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COSE Receipts with CCF
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Abstract

This document defines a new verifiable data structure type for COSE Signed Merkle Tree Proofs specifically designed for transaction ledgers produced via Trusted Execution Environments (TEEs), such as the Confidential Consortium Framework ([CCF]) to provide stronger tamper-evidence guarantees.

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1. Introduction

The COSE Receipts document [I-D.ietf-cose-merkle-tree-proofs] defines a common framework for defining different types of proofs, such as proof of inclusion, about verifiable data structures (VDS). For instance, inclusion proofs guarantee to a verifier that a given serializable element is recorded at a given state of the VDS, while consistency proofs are used to establish that an inclusion proof is still consistent with the new state of the VDS at a later time.

In this document, we define a new type of VDS, associated with the Confidential Consortium Framework (CCF) ledger. This VDS carries indexed transaction information in a binary Merkle Tree, where new transactions are appended to the right, so that the binary decomposition of the index of a transaction can be interpreted as the position in the tree if 0 represents the left branch and 1 the right branch. Compared to [RFC9162], the leaves of CCF trees carry additional internal information for the following purposes:

1. To bind the full details of the transaction executed, which is a super-set of what is exposed in the proof and captures internal information details useful for detailed system audit, but not for application purposes.
2. To verify that elements are only written by the Trusted Execution Environment, which addresses the persistence of committed transactions that happen between new signatures of the Merkle Tree root.

1.1. Requirements Notation

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.

2. Description of the CCF Ledger Verifiable Data Structure

This documents extends the verifiable data structure registry of [I-D.ietf-cose-merkle-tree-proofs] with the following value:

Name	Value	Description	Reference
CCF_LEDGER_SHA256	TBD_1 (requested assignment 2)	Historical transaction ledgers, such as the CCF ledger	RFCthis

Table 1: Verifiable Data Structure Algorithms

This document defines inclusion proofs for CCF ledgers. Corresponding CCF Verifiers MUST reject proof types they do not support.

2.1. Merkle Tree Shape

A CCF ledger is a binary Merkle Tree constructed from a hash function H, which is defined from the log type. For instance, the hash function for CCF_LEDGER_SHA256 is SHA256, whose HASH_SIZE is 32 bytes.

The Merkle tree encodes an ordered list of n transactions $T_n = \{T[0], T[1], \dots, T[n-1]\}$. We define the Merkle Tree Hash (MTH) function, which takes as input a list of serialized transactions (as byte strings), and outputs a single `HASH_SIZE` byte string called the Merkle root hash, by induction on the list:

This function is defined as follows:

The hash of an empty list is the hash of an empty string:

$MTH(\{\}) = HASH()$.

The hash of a list with one entry (also known as a leaf hash) is:

$MTH(\{d[0]\}) = HASH(d[0])$.

For $n > 1$, let k be the largest power of two smaller than n (i.e., $k < n \leq 2k$). The Merkle Tree Hash of an n -element list D_n is then defined recursively as:

$MTH(D_n) = HASH(MTH(D[0:k]) || MTH(D[k:n]))$,

where:

- * `||` denotes concatenation
- * `:` denotes concatenation of lists
- * $D[k_1:k_2] = D'_-(k_2-k_1)$ denotes the list $\{d'[0] = d[k_1], d'[1] = d[k_1+1], \dots, d'[k_2-k_1-1] = d[k_2-1]\}$ of length $(k_2 - k_1)$.

2.2. Transaction Components

Each leaf in a CCF ledger carries the following components:

```
ccf-leaf = [
  ; Byte string of size HASH_SIZE(32)
  internal-transaction-hash: bstr .size 32

  ; Text string of at most 1024 bytes
  internal-evidence: tstr .size (1..1024)

  ; Byte string of size HASH_SIZE(32)
  data-hash: bstr .size 32
]
```

The internal-transaction-hash and internal-evidence byte strings are internal to the CCF implementation. They can be safely ignored by receipt Verifiers, but they commit the TS to the whole tree contents and may be used for additional, CCF-specific auditing.

internal-transaction-hash is a hash over the complete entry in the [CCF-Ledger-Format], and internal-evidence is a revealable [CCF-Commit-Evidence] value that allows early persistence of ledger entries before distributed consensus can be established.

data-hash summarises the subject of the proof: the data which is included in the ledger at this transaction.

3. CCF Inclusion Proofs

CCF inclusion proofs consist of a list of digests tagged with a single left-or-right bit.

```
ccf-proof-element = [  
  ; Position of the element  
  left: bool  
  
  ; Hash of the proof element: byte string of size HASH_SIZE(32)  
  hash: bstr .size 32  
]  
  
ccf-inclusion-proof = bstr .cbor {  
  &(leaf: 1) => ccf-leaf  
  &(path: 2) => [+ ccf-proof-element]  
}
```

Unlike some other tree algorithms, the index of the element in the tree is not explicit in the inclusion proof, but the list of left-or-right bits can be treated as the binary decomposition of the index, from the least significant (leaf) to the most significant (root).

3.1. CCF Inclusion Proof Signature

The proof signature for a CCF inclusion proof is a COSE signature (encoded with the COSE_Sign1 CBOR type) which includes the following additional requirements for protected and unprotected headers. Please note that there may be additional header parameters defined by the application.

The protected header parameters for the CCF inclusion proof signature MUST include the following:

- * verifiable-data-structure: int/tstr. This header MUST be set to the verifiable data structure algorithm identifier for ccf-ledger (TBD_1).
- * label: int. This header MUST be set to the value of the inclusion proof type in the IANA registry of Verifiable Data Structure Proof Type (-1).

The unprotected header for a CCF inclusion proof signature MUST include the following:

- * inclusion-proof: bstr .cbor ccf-inclusion-proof. This contains the serialized CCF inclusion proof, as defined above.

The payload of the signature is the CCF ledger Merkle root digest, and MUST be detached in order to force verifiers to recompute the root from the inclusion proof in the unprotected header. This provides a safeguard against implementation errors that use the payload of the signature but do not recompute the root from the inclusion proof.

3.2. Inclusion Proof Verification Algorithm

CCF uses the following algorithm to verify an inclusion receipt:

```
compute_root(proof):
  h := proof.leaf.internal-transaction-hash
      || HASH(proof.leaf.internal-evidence)
      || proof.leaf.data-hash

  for [left, hash] in proof:
    h := HASH(hash + h) if left
        HASH(h + hash) else
  return h

verify_inclusion_receipt(inclusion_receipt):
  let label = INCLUSION_PROOF_LABEL
  assert(label in inclusion_receipt.unprotected_header)
  let proof = inclusion_receipt.unprotected_header[label]
  assert(inclusion_receipt.payload == nil)
  let payload = compute_root(proof)

  # Use the Merkle Root as the detached payload
  return verify_cose(inclusion_receipt, payload)
```

A description can also be found at [CCF-Receipt-Verification].

4. Usage in COSE Receipts

A COSE Receipt with a CCF inclusion proof is described by the following CDDL definition:

```
protected-header-map = {  
  &(alg: 1) => int  
  &(vds: 395) => 2  
  * cose-label => cose-value  
}  
  
* alg (label: 1): REQUIRED. Signature algorithm identifier. Value  
  type: int.  
  
* vds (label: 395): REQUIRED. verifiable data structure algorithm  
  identifier. Value type: int.
```

The unprotected header for an inclusion proof signature is described by the following CDDL definition:

```
inclusion-proof = ccf-inclusion-proof  
  
inclusion-proofs = [ + inclusion-proof ]  
  
verifiable-proofs = {  
  &(inclusion-proof: -1) => inclusion-proofs  
}  
  
unprotected-header-map = {  
  &(vdp: 396) => verifiable-proofs  
  * cose-label => cose-value  
}
```

5. Privacy Considerations

See the privacy considerations section of:

- * [I-D.ietf-cose-merkle-tree-proofs]

6. Security Considerations

The security consideration of [I-D.ietf-cose-merkle-tree-proofs] apply.

6.1. Trusted Execution Environments

CCF networks of nodes rely on executing in Trusted Execution Environments to secure their function, in particular:

1. The evaluation of registration policies
2. The creation and usage of receipt signing keys

A compromise in the Trusted Execution Environment platform used to execute the network may allow an attacker to produce invalid and incompatible ledger branches. Clients can mitigate this risk in two ways: by regularly auditing the consistency of the CCF ledger; and by regularly fetching attestation information about the TEE instances, available in the ledger and from the network itself, and confirming that the nodes composing the network are running up-to-date, trusted platform components.

6.2. Operators

The operator of a CCF network has the ability to start successor networks, with a distinct identity, which endorse the receipts produced by a previous instance. This functionality is important to provide service continuity in the case of a catastrophic failure of a majority of nodes, but allows a potentially malicious operator to start from a prefix of an earlier ledger. Clients can mitigate this risk by auditing the successor ledger and its attestation information, as described above. In particular, clients can check that the latest receipt they hold is present in the successor ledger before they begin making use of it.

7. IANA Considerations

7.1. Additions to Existing Registries

7.1.1. Tree Algorithms

This document requests IANA to add the following new value to the 'COSE Verifiable Data Structures' registry:

- * Name: CCF_LEDGER_SHA256
- * Value: 2 (requested assignment)
- * Description: Append-only logs that are integrity-protected by a Merkle Tree and signatures produced via Trusted Execution Environments containing a mix of public and confidential information, as specified by the Confidential Consortium Framework.
- * Reference: This document

8. Normative References

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