)
SUIT_Parameters //= (suit-parameter-run-args => bstr)

SUIT_Parameters //= (suit-parameter-device-identifier => RFC4122_UUID)

SUIT_Parameters //= (suit-parameter-custom => int/bool/tstr/bstr)

SUIT_Parameters //= (suit-parameter-strict-order => bool)
SUIT_Parameters //= (suit-parameter-soft-failure => bool)

RFC4122_UUID = bstr .size 16

SUIT_Text_Map = {
    SUIT_Text_Keys,
    * SUIT_Component_Identifier => {
        SUIT_Text_Component_Keys
    }
}

SUIT_Text_Component_Keys = {
    ? suit-text-vendor-name => tstr,
    ? suit-text-model-name => tstr,
    ? suit-text-vendor-domain => tstr,
    ? suit-text-model-info => tstr,
    ? suit-text-component-description => tstr,
}
? suit-text-component-version => tstr,
* $$suit-text-component-key-extensions
}

SUIT_Text_Keys = {
  ? suit-text-manifest-description => tstr,
  ? suit-text-update-description => tstr,
  ? suit-text-manifest-json-source => tstr,
  ? suit-text-manifest-yaml-source => tstr,
  * $$suit-text-key-extensions
}

suit-authentication-wrapper = 2
suit-manifest = 3

;REQUIRED to implement:
cose-alg-sha-256 = -16

;OPTIONAL to implement:
cose-alg-shake128 = -18
cose-alg-sha-384 = -43
cose-alg-sha-512 = -44
cose-alg-shake256 = -45

;Unseverable, recipient-necessary
suit-manifest-version = 1
suit-manifest-sequence-number = 2
suit-common = 3
suit-reference-uri = 4
suit-validate = 7
suit-load = 8
suit-run = 9
;Severable, recipient-necessary
suit-payload-fetch = 16
suit-install = 17
;Severable, recipient-unnecessary
suit-text = 23

suit-components = 2
suit-common-sequence = 4

suit-command-custom = nint

suit-condition-vendor-identifier = 1
suit-condition-class-identifier = 2
suit-condition-image-match = 3
suit-condition-component-slot = 5
Appendix B. Examples

The following examples demonstrate a small subset of the functionality of the manifest. Even a simple manifest processor can execute most of these manifests.
The examples are signed using the following ECDSA secp256r1 key:

```
-----BEGIN PRIVATE KEY-----
MIGHAgEAMBMGByqGSM49AgEGCCqGSM49AwIBAQgApZyj2CUGLM50VBC
CjYsX+09jGmnyJPrpDLTz/hiXOhRANCAASEeloEarguqq9JhVxie7NomvqqL8Rtv
P+bitWWhdvArTsflKtsCYExwKNtrNHXi9OB3N+wnAUtszmR23M4tK1W
-----END PRIVATE KEY-----
```

The corresponding public key can be used to verify these examples:

```
-----BEGIN PUBLIC KEY-----
MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEhJaBGq4LqqvSYVcYnuzaJr6qi/Er
bz/m4rV1nIXbwK07HypLbAmBMcCjbazR14vTgdzfsJwFLbM5kdtzOLSo1g==
-----END PUBLIC KEY-----
```

Each example uses SHA256 as the digest function.

Note that reporting policies are declared for each non-flow-control command in these examples. The reporting policies used in the examples are described in the following tables.

```
+-----------------------------+----------+
| Policy                      | Label    |
+-----------------------------+----------+
| suit-send-record-on-success | Rec-Pass |
+-----------------------------+----------+
| suit-send-record-on-failure | Rec-Fail |
+-----------------------------+----------+
| suit-send-sysinfo-success   | Sys-Pass |
+-----------------------------+----------+
| suit-send-sysinfo-failure   | Sys-Fail |
```

Table 12
<table>
<thead>
<tr>
<th>Command</th>
<th>Sys-Fail</th>
<th>Sys-Pass</th>
<th>Rec-Fail</th>
<th>Rec-Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>suit-condition-vendor-identifier</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>suit-condition-class-identifier</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>suit-condition-image-match</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>suit-condition-component-slot</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>suit-directive-fetch</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>suit-directive-copy</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>suit-directive-run</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 13

B.1. Example 0: Secure Boot

This example covers the following templates:

* Compatibility Check (Section 7.1)
* Secure Boot (Section 7.2)

It also serves as the minimum example.

```
107({
    / authentication-wrapper / 2:<<[
      digest: <<[
        / algorithm-id / -16 / "sha256" /,
        / digest-bytes / h'6658ea560262696dd1f13b782239a064da7c6c5cbaf52fbed428a6fc83c7e5af' ]>>,
      signature: <<18({
        / protected / <<{
          / alg / 1:-7 / "ES256" /,
        }>>,
```
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/ unprotected / {
},
/ payload / F6 / nil /,
/ signature / h'01d9cbf51b1ccadf839ec867da85735118
ba4c1b513f5df60583e8dd7f8ce4274cd2e2a0f70f8832bfeea63983172e77a951e9a36
e74cada19321b903a097e4e7'
});>>
}

/ manifest / 3:<<{
    / manifest-version / 1:1,
    / manifest-sequence-number / 2:0,
    / common / 3:<<{
        / components / 2:
            [h'00'
        ],
        / common-sequence / 4:<<{
            / directive-override-parameters / 20,{
                / vendor-id /
                1:h'fa6b4a53d5ad5fdfe9de663e4d41ffe' / fa6b4a53-d5ad-5fdf-be9d-e663e4d41ffe /,
                / class-id /
                2:h'1492af1425695e48bf429b2d5f2ab45' /
                1492af14-2569-5e48-bf42-9b2d5f2ab45 /
            },
            / image-digest / 3:<<{
                / algorithm-id / -16 / "sha256" /,
                / digest-bytes /
                h'00112233445566778899abbcdddeeff0123456789abcdeffedcba9876543210'
            }>>
        },
        / image-size / 14:34768,
    },
    / condition-vendor-identifier / 1,15
    / condition-class-identifier / 2,15
});>>

/ validate / 7:<<{
    / condition-image-match / 3,15
}>>

/ run / 9:<<{
    / directive-run / 23,2
}>>

}else

Total size of Envelope without COSE authentication object: 161

Envelope:

Total size of Envelope with COSE authentication object: 237

Envelope with COSE authentication object:

d86ba2025873825824822f582066658ea560262696dd1f3b782239a064da
7c6c5cbaf52fde428a6fc83c7e5af035871a50101020003585fa2028181
41000458568614a40150fa6b4a53d5ad5fdbe9de6e45ed41ffe02501492
af1425695e48bf429b2d5f2ab45035824822f58200011233445567788
99aabbccddeeff0123456789abceffedcb89765432100e1987d0010f02
0f074382030f0943821702

B.2. Example 1: Simultaneous Download and Installation of Payload

This example covers the following templates:

* Compatibility Check (Section 7.1)

* Firmware Download (Section 7.3)

Simultaneous download and installation of payload. No secure boot is present in this example to demonstrate a download-only manifest.

107({
  / authentication-wrapper / 2:<<[
    digest: <<[
      / algorithm-id / -16 / "sha256" /,
      / digest-bytes /
      h’176653ec0387a8d32b1eb0b91ea5e8a2256bc2e7c02e5bb7f45f431fa926f3e’
    ]>>,
    signature: <<18({
      / protected / <<{
        / alg / 1:-7 / "ES256" /,
      }>>,
      / unprotected / {
        / payload / F6 / nil /,
        / signature / h’aa78dbd584dbdea66ab024179dac2f4b244
        940e9def1337bb833e3edf2562a0fceb77e64980e0dccc24b8abb63b78aad9ad42fd2
        44b684dd39859f84740239e8’
    ]})
  ]
})
Total size of Envelope without COSE authentication object: 196

Envelope: 
B.3. Example 2: Simultaneous Download, Installation, Secure Boot, Severed Fields

This example covers the following templates:

* Compatibility Check (Section 7.1)
* Secure Boot (Section 7.2)
* Firmware Download (Section 7.3)

This example also demonstrates severable elements (Section 5.4), and text (Section 8.4.4).

```json
107({
   / authentication-wrapper / 2:<<[
      digest: <<[
         / algorithm-id / -16 / "sha256" /,
         / digest-bytes /
      h’a85153c05f709e681787ee23c0de3e2f92b6cf61ad6f41b39157ac7cb6a5a62’ ]>>,
      signature: <<18(
         / protected / <<{
            / alg / 1:-7 / "ES256" /,
         }>
      ]>)
})
```
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/ unprotected / {
},
/ payload / F6 / nil /,
/ signature / h'4ba6e9c4bddd65212e2e4775b7f5b32faf
14209f88d9f8b198e21c338770aa542d9de07e31fa17ca9dadee4d94c43dfba81819d35
88d7fde5eff010b8c7c89277'
}>>
]
}>>, / manifest / 3:<<{
/ manifest-version / 1:1,
/ manifest-sequence-number / 2:2,
/ common / 3:<<{
/ components / 2:[
  [h'00'
],
/ common-sequence / 4:<<{
/ directive-override-parameters / 20,{
/ vendor-id / 1:h'fa6b4a53d5ad5f9be9de663e4d41ffe' / fa6b4a53-d5ad-5f9be9de663e4d41ffe /,
/ class-id / 2:h'1492af1425695e48bf429b2d5f2ab45' / 1492af14-2569-5e48-bf42-9b2d5f2ab45 /,
/ image-digest / 3:<<{
/ algorithm-id / -16 / "sha256" /,
/ digest-bytes / h'00112233445566778899aabbccddeeff0123456789abcdeffedc9a876543210'
}>>, / image-size / 14:34768,
}>,
/ condition-vendor-identifier / 1,15,
/ condition-class-identifier / 2,15
}>>,
}>>, / validate / 7:<<{
/ condition-image-match / 3,15
}>>, / run / 9:<<{
/ directive-run / 23,2
}>>, / install / 17:{
/ algorithm-id / -16 / "sha256" /,
/ digest-bytes / h'3ee96dc79641970ae46b929ccf0b72ba9536dd846020dbdc9f949d84ea0e18d2'
},
/ text / 23:{
/ algorithm-id / -16 / "sha256" /,

/ digest-bytes /
h'2bfc4d0cc6680be7dd9f5ca30aa2bb5d1998145de33d54101b80e2ca49faf918' 
}
)}

/ install / 17:<<[
/ direct-set-parameters / 19,
/ uri /
21:'http://example.com/very/long/path/to/file/file.bin',
]/
/ directive-fetch / 21,2 ,
/ condition-image-match / 3,15
]>>
/
text / 13:<<( 
["h'00'":{
/ vendor-domain / 3:'arm.com',
/ component-description / 5:'This component is a demonstration. The digest is a sample pattern, not a real one.',
}]
)>
}

Total size of the Envelope without COSE authentication object or Severable Elements: 235

Envelope:
d86ba2025827815824822f5820a85153c05f709e681877ee23c0de3e2f92
bcc66c1ad6f41b39157ac7cb6a5a620358bba70101020203585fa2028181
41000458568614a40150fa6b4a53d5ad5fdbe9de663e4d41ffe02501492
af1425695e48bf429b2d5lfzab45035824822f5820001122334455667788
99abccdddeeff0123456789abcdefedcb98765432100e1987d0010f02
0f074382030f94382170211822f58203ee96dc79641970ae46b929ccf0b
72ba9536dd846020dbdc9f949d84ea0e18d217822f58202bfc4d0cc6680b
e7dd9f5ca30aa2bb5d1998145de33d54101b80e2ca49faf918

Total size of the Envelope with COSE authentication object but without Severable Elements: 311

Envelope:
Total size of Envelope with COSE authentication object and Severable Elements: 894
B.4. Example 3: A/B images

This example covers the following templates:

* Compatibility Check (Section 7.1)
* Secure Boot (Section 7.2)
* Firmware Download (Section 7.3)
* A/B Image Template (Section 7.7)

```
107({
  / authentication-wrapper / 2:<<[
    digest: <<[
      / algorithm-id / -16 / "sha256" /,
      / digest-bytes /
      h'c98d9240343e12ba833c04fb9006e70f62e4c36ed0b2a356d59c2f86c'
    ]>>,
    signature: <<18({
      / protected / <<{
        / alg / 1:-7 / "ES256" /,
      }>>,
      / unprotected / {
      },
      / payload / F6 / nil /,
      / signature / h'451b3099c791ef4c54b6336c471b8d0f
      940d09f044b333c04fb9006e70f62e4c36ed0b2a356d59c2f86c'
    }>>()
  ]>>) ,
  / manifest / 3:<<{
    / manifest-version / 1:1,
    / manifest-sequence-number / 2:3,
    / common / 3:<<{
      / components / 2:[
        [h'00'
      ],
      / common-sequence / 4:<<{
        / directive-override-parameters / 20,{
          / vendor-id / 1:h'fa6b4a53d5ad5f6be9de663e4d41ffe' / fa6b4a53-d5ad-5f6be9de663e4d41ffe /,
          / class-id / 2:h'1492af1425695e48bf429b2d51f2ab45' /
          1492af14-2569-5e48-bf42-9b2d51f2ab45 /,
        },
      ]
    }
  }
})
```
/ directive-try-each / 15,[
  <<[
    / directive-override-parameters / 20,{
      / slot / 5:0,
    },
    / condition-component-slot / 5,5 ,
    / directive-override-parameters / 20,{
      / image-digest / 3:<<[
        / algorithm-id / -16 / "sha256" /,
        / digest-bytes / h'00112233445566778899aabbccddeeff0123456789abcdeffedcba9876543210'
      ]>>,
      / image-size / 14:34768,
    }
  ]>>,}
  <<[
    / directive-override-parameters / 20,{
      / slot / 5:1,
    },
    / condition-component-slot / 5,5 ,
    / directive-override-parameters / 20,{
      / image-digest / 3:<<[
        / algorithm-id / -16 / "sha256" /,
        / digest-bytes / h'0123456789abcdeffedcba98765432100011223345566778899aabbccddeeff'
      ]>>,
      / image-size / 14:76834,
    }
  ]>>,}
  / condition-vendor-identifier / 1,15 ,
  / condition-class-identifier / 2,15
]>>],
/ validate / 7:<<[
  / condition-image-match / 3,15
]>>],
/ install / 17:<<[
  / directive-try-each / 15,[
    <<[
      / directive-set-parameters / 19,{
        / slot / 5:0,
      },
      / condition-component-slot / 5,5 ,
      / directive-set-parameters / 19,{
        / uri / 21:'http://example.com/file1.bin',
      }
    ]>>,
  ]>>]
<<[
    / directive-set-parameters / 19,
    / slot / 5:1,
    ]>>

Total size of Envelope without COSE authentication object: 320

Envelope:

d86ba2025827815824822f5820c98d9240343ee1ac12ba833c04fb9006e7
0f62c7e4c36ed0b2a356d59c2f86c0359010fa501010230358a4a20281
81410004589b8814a20150fa6b4a53d5ad5fdfe9de663e4d4f4e025014
92af1425695e48bf4298bd51f2ab450f8258348614a10500050514a20358
24822f5820011223344556778899aabbccdeeef0123456789abcdeffe
dcba98765432100e1987d058368614a10501050154a2035824822f582001
23456789abcdefefedcba9876543210011223344556778899aabbccdee
ff0e1a00012c22010f020f0743823030f11585b860f8258288613a1050005
0513a15781c687474703a2f2f6578616d706c652e6366f62f66696ce6531
2e62696e58288613a10501050153a115781c687474703a2f2f6578616d70
6c652e6366f62f66696ce532e62696e1502030f

Total size of Envelope with COSE authentication object: 396

Envelope with COSE authentication object:
B.5. Example 4: Load from External Storage

This example covers the following templates:

* Compatibility Check (Section 7.1)
* Secure Boot (Section 7.2)
* Firmware Download (Section 7.3)
* Install (Section 7.4)
* Load (Section 7.6)

107({
   / authentication-wrapper / 2:<<[
      digest: <<[
         / algorithm-id / -16 / "sha256" /,
         / digest-bytes / h'601ebc1bb2e12cbaf408b1bca72fae0d9987498acfa16130ce4cf55c9ea74c7c'
      ]>>,
      signature: <<18({
         / protected / <<[
            / alg / 1:-7 / "ES256" /,
         ]>>,
         / unprotected / { },
         / payload / F6 / nil /,
         / signature / h'2e263599b0f3613fd3feb0ce1ff55c6b37c521339ef2680dc63de3a5cdfb0e3f44237313e1c17c35f7fa84af82234f50cea551c fdd8179a40dac5136167cd5e'
      ]>)
   ]
})

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>>>,
/ manifest / 3:<<{
    / manifest-version / 1:1,
    / manifest-sequence-number / 2:4,
    / common / 3:<<{
        / components / 2:[
            [h’00’],
            [h’02’],
            [h’01’]
        ],
        / common-sequence / 4:<<{
            / directive-set-component-index / 12,0 ,
            / directive-override-parameters / 20,{
                / vendor-id /
                1:h’fa6b4a53d5ad5fdfbe9de663e4d41ffe’ / fa6b4a53-d5ad-5fdf-
                be9d-e663e4d41ffe ,
                / class-id /
                2:h’1492af1425695e48bf429b2d51f2ab45’ /
                1492af14-2569-5e48-bf42-9b2d51f2ab45 ,
                / image-digest / 3:<<{
                    / algorithm-id / -16 / "sha256" ,
                    / digest-bytes /
                    h’00112233445566778899aabbccddeeff0123456789abcdeffedcba9876543210’
                },
                / image-size / 14:34768,
            },
            / condition-vendor-identifier / 1,15 ,
            / condition-class-identifier / 2,15
        }},
    }},
/ validate / 7:<<{
    / directive-set-component-index / 12,0 ,
    / directive-image-match / 3,15
}>,
/ load / 8:<<{
    / directive-set-component-index / 12,2 ,
    / directive-set-parameters / 19,{
        / image-digest / 3:<<{
            / algorithm-id / -16 / "sha256" ,
            / digest-bytes /
            h’0123456789abcdefeffedcba987654321000112233456778899aabbccddeeff’
        }},
        / image-size / 14:76834,
        / source-component / 22:0 / [h’00’] ,
        / compression-info / 19:<<{
            / compression-algorithm / 1:1 / "zlib" ,
        }>,
    },
},
Total size of Envelope without COSE authentication object: 332

Envelope:

d86ba20258278158524822f5820601ebc1bb2e12cbaf408b1bca72fae0d99
87498acfa16130cc4cf5c9ea74c7c0359011ba801010204035867a20283
81410081410281410104585880c0014a40150fa6b4a53d5ad5f8be9de6
636441ffe02501499e48bf429b2d5f2a850358248221582021001123456789abcdeffedcba9876543210
15781b6874703a2f2f6578616d70
6c652e636f6d702f66696c652e62696e1502030f114b880c0013a116011602
030f
Total size of Envelope with COSE authentication object: 408

Envelope with COSE authentication object:

d86ba2025873825824822f05820601ebc1bb2e12cbaf408b1bca72fae0d99
87499acfa16130ce4cf5c9ea74c7c584ad28443a10126a0f658402e2635
99b0f3613fd3fe00cecf1ff55c6b37c521339ef2680dc63de35cdff0e3f4
4237313e1c17c35f7fa84af82234f50cea551cfdd8179a40dac5136167cd
5e0359011ba801010204035887a20283814100814102814101045858880c
0014a40150fa6b4a53d5ad5f6bfe9de663e4d41ffe02501492af1425695e
48bf429b2d5f2ab45035824822f582001122334556778899aabcccddeeff0123456789abceffedcb98
7654321001122334556778899aabcccddeeff0123456789abceffedcb98
10116001602030f0945840c021702010584e880c0213a0235824822f582000
1122334556778899aabcccddeeff0123456789abceffedcb989765432
00116001602030f0945840c021702010584e880c0213a0235824822f582000

B.6. Example 5: Two Images

This example covers the following templates:

* Compatibility Check (Section 7.1)
* Secure Boot (Section 7.2)
* Firmware Download (Section 7.3)

Furthermore, it shows using these templates with two images.

107({
    / authentication-wrapper / 2:<<[
        digest: <<[
            / algorithm-id / -16 / "sha256" /,
            / digest-bytes / h’a4c6d5f5c3800c19c4af55aacc1c2dc6e37e2bf10b2aab335f70226961e310d3’
        ]>>,
        signature: <<18([
            / protected / <<{
                / alg / 1:-7 / "ES256" /,
            }>>,
            / unprotected / {
                / payload / F6 / nil /,
                / signature / h’91d95d3bb2eaa8b31ff11f4761056e491bcb07470119f9c69388982c3238eabfcb477ec7887f36c31e7d957fe8830b3ae8b9d7d71372de2e71a9a3b67444c4a’
        ])
    ])
})


```json

cbored-manifest-

manifest:
  manifest-version: 1.1,
  manifest-sequence-number: 2.5,
  common:
    components: 2:
      [h'00'],
      [h'01'],
    common-sequence: 4:
      directive-set-component-index: 12,0,
      directive-override-parameters: 20,
      vendor-id: 1:h'fa6b4a53d5ad5fdfbe9de663e4d41ffe',
      class-id: 2:h'1492af14-2569-5e48-bf42-9b2d5f2ab45',
      image-digest: 3:
        algorithm-id: -16 / "sha256" /,
        digest-bytes:
        h'00112233445566778899aabbccddeeff0123456789abcede
      image-size: 14:34768,
    condition-vendor-identifier: 1,15,
    condition-class-identifier: 2,15,
    directive-set-component-index: 12,1,
    directive-override-parameters: 20,
    image-digest: 3:
      algorithm-id: -16 / "sha256" /,
      digest-bytes:
      h'0123456789abcdefdcb
      image-size: 14:76834,
  validate:
    directive-set-component-index: 12,0,
    condition-image-match: 3,15,
    directive-set-component-index: 12,1,
    condition-image-match: 3,15
  run:
    directive-set-component-index: 12,0,
```
/ directive-run / 23,2
}>>,
/ install / 17:<<[
   / directive-set-component-index / 12,0 ,
   / directive-set-parameters / 19,
      / uri / 21:'http://example.com/file1.bin',
   },
   / directive-fetch / 21,2 ,
   / condition-image-match / 3,15 ,
   / directive-set-component-index / 12,1 ,
   / directive-set-parameters / 19,
      / uri / 21:'http://example.com/file2.bin',
   },
   / directive-fetch / 21,2 ,
   / condition-image-match / 3,15
]>>,
})
}

Total size of Envelope without COSE authentication object: 306

Envelope:

d86ba2025827815824822f5820a4c6d5f5c3800c19c4af55aacc1c2dc6e3
7e2bf10b2aab335f70226961e310d303590101a601010205035895a20282
8141008141010458898c01014a40150fa6b4a53d5ad5fdffbe9de663e4d4
1ffe02501492af1425695e48bf429b2d51f2ab45035824822f5820001122
3344556678899abbcdddeeff0123456789abdedefedcba98765432100e
1987d0010f020f0c0114a2035824822f58200123456789abdedefedcba98
765432100011223445566778899aabbccddeeff0e1a00012c220749880c
00030f0c01030f0945840c00170211584f900c0013a115781c687474703a
2f2f6578616d706c652e636f6d2f6669666531e62696e1502030f0c0113
a115781c687474703a2f2f6578616d706c652e636f6d2f66696665322e62
696e1502030f

Total size of Envelope with COSE authentication object: 382

Envelope with COSE authentication object:
In order to provide flexible behavior to constrained devices, while still allowing more powerful devices to use their full capabilities, the SUIT manifest encodes the required behavior of a Recipient device. Behavior is encoded as a specialized byte code, contained in a CBOR list. This promotes a flat encoding, which simplifies the parser. The information encoded by this byte code closely matches the operations that a device will perform, which promotes ease of processing. The core operations used by most update and trusted invocation operations are represented in the byte code. The byte code can be extended by registering new operations.

The specialized byte code approach gives benefits equivalent to those provided by a scripting language or conventional byte code, with two substantial differences. First, the language is extremely high level, consisting of only the operations that a device may perform during update and trusted invocation of a firmware image. Second, the language specifies linear behavior, without reverse branches. Conditional processing is supported, and parallel and out-of-order processing may be performed by sufficiently capable devices.

By structuring the data in this way, the manifest processor becomes a very simple engine that uses a pull parser to interpret the manifest. This pull parser invokes a series of command handlers that evaluate a Condition or execute a Directive. Most data is structured in a highly regular pattern, which simplifies the parser.

The results of this allow a Recipient to implement a very simple parser for constrained applications. If needed, such a parser also allows the Recipient to perform complex updates with reduced overhead. Conditional execution of commands allows a simple device to perform important decisions at validation-time.
Dependency handling is vastly simplified as well. Dependencies function like subroutines of the language. When a manifest has a dependency, it can invoke that dependency’s commands and modify their behavior by setting parameters. Because some parameters come with security implications, the dependencies also have a mechanism to reject modifications to parameters on a fine-grained level.

Developing a robust permissions system works in this model too. The Recipient can use a simple ACL that is a table of Identities and Component Identifier permissions to ensure that operations on components fail unless they are permitted by the ACL. This table can be further refined with individual parameters and commands.

Capability reporting is similarly simplified. A Recipient can report the Commands, Parameters, Algorithms, and Component Identifiers that it supports. This is sufficiently precise for a manifest author to create a manifest that the Recipient can accept.

The simplicity of design in the Recipient due to all of these benefits allows even a highly constrained platform to use advanced update capabilities.

C.1 Design Rationale: Envelope

The Envelope is used instead of a COSE structure for several reasons:

1. This enables the use of Severable Elements (Section 8.5)
2. This enables modular processing of manifests, particularly with large signatures.
3. This enables multiple authentication schemes.
4. This allows integrity verification by a dependent to be unaffected by adding or removing authentication structures.

Modular processing is important because it allows a Manifest Processor to iterate forward over an Envelope, processing Delegation Chains and Authentication Blocks, retaining only intermediate values, without any need to seek forward and backwards in a stream until it gets to the Manifest itself. This allows the use of large, Post-Quantum signatures without requiring retention of the signature itself, or seeking forward and back.

Four authentication objects are supported by the Envelope:

* COSE_Sign_Tagged
The SUIT Envelope allows an Update Authority or intermediary to mix and match any number of different authentication blocks it wants without any concern for modifying the integrity of another authentication block. This also allows the addition or removal of an authentication blocks without changing the integrity check of the Manifest, which is important for dependency handling. See Section 6.2.

C.2  C.2 Byte String Wrappers

Byte string wrappers are used in several places in the suit manifest. The primary reason for wrappers it to limit the parser extent when invoked at different times, with a possible loss of context.

The elements of the suit envelope are wrapped both to set the extents used by the parser and to simplify integrity checks by clearly defining the length of each element.

The common block is re-parsed in order to find components identifiers from their indices, to find dependency prefixes and digests from their identifiers, and to find the common sequence. The common sequence is wrapped so that it matches other sequences, simplifying the code path.

A severed SUIT command sequence will appear in the envelope, so it must be wrapped as with all envelope elements. For consistency, command sequences are also wrapped in the manifest. This also allows the parser to discern the difference between a command sequence and a SUIT_Digest.

Parameters that are structured types (arrays and maps) are also wrapped in a bstr. This is so that parser extents can be set correctly using only a reference to the beginning of the parameter. This enables a parser to store a simple list of references to parameters that can be retrieved when needed.

Appendix D.  D.  Implementation Conformance Matrix

This section summarizes the functionality a minimal manifest processor implementation needs to offer to claim conformance to this specification, in the absence of an application profile standard specifying otherwise.
The subsequent table shows the conditions.

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor Identifier</td>
<td>Section 8.4.8.2</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Class Identifier</td>
<td>Section 8.4.8.2</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Device Identifier</td>
<td>Section 8.4.8.2</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Image Match</td>
<td>Section 8.4.9.2</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Component Slot</td>
<td>Section 8.4.9.3</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Abort</td>
<td>Section 8.4.9.4</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Custom Condition</td>
<td>Section 8.4.9.5</td>
<td>OPTIONAL</td>
</tr>
</tbody>
</table>

Table 14

The subsequent table shows the directives.

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set Component Index</td>
<td>Section 8.4.10.1</td>
<td>REQUIRED if more than one component</td>
</tr>
<tr>
<td>Try Each</td>
<td>Section 8.4.10.2</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Override Parameters</td>
<td>Section 8.4.10.3</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Fetch</td>
<td>Section 8.4.10.4</td>
<td>REQUIRED for Updater</td>
</tr>
<tr>
<td>Copy</td>
<td>Section 8.4.10.5</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Run</td>
<td>Section 8.4.10.6</td>
<td>REQUIRED for Bootloader</td>
</tr>
<tr>
<td>Run Sequence</td>
<td>Section 8.4.10.7</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Swap</td>
<td>Section 8.4.10.8</td>
<td>OPTIONAL</td>
</tr>
</tbody>
</table>

Table 15
The subsequent table shows the parameters.

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor ID</td>
<td>Section 8.4.8.3</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Class ID</td>
<td>Section 8.4.8.4</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Image Digest</td>
<td>Section 8.4.8.6</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Image Size</td>
<td>Section 8.4.8.7</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Component Slot</td>
<td>Section 8.4.8.8</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>URI</td>
<td>Section 8.4.8.9</td>
<td>REQUIRED for Updater</td>
</tr>
<tr>
<td>Source Component</td>
<td>Section 8.4.8.10</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Run Args</td>
<td>Section 8.4.8.11</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Device ID</td>
<td>Section 8.4.8.5</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Strict Order</td>
<td>Section 8.4.8.13</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Soft Failure</td>
<td>Section 8.4.8.14</td>
<td>OPTIONAL</td>
</tr>
<tr>
<td>Custom</td>
<td>Section 8.4.8.15</td>
<td>OPTIONAL</td>
</tr>
</tbody>
</table>

Table 16

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Secure Reporting of Update Status
draft-ietf-suit-report-02

Abstract

The Software Update for the Internet of Things (SUIT) manifest provides a way for many different update and boot workflows to be described by a common format. However, this does not provide a feedback mechanism for developers in the event that an update or boot fails.

This specification describes a lightweight feedback mechanism that allows a developer in possession of a manifest to reconstruct the decisions made and actions performed by a manifest processor.

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1. Introduction

A SUIT manifest processor can fail to install or boot an update for many reasons. Frequently, the error codes generated by such systems fail to provide developers with enough information to find root causes and produce corrective actions, resulting in extra effort to reproduce failures. Logging the results of each SUIT command can simplify this process.

While it is possible to report the results of SUIT commands through existing logging or attestation mechanisms, this comes with several drawbacks:

* data inflation, particularly when designed for text-based logging
* missing information elements
* missing support for multiple components

The CBOR objects defined in this document allow devices to:

* report a trace of how an update was performed
* report expected vs. actual values for critical checks
* describe the installation of complex multi-component architectures
* describe the measured properties of a system
* report the exact reason for a parsing failure

This document provides a definition of a SUIT-specific logging container that may be used in a variety of scenarios.

2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Terms used in this specification include:

* Boot: initialization of an executable image. Although this specification refers to boot, any boot-specific operations described are equally applicable to starting an executable in an OS context.

3. The SUIT Record

If the developer can be assumed to have a copy of the manifest, then they need little information to reconstruct what the manifest processor has done. They simply need any data that influences the control flow of the manifest. The manifest only supports the following control flow primitives:

* Set Component/Dependency Index
* Set/Override Parameters
* Try-Each
* Run Sequence
* Conditions

Of these, only conditions change the behavior of the processor from the default, and then only when the condition fails.

Then, to reconstruct the flow of a manifest, all a developer needs is a list of metadata about failed conditions:

* the current manifest
* the current section
the offset into the current section
the current component index
the "reason" for failure

Most conditions compare a parameter to an actual value, so the "reason" is typically simply the actual value.

Since it is possible that a non-condition command (directive) may fail in an exceptional circumstance, this must be included as well. However, a failed directive will terminate processing of the manifest. To accommodate for a failed command and for explicit "completion," an additional "result" element is added as well. In the case of a command failure, the failure reason is typically a numeric error code. However, these error codes need to be standardised in order to be useful.

Reconstructing what a device has done in this way is compact, however it requires some reconstruction effort. This is an issue that can be solved by tooling.

\[
\text{SUIT\_Record} = \{
\begin{array}{l}
  \text{suit-record-manifest-id} \Rightarrow [\star \text{uint }], \\
  \text{suit-record-manifest-section} \Rightarrow \text{int}, \\
  \text{suit-record-section-offset} \Rightarrow \text{uint}, \\
  ( \\
    \begin{array}{l}
      \text{suit-record-component-index} \Rightarrow \text{uint} // \\
      \text{suit-record-dependency-index} \Rightarrow \text{uint}\n    \\
  ),
\end{array}
\text{suit-record-properties} \Rightarrow \text{SUIT\_Parameters},
\end{array}
\}
\]

\text{suit-record-manifest-id} is used to identify which manifest contains the command that caused the record to be generated. The manifest id is a list of integers that form a walk of the manifest tree, starting at the root. An empty list indicates that the command was contained in the root manifest. If the list is not empty, the command was contained in one of the root manifest’s dependencies, or nested even further below that.

For example, suppose that the root manifest has 3 dependencies and each of those dependencies has 2 dependencies of its own:

* Root
  - Dependency A
A manifest-id of [1,0] would indicate that the current command was contained within Dependency B0. Similarly, a manifest-id of [2,1] would indicate Dependency C1.

suit-record-manifest-section indicates which section of the manifest was active. This is used in addition to an offset so that the developer can index into severable sections in a predictable way. The value of this element is the value of the key that identified the section in the manifest.

suit-record-section-offset is the number of bytes into the current section at which the current command is located.

suit-record-component-index is the index of the component that was specified at the time that the report was generated. This field is necessary due to the availability of set-current-component values of True and a list of components. Both of these values cause the manifest processor to loop over commands using a series of component-ids, so the developer needs to know which was selected when the command executed.

suit-record-dependency-index is similar to suit-record-component-index but is used to identify the dependency that was active.

suit-record-properties contains any measured properties that led to the command failure. For example, this could be the actual value of a SUIT_Digest or class identifier. This is encoded in a SUIT_Parameters block as defined in [I-D.ietf-suit-manifest].
4. The SUIT Report

Some metadata is common to all records, such as the root manifest: the manifest that is the entry-point for the manifest processor. This metadata is aggregated with a list of SUIT_Records. The SUIT_Report may also contain a list of any system properties that were measured and reported, and a reason for a failure if one occurred.

SUIT_Report = {
    suit-report-manifest-digest => SUIT_Digest,
    ? suit-report-manifest-uri  => tstr,
    ? suit-report-nonce         => bstr,
    suit-report-records         => [ * SUIT_Record ],
    ? suit-system-properties      => [ + system-property-claims ],
    suit-report-result          => true / {
        suit-report-result-code   => int, ; could condense to enum later
        suit-report-result-record => SUIT_Record,
    }
}

system-property-claims = {
    system-component-id => SUIT_Component_Identifier,
    + SUIT_Parameters,
}

suit-report-manifest-digest provides a SUIT_Digest (as defined in [I-D.ietf-suit-manifest]) that is the characteristic digest of the Root manifest.

suit-report-manifest-uri provides the reference URI that was provided in the root manifest.

suit-report-nonce provides a container for freshness or replay protection information. This field MAY be omitted where the suit-report is authenticated within a container that provides freshness already. For example, attestation evidence typically contains a proof of freshness.

suit-system-properties provides a list of measured or asserted properties of the system that creates the suit report. These properties are scoped by component identifier. Because this list is expected to be constructed on the fly by a constrained node, component identifiers may appear more than once. A recipient may convert the result to a more conventional structure:
SUIT_Record_System_Properties = { 
  * component-id => { 
    + SUIT_Parameters, 
  } 
}

suit-report-records is a list of 0 or more SUIT Records. Because SUIT Records are only generated on failure, in simple cases this can be an empty list.

suit-report-result provides a mechanism to show that the SUIT procedure completed successfully (value is true) or why it failed (value is a map of an error code and a SUIT_Record).

The suit-report-result-code indicates the reason for the failure. Values are expected to be CBOR parsing failures, Schema validation failures, COSE validation failures or SUIT processing failures.

The suit-report-result-record indicates the exact point in the manifest or manifest dependency tree where the error occurred.

5. Attestation

This document "can allow" describes how a well-informed verifier can infer the trustworthiness of a remote device. Remote attestation is done by using the SUIT_Manifest_Envelope along with the SUIT_Report to reconstruct the state of the device at boot time. By embedding data used for remote attestation in the SUIT_Report, a remote device can use an append-only log to collect both measurements and debug/failure information into the same document. This document can then be conveyed to a verifier as a part of the attestation evidence. A remote attestation format to convey attestation evidence, such as an Entity Attestation Token (EAT, see [I-D.ietf-rats-eat]), that contains a SUIT_Report MUST also include an integrity measurement of the Manifest Parser & Report Generator.

When a Concise Reference Integrity Manifest (CoRIM, see [I-D.birkholz-rats-corim] is delivered in a SUIT_Manifest_Envelope, this codifies the delivery of verification information to the verifier:

* The Firmware Distributor:
  - sends the SUIT_Manifest_Envelope to the Verifier without payload or text, but with CoRIM
  - sends the SUIT_Manifest_Envelope to the recipient without CoRIM, or text, but with payload
* The Recipient:
  - Installs the firmware as described in the SUIT_Manifest and generates a SUIT_report, which is encapsulated in an EAT by the installer and sent to the Firmware Distributor.
  - Boots the firmware as described in the SUIT_Manifest and creates a SUIT_report, which is encapsulated in an EAT by the installer and sent to the Firmware Distributor.

* The Firmware Distributor sends both reports to the verifier (separately or together)

* The Verifier:
  - Reconstructs the state of the device using the manifest
  - Compares this state to the CoRIM
  - Returns an Attestation Report to the Firmware Distributor

This approach simplifies the design of the bootloader since it is able to use an append-only log. It allows a verifier to validate this report against a signed CoRIM that is provided by the firmware author, which simplifies the delivery chain of verification information to the verifier.

This information is not intended as Attestation Evidence and while an Attestation Report MAY provide this information for conveying error codes and/or failure reports, it SHOULD be translated into general-purpose claims for use by the Relying Party.

6. IANA Considerations

IANA is requested to allocate a CBOR tag for the SUIT Report.

7. Security Considerations

The SUIT Report should either be carried over a secure transport, or signed, or both. Ideally, attestation should be used to prove that the report was generated by legitimate hardware.

8. Acknowledgements

9. References

9.1. Normative References
9.2. Informative References

[I-D.birkholz-rats-corim]

[I-D.ietf-rats-eat]

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Abstract

The Manufacturer Usage Description (MUD) specification describes the access and network functionality required a device to properly function. The MUD description has to reflect the software running on the device and its configuration. Because of this, the most appropriate entity for describing device network access requirements is the same as the entity developing the software and its configuration.

A network presented with a MUD file by a device allows detection of misbehavior by the device software and configuration of access control.

This document defines a way to link a SUIT manifest to a MUD file offering a stronger binding between the two.

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1. Introduction

Under [RFC8520], devices report a URL to a MUD manager in the network. RFC 8520 envisions different approaches for conveying the information from the device to the network such as:

- DHCP,
- IEEE802.1AB Link Layer Discovery Protocol (LLDP), and
- IEEE 802.1X whereby the URL to the MUD file would be contained in the certificate used in an EAP method.
The MUD manager then uses the URL to fetch the MUD file, which contains access and network functionality required a device to properly function.

The MUD manager must trust the service from which the URL is fetched and to return an authentic copy of the MUD file. This concern may be mitigated using the optional signature reference in the MUD file. The MUD manager must also trust the device to report a correct URL. In case of DHCP and LLDP the URL is unprotected. When the URL to the MUD file is included in a certificate then it is authenticated and integrity protected. A certificate created for use with network access authentication is typically not signed by the entity that wrote the software and configured the device, which leads to conflation of local network access rights with rights to assert all network access requirements.

There is a need to bind the entity that creates the software and configuration to the MUD file because only that entity can attest the network access requirements of the device. This specification defines an extension to the SUIT manifest to include a MUD file (per reference or by value). When combining a manufacturer usage description with a manifest used for software/firmware updates (potentially augmented with attestation) then a network operator can get more confidence in the description of the access and network functionality required a device to properly function.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Architecture

The intended workflow is as follows:

- At the time of onboarding, devices report their manifest in use to the MUD manager.

- If the SUIT_MUD_container has been severed, the suit-reference-uri can be used to retrieve the complete manifest.

- The manifest authenticity is verified by the MUD manager, which enforces that the MUD file presented is also authentic and as intended by the device software vendor.
- Each time a device is updated, rebooted, or otherwise substantially changed, it will execute an attestation.
  
  o Among other claims in the Entity Attestation Token (EAT) [I-D.ietf-rats-eat], the device will report its software digest(s), configuration digest(s), primary manifest URI, and primary manifest digest to the MUD manager.

  o The MUD manager can then validate these attestation reports in order to check that the device is operating with the expected version of software and configuration.

  o Since the manifest digest is reported, the MUD manager can look up the corresponding manifest.

- If the MUD manager does not already have a full copy of the manifest, it can be acquired using the reference URI.

- Once a full copy of the manifest is provided, the MUD manager can verify the device attestation report and apply any appropriate policy as described by the MUD file.

4. Extensions to SUIT

To enable strong assertions about the network access requirements that a device should have for a particular software/configuration pair, we include the ability to add MUD files to the SUIT manifest. However, there are also circumstances in which a device should allow the MUD to be changed without a firmware update. To enable this, we add a MUD url to SUIT along with a subject-key identifier, according to [RFC7093], mechanism 4 (the keyIdentifier is composed of the hash of the DER encoding of the SubjectPublicKeyInfo value).

The following CDDL describes the extension to the SUIT_Manifest structure:

\[
? \text{suit-manifest-mud} \Rightarrow \text{SUIT_Digest}
\]

The SUIT_Envelope is also amended:

\[
? \text{suit-manifest-mud} \Rightarrow \text{bstr} \, \text{.cbor} \, \text{SUIT_MUD_container}
\]

SUIT_MUD_container = {
    ? suit-mud-url => #6.32(tstr),
    ? suit-mud-ski => SUIT_Digest,
    ? suit-mud-file => bstr
}
The MUD file is included verbatim within the bstr. No limits are placed on the MUD file: it may be any RFC8520-compliant file.

5. Security Considerations

This specification links MUD files to other IETF technologies, particularly to SUIT manifests, for improving security protection and ease of use. By including MUD files (per reference or by value) in SUIT manifests an extra layer of protection has been created and synchronization risks can be minimized. If the MUD file and the software/firmware loaded onto the device gets out-of-sync a device may be firewalled and, with firewalling by networks in place, the device may stop functioning.

6. IANA Considerations

suit-manifest-mud must be added as an extension point to the SUIT manifest registry.

7. Normative References

[I-D.ietf-rats-eat]

[I-D.ietf-suit-manifest]


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