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Unmanned Aircraft System Remote Identification (UAS RID)

Abstract

This document describes the use of Hierarchical Host Identity Tags (HHITs) as self-asserting IPv6 addresses and thereby a trustable identifier for use as the Unmanned Aircraft System Remote Identification and tracking (UAS RID). HHITs self-attest to the included explicit hierarchy that provides Registrar discovery for 3rd-party identifier attestation.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

[drip-requirements] describes an Unmanned Aircraft System Remote Identification and tracking (UAS ID) as unique (ID-4), non-spoofable (ID-5), and identify a registry where the ID is listed (ID-2); all within a 20 character identifier (ID-1).

This document describes the use of Hierarchical Host Identity Tags (HHITs) (Section 3) as self-asserting IPv6 addresses and thereby a trustable identifier for use as the UAS Remote ID. HHITs include explicit hierarchy to enable DNS HHIT queries (Host ID for authentication, e.g. Section 6.2.1) and for EPP Registrar discovery [RFC7484] for 3rd-party identification attestation (e.g. Section 6.2.1).

HITs are statistically unique through the cryptographic hash feature of second-preimage resistance. The cryptographically-bound addition of the Hierarchy and a HHIT registration process (TBD; e.g. based on Extensible Provisioning Protocol, [RFC5730]) provide complete, global HHIT uniqueness. This is in contrast to using general identifiers (e.g. a Universally Unique IDentifier (UUID) [RFC4122] or device serial number) as the subject in an X.509 [RFC5280] certificate.

In a multi-CA (multi Certificate Authority) PKI alternative to HHITs, a Remote ID as the Subject (Section 4.1.2.6 of [RFC5280]) can occur in multiple CAs, possibly fraudulently. CAs within the PKI would need to implement an approach to enforce assurance of the uniqueness achieved with HHITs.

Hierarchical HITs provide self-attestation of the HHIT registry. A HHIT can only be in a single registry within a registry system (e.g. Extensible Provisioning Protocol (EPP) [RFC5730] and DNS).

Hierarchical HITs are valid, though non-routable, IPv6 addresses [RFC8200]. As such, they fit in many ways within various IETF technologies.

2. Terms and Definitions

2.1. Requirements 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.

2.2. Notations

| Signifies concatenation of information - e.g., X | Y is the concatenation of X and Y.

Claim(X,Y):
Form of a predicate (X is Y, X has property Y, and most importantly X owns Y).

Assertion({X...}):
A set of one or more claims. This definition is borrowed from JWT/CWT ([RFC7519]/[RFC8392]).

Attestation(X,Y):
A signed claim. X attests to Y.

Certificate(X,Y):
A claim or attestation, Y, signed exclusively by a third party, X, and are only over identities.

2.3. Definitions

This document uses the terms defined in [drip-requirements]. The following new terms are used in the document:

cSHAKE (The customizable SHAKE function [NIST.SP.800-185]):
Extends the SHAKE [NIST.FIPS.202] scheme to allow users to customize their use of the SHAKE function.

HDA (Hierarchical HIT Domain Authority):
The 16-bit field that identifies the HHIT Domain Authority under an Registered Assigning Authority (RAA).

HHIT
Hierarchical Host Identity Tag. A HIT with extra hierarchical information not found in a standard HIT [RFC7401].

HI
: Host Identity. The public key portion of an asymmetric key pair used in HIP.

HID (Hierarchy ID):
: The 32 bit field providing the HIT Hierarchy ID.

HIP (Host Identity Protocol)
: The origin of HI, HIT, and HHIT, required for DRIP.

HIT
: Host Identity Tag. A 128-bit handle on the HI. HITs are valid IPv6 addresses.

Keccak (KECCAK Message Authentication Code):
: The family of all sponge functions with a KECCAK-f permutation as the underlying function and multi-rate padding as the padding rule. In particular all the functions referenced from [NIST.FIPS.202] and [NIST.SP.800-185].

KMAC (KECCAK Message Authentication Code [NIST.SP.800-185]):
: A PRF and keyed hash function based on KECCAK.

RAA (Registered Assigning Authority):
: The 16 bit field identifying the business or organization that manages a registry of HDAs.

RVS (Rendezvous Server):
: The HIP Rendezvous Server for enabling mobility, as defined in [RFC8004].

SHAKE (Secure Hash Algorithm KECCAK [NIST.FIPS.202]):
: A secure hash that allows for an arbitrary output length.

XOF (eXtendable-Output Function [NIST.FIPS.202]):
: A function on bit strings (also called messages) in which the output can be extended to any desired length.

3. The Hierarchical Host Identity Tag (HHIT)

The Hierarchical HIT (HHIT) is a small but important enhancement over the flat HIT space. By adding two levels of hierarchical administration control, the HHIT provides for device registration/ownership, thereby enhancing the trust framework for HITs.

HHITs represent the HI in only a 64 bit hash and uses the other 32 bits to create a hierarchical administration organization for HIT domains. Hierarchical HIT construction is defined in Section 3.5. The input values for the Encoding rules are in Section 3.5.1.

A HHIT is built from the following fields:

- *IANA prefix (max 28 bit)
- *32 bit Hierarchy ID (HID)
- *4 (or 8) bit HIT Suite ID
- *ORCHID hash (96 - prefix length - Suite ID length bits, e.g. 64) See Section 3.5

The Context ID for the ORCHID hash is:

```
Context ID :=  0x00B5 A69C 795D F5D5 F008 7F56 843F 2C40
```

3.1. HHIT prefix

A unique IANA IPv6 prefix, no larger than 28 bit, for HHITs is recommended. It clearly separates the flat-space HIT processing from HHIT processing per Section 3.5.

Without a unique prefix, the first 4 bits of the RRA would be interpreted as the HIT Suite ID per HIPv2 [RFC7401].

3.2. HHIT Suite IDs

The HIT Suite IDs specifies the HI and hash algorithms. Any HIT Suite ID can be used for HHITs. The 8 bit format is supported (only when the first 4 bits are ZERO), but this reduces the ORCHID hash length.

3.2.1. 8 bit HIT Suite IDs

Support for 8 bit HIT Suite IDs is allowed in Section 5.2.10 of [RFC7401], but not specified in how ORCHIDs are generated with these longer OGAs. Section 3.5 provides the algorithmic flexibility, allowing for HDA custom HIT Suite IDs as follows:

HIT Suite	Four-bit ID	Eight-bit encoding
HDA Assigned 1	NA	TBD3 (suggested value 0x0E)
HDA Assigned 2	NA	TBD4 (suggested value 0x0F)

This feature may be used for large-scale experimenting with post quantum computing hashes or similar domain specific needs. Note that currently there is no support for domain specific HI algorithms.

3.3. The Hierarchy ID (HID)

The Hierarchy ID (HID) provides the structure to organize HITs into administrative domains. HIDs are further divided into 2 fields:

*16 bit Registered Assigning Authority (RAA)

*16 bit Hierarchical HIT Domain Authority (HDA)

3.3.1. The Registered Assigning Authority (RAA)

An RAA is a business or organization that manages a registry of HDAs. For example, the Federal Aviation Authority (FAA) could be an RAA.

The RAA is a 16 bit field (65,536 RAAs) assigned by a numbers management organization, perhaps ICANN's IANA service. An RAA must provide a set of services to allocate HDAs to organizations. It must have a public policy on what is necessary to obtain an HDA. The RAA need not maintain any HIP related services. It must maintain a DNS zone minimally for discovering HID RVS servers.

As HHITs may be used in many different domains, RAA should be allocated in blocks with consideration on the likely size of a particular usage. Alternatively, different Prefixes can be used to separate different domains of use of HHTs.

This DNS zone may be a PTR for its RAA. It may be a zone in a HHIT specific DNS zone. Assume that the RAA is 100. The PTR record could be constructed:

```
100.hhit.arpa   IN PTR      raa.bar.com.
```

3.3.2. The Hierarchical HIT Domain Authority (HDA)

An HDA may be an ISP or any third party that takes on the business to provide RVS and other needed services for HIP enabled devices.

The HDA is an 16 bit field (65,536 HDAs per RAA) assigned by an RAA. An HDA should maintain a set of RVS servers that its client HIP-enabled customers use. How this is done and scales to the potentially millions of customers is outside the scope of this document. This service should be discoverable through the DNS zone maintained by the HDA's RAA.

An RAA may assign a block of values to an individual organization. This is completely up to the individual RAA's published policy for delegation.

3.4. Edward Digital Signature Algorithm for HITs

Edwards-Curve Digital Signature Algorithm (EdDSA) [RFC8032] are specified here for use as Host Identities (HIs) per HIPv2 [RFC7401]. Further the HIT_SUITE_LIST is specified as used in [RFC7343].

See Section 3.2 for use of the HIT Suite for this document.

3.4.1. HOST_ID

The HOST_ID parameter specifies the public key algorithm, and for elliptic curves, a name. The HOST_ID parameter is defined in Section 5.2.19 of [RFC7401].

Algorithm profiles	Values	
EdDSA	TBD1 (suggested value 13) [RFC8032]	(RECOMMENDED)

For hosts that implement EdDSA as the algorithm, the following EdDSA curves are available:

Algorithm	Curve	Values
EdDSA	RESERVED	0
EdDSA	EdDSA25519	1 [RFC8032]
EdDSA	EdDSA25519ph	2 [RFC8032]
EdDSA	EdDSA448	3 [RFC8032]
EdDSA	EdDSA448ph	4 [RFC8032]

3.4.2. HIT_SUITE_LIST

The HIT_SUITE_LIST parameter contains a list of the supported HIT suite IDs of the Responder. Based on the HIT_SUITE_LIST, the Initiator can determine which source HIT Suite IDs are supported by the Responder. The HIT_SUITE_LIST parameter is defined in Section 5.2.10 of [RFC7401].

The following HIT Suite ID is defined, and the relationship between the four-bit ID value used in the OGA ID field and the eight-bit encoding within the HIT_SUITE_LIST ID field is clarified:

HIT Suite	4-bit ID	8-bit encoding
RESERVED	0	0x00
EdDSA/cSHAKE128	TBD2 (suggested value 5)	0x50 (RECOMMENDED)

The following table provides more detail on the above HIT Suite combinations. The input for each generation algorithm is the encoding of the HI as defined in this Appendix.

The output of cSHAKE128 is variable per the needs of a specific ORCHID construction. It is at most 96 bits long and is directly used in the ORCHID (without truncation).

Index	Hash function	HMAC	Signature algorithm family	Description
5	cSHAKE128	KMAC128	EdDSA	EdDSA HI hashed with cSHAKE128, output is variable

Table 1: HIT Suites

3.5. ORCHIDs for Hierarchical HITs

This section improves on ORCHIDv2 [RFC7343] with three enhancements:

- Optional Info field between the Prefix and OGA ID.
- Increased flexibility on the length of each component in the ORCHID construction, provided the resulting ORCHID is 128 bits.
- Use of cSHAKE, NIST SP 800-185 [NIST.SP.800-185], for the hashing function.

The Keccak [Keccak] based cSHAKE XOF hash function is a variable output length hash function. As such it does not use the truncation operation that other hashes need. The invocation of cSHAKE specifies the desired number of bits in the hash output. Further, cSHAKE has a parameter 'S' as a customization bit string. This parameter will be used for including the ORCHID Context Identifier in a standard fashion.

This ORCHID construction includes the fields in the ORCHID in the hash to protect them against substitution attacks. It also provides for inclusion of additional information, in particular the hierarchical bits of the Hierarchical HIT, in the ORCHID generation. This should be viewed as an addendum to ORCHIDv2 [RFC7343], as it can produce ORCHIDv2 output.

3.5.1. Adding additional information to the ORCHID

ORCHIDv2 [RFC7343] is currently defined as consisting of three components:

```
ORCHID     :=  Prefix | OGA ID | Encode_96( Hash )

where:

Prefix          : A constant 28-bit-long bitstring value
                  (IANA IPv6 assigned).

OGA ID          : A 4-bit long identifier for the Hash_function
                  in use within the specific usage context.  When
                  used for HIT generation this is the HIT Suite ID.

Encode_96( )    : An extraction function in which output is obtained
                  by extracting the middle 96-bit-long bitstring
                  from the argument bitstring.
```

This addendum will be constructed as follows:

```
ORCHID     :=  Prefix (p) | Info (n) | OGA ID (o) | Hash (m)

where:

Prefix (p)      : An IANA IPv6 assigned prefix (max 28-bit-long).

Info (n)        : n bits of information that define a use of the
                  ORCHID.  n can be zero, that is no additional
                  information.

OGA ID (o)      : A 4 or 8 bit long identifier for the Hash_function
                  in use within the specific usage context.  When
                  used for HIT generation this is the HIT Suite ID.

Hash (m)        : An extraction function in which output is m bits.

p + n + o + m = 128 bits
```

With a 28 bit IPv6 Prefix, the remaining 100 bits can be divided in any manner between the additional information, OGA ID, and the hash output. Care must be taken in determining the size of the hash portion, taking into account risks like pre-image attacks. Thus 64 bits as used in Hierarchical HITs may be as small as is acceptable.

3.5.2. ORCHID Encoding

This addendum adds a different encoding process to that currently used in ORCHIDv2. The input to the hash function explicitly includes all the header content plus the Context ID. The header content consists of the Prefix, the Additional Information, and OGA ID (HIT Suite ID). Secondly, the length of the resulting hash is set by sum of the length of the ORCHID header fields. For example, a 28 bit Prefix with 32 bits for the HID and 4 bits for the OGA ID leaves 64 bits for the hash length.

To achieve the variable length output in a consistent manner, the cSHAKE hash is used. For this purpose, cSHAKE128 is appropriate. The the cSHAKE function call for this addendum is:

```
cSHAKE128(Input, L, "", Context ID)

Input      :=  Prefix | Additional Information | OGA ID | HOST_ID
L          :=  Length in bits of hash portion of ORCHID
```

For full Suite ID support (those that use fixed length hashes like SHA256), the following hashing can be used (Note: this does NOT produce output Identical to ORCHIDv2 for Prefix of /28 and Additional Information of ZERO length):

```
Hash[L](Context ID | Input)

Input      :=  Prefix | Additional Information | OGA ID | HOST_ID
L          :=  Length in bits of hash portion of ORCHID

Hash[L]    :=  An extraction function in which output is obtained
               by extracting the middle L-bit-long bitstring
               from the argument bitstring.
```

Hierarchical HIT uses the same context as all other HIPv2 HIT Suites as they are clearly separated by the distinct HIT Suite ID.

3.5.2.1. Encoding ORCHIDs for HITv2

This section is included to provide backwards compatibility for ORCHIDv2 [RFC7343] as used for HITv2 [RFC7401].

For HITv2s, the Prefix MUST be 2001:20::/28. Info is length ZERO (not included), and OGA ID is length 4. Thus the HI Hash is length 96. Further the Prefix and OGA ID are NOT included in the hash

calculation. Thus the following ORCHID calculations for fixed output length hashes are used:

```
 Hash[L](Context ID | Input)

 Input      :=  HOST_ID
 L          :=  96
 Context ID :=  0xF0EF F02F BFF4 3D0F E793 0C3C 6E61 74EA

 Hash[L]    :=  An extraction function in which output is obtained
                by extracting the middle L-bit-long bitstring
                from the argument bitstring.
```

For variable output length hashes use:

```
 Hash[L](Context ID | Input)

 Input      :=  HOST_ID
 L          :=  96
 Context ID :=  0xF0EF F02F BFF4 3D0F E793 0C3C 6E61 74EA

 Hash[L]    :=  The L bit output from the hash function
```

Then the ORCHID is constructed as follows:

```
 Prefix | OGA ID | Hash Output
```

3.5.3. ORCHID Decoding

With this addendum, the decoding of an ORCHID is determined by the Prefix and OGA ID (HIT Suite ID). ORCHIDv2 [RFC7343] decoding is selected when the Prefix is: 2001:20::/28.

For Hierarchical HITs, the decoding is determined by the presence of the HHIT Prefix as specified in the HHIT document.

3.5.4. Decoding ORCHIDs for HITv2

This section is included to provide backwards compatibility for ORCHIDv2 [RFC7343] as used for HITv2 [RFC7401].

HITv2s are identified by a Prefix of 2001:20::/28. The next 4 bits are the OGA ID. is length 4. The remaining 96 bits are the HI Hash.

4. Hierarchical HITs as Remote ID

Hierarchical HITs are a refinement on the Host Identity Tag (HIT) of HIPv2 [RFC7401]. HHITs require a new Overlay Routable Cryptographic Hash Identifier (ORCHID [RFC7343]) mechanism as described in Section 3.5. HHITs for UAS ID also use the new EdDSA/SHAKE128 HIT suite defined in Section 3.4 (GEN-2 in [drip-requirements]). This hierarchy, cryptographically embedded within the HHIT, provides the information for finding the UA's HHIT registry (ID-3 in [drip-requirements]).

ASTM Standard Specification for Remote ID and Tracking [F3411-19] specifies three UAS ID types:

TYPE-1 A static, manufacturer assigned, hardware serial number per ANSI/CTA-2063-A "Small Unmanned Aerial System Serial Numbers" [CTA2063A].

TYPE-2 A CAA assigned (presumably static) ID.

TYPE-3 A UTM system assigned UUID [RFC4122]. These can be dynamic, but do not need to be.

For HHITs to be used effectively as UAS IDs, F3411 should add UAS ID type 4 as HHIT.

4.1. Nontransferablity of HHITs

A HI and its HHIT SHOULD NOT be transferable between UA or even between replacement electronics (e.g. replacement of damaged controller CPU) for a UA. The private key for the HI SHOULD be held in a cryptographically secure component.

4.2. Encoding HHITs in CTA 2063-A Serial Numbers

In some cases it is advantageous to encode HHITs as a CTA 2063-A Serial Number [CTA2063A]. For example, the FAA Remote ID Rules [FAA_RID] state that a Remote ID Module (i.e. not integrated with UA controller) must only use "the serial number of the unmanned aircraft"; CTA 2063-A meets this requirement.

Encoding a HHIT within the 2063-A format is not simple. There is no place for the HID; there will need to be a mapping service from Manufacturer Code to HID. The HIT Suite ID and ORCHID hash will take 14 characters (see below), leaving only 1 character for the Manufacturer's use of other information.

A character in a CTA 2063-A Serial Number "shall include any combination of digits and uppercase letters, except the letters O and I, but may include all digits". This would allow for a Base34

encoding of the binary HIT Suite ID and ORCHID hash. Although, programatically, such a conversion is not hard, other technologies (e.g. credit card payment systems) that have used such odd base encoding have had performance challenges. Thus here a Base32 encoding will be used by also excluding the letters Z and S (too similar to the digits 2 and 5).

The low-order 68 bits (HIT Suite ID | ORCHID hash) of the HHIT SHALL be left-padded with 2 bits of ZERO. This 70 bit number will be encoded into 14 characters using the digit/letters above. The Manufacturer MAY use a Length Code of 14 or 15. If 15, the first character after the Length Code is set by the Manufacturer with the low order 14 characters for the encoded HIT Suite ID and ORCHID hash.

A mapping service (e.g. DNS) MUST provide a trusted (e.g. via DNSSEC) conversion of the 4 character Manufacturer Code to high-order 60 bits (Prefix | HID) of the HHIT. Definition of this mapping service is currently out of scope of this document.

4.3. Remote ID as one class of Hierarchical HITs

UAS Remote ID may be one of a number of uses of HHITs. However, it is out of the scope of the document to elaborate on other uses of HHITs. As such these follow-on uses need to be considered in allocating the RAAs Section 3.3.1 or HHIT prefix assignments Section 10.

4.4. Hierarchy in ORCHID Generation

ORCHIDS, as defined in [RFC7343], do not cryptographically bind an IPv6 prefix nor the Orchid Generation Algorithm (OGA) ID (the HIT Suite ID) to the hash of the HI. The rational at the time of developing ORCHID was attacks against these fields are DoS attacks against protocols using ORCHIDs and thus up to those protocols to address the issue.

HHITs, as defined in Section 3.5, cryptographically bind all content in the ORCHID through the hashing function. A recipient of a HHIT that has the underlying HI can directly trust and act on all content in the HHIT. This provides a strong, self-attestation for using the hierarchy to find the HHIT Registry.

4.5. Hierarchical HIT Registry

HHITs are registered to Hierarchical HIT Domain Authorities (HDAs). A registration process, [drip-registries], ensures UAS ID global uniqueness (ID-4 in [drip-requirements]). It also provides the mechanism to create UAS Public/Private data that are associated with the HHIT UAS ID (REG-1 and REG-2 in [drip-requirements]).

The two levels of hierarchy within an HHIT allows for CAAs to have their own Registered Assigning Authority (RAA) for their National Air Space (NAS). Within the RAA, the CAAs can delegate HDAs as needed. There may be other RAAs allowed to operate within a given NAS; this is a policy decision by the CAA.

4.6. Remote ID Authentication using HHITs

The EdDSA25519 Host Identity (HI) [Section 3.4] underlying the HHIT can be used in an 84-byte self proof attestation as shown in Appendix B to provide proof of Remote ID ownership (GEN-1 in [drip-requirements]). An lookup service like DNS can provide the HI and registration proof (GEN-3 in [drip-requirements]).

Similarly the 200-byte offline self-attestation shown in Appendix B.1 provides the same proofs without Internet access and with a small cache that contains the HDA's HI/HHIT and HDA meta-data. These self-attestations are carried in the ASTM Authentication Message (Msg Type 0x2).

Hashes of previously sent ASTM messages can be placed in a signed "Manifest" Authentication Message (GEN-2 in [drip-requirements]). This can be either a standalone Authentication Message, or an enhanced self attestation Authentication Message. Alternatively the ASTM Message Pack (Msg Type 0xF) can provide this feature, but only over Bluetooth 5 or WiFi NAN broadcasts.

5. UAS ID HHIT in DNS

There are two approaches for storing and retrieving the HHIT using DNS. These are:

*As FQDNs in the .aero TLD.

*Reverse DNS lookups as IPv6 addresses per [RFC8005].

An HHIT can be used to construct an FQDN that points to the USS that has the Public/Private information for the UA (REG-1 and REG-2 in [drip-requirements]). For example, the USS for the HHIT could be found via the following: Assume the RAA is 100 and the HDA is 50. The PTR record is constructed as:

```
100.50.hhit.uas.aero   IN PTR      foo.uss.aero.
```

The individual HHITs are potentially too numerous (e.g. 60 - 600M) and dynamic to actually store in a signed, DNS zone. The HDA SHOULD provide DNS service for its zone and provide the HHIT detail response.

The HHIT reverse lookup can be a standard IPv6 reverse look up, or it can leverage off the HHIT structure. Assume a prefix of 2001:30::/28, the RAA is 10 and the HDA is 20 and the HHIT is:

```
2001:30:a0:145:a3ad:1952:ad0:a69e
```

An HHIT reverse lookup could be to:

```
a69e.ad0.1952.a3ad.145.a0.30.2001.20.10.hhit.arpa.
```

A 'standard' ip6.arpa RR has the advantage of only one Registry service supported.

```
$ORIGIN  5.4.1.0.0.a.0.0.0.3.0.0.1.0.0.2.ip6.arpa.
e.9.6.a.0.d.a.0.2.5.9.1.d.a.3.a    IN   PTR
```

6. DRIP Proofs

The DRIP Proofs are a set of custom objects to be used in the USS/UTM system. They are created during the enrollment of an Operator and the provisioning of an Aircraft and are tied to the Operator ID and UAS RID.

These structures, when chained together, create two distinct roots of trust. One back to the UAS manufacturer, back to the initial production of a given Aircraft. The other back to the authorizing CAA. These chains can also be used by authorized entities to trace an Aircraft through all owners and flights in the Aircraft's lifetime (something of interest to ICAO).

The rest of this section will define the formats of proofs in DRIP as forms of certificates and attestations and their common uses.

6.1. Claim / Assertion: HHIT

The HHIT can be taken in its entirety as a single claim or broken into various claims and thus be classified as an assertion.

There are a number of different claims that an HHIT can be broken into:

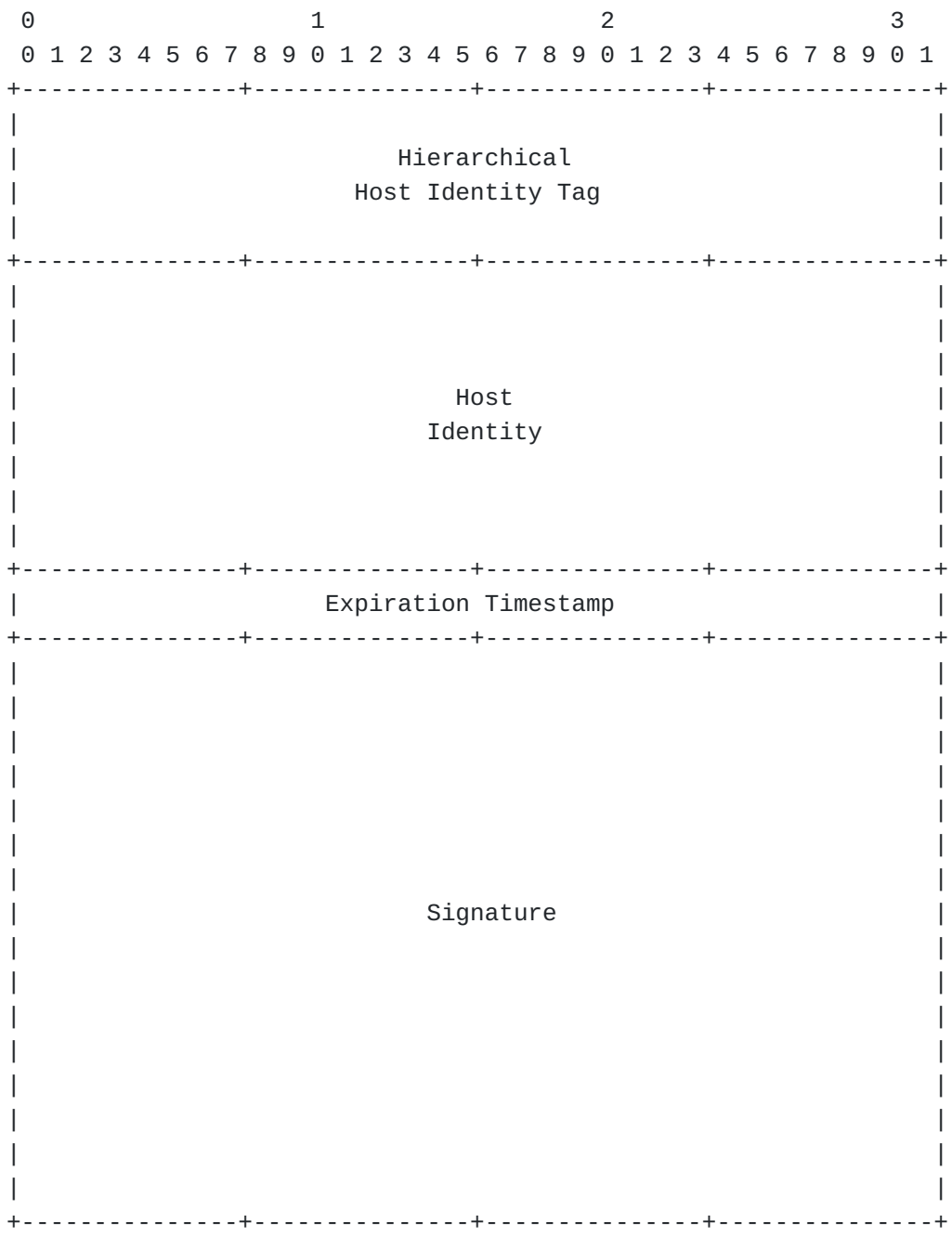
*Valid ORCHID construction. To validate would require the Host Identity used.

*Ownership of the asymmetric keypair used to generate the hash.

*Being a member of a specified Registry. This is defined by the RAA and HDA pairing encoded. This is a baseless claim on its own that is attested to by the Registry.

6.2. Self-Attestation: Attestation(X,X)

This DRIP Proof is a self-signed attestation (by an entity known as 'X') staking an unverified claim on a HHIT/HI pairing until an expiration date/time.



HHIT	The HHIT of the entity, derived from the HI and other information.
HI	The HI of the entity. This is the public half of an EdDSA25519 asymmetric keypair.
Expiration Timestamp	A timestamp signaling the expiration of the attestation.
Signature	Generated using the asymmetric keypair of the entity.

Figure 1: Self-Attestation: Attestation(X,X)

This Self-Attestation is 116 bytes attesting to a number of claims and assertions. Overall the entire structure creates an assertion of the ownership of this first two claims (HHIT and HI), a binding (between HHIT and HI) and an upper time bound of relevance (the Expiration Timestamp).

The offset of the Expiration Timestamp (ETS) SHOULD be of significant length (possibly years).

These are 5 (five) Self-Attestations that can be created in a standard DRIP UAS RID system:

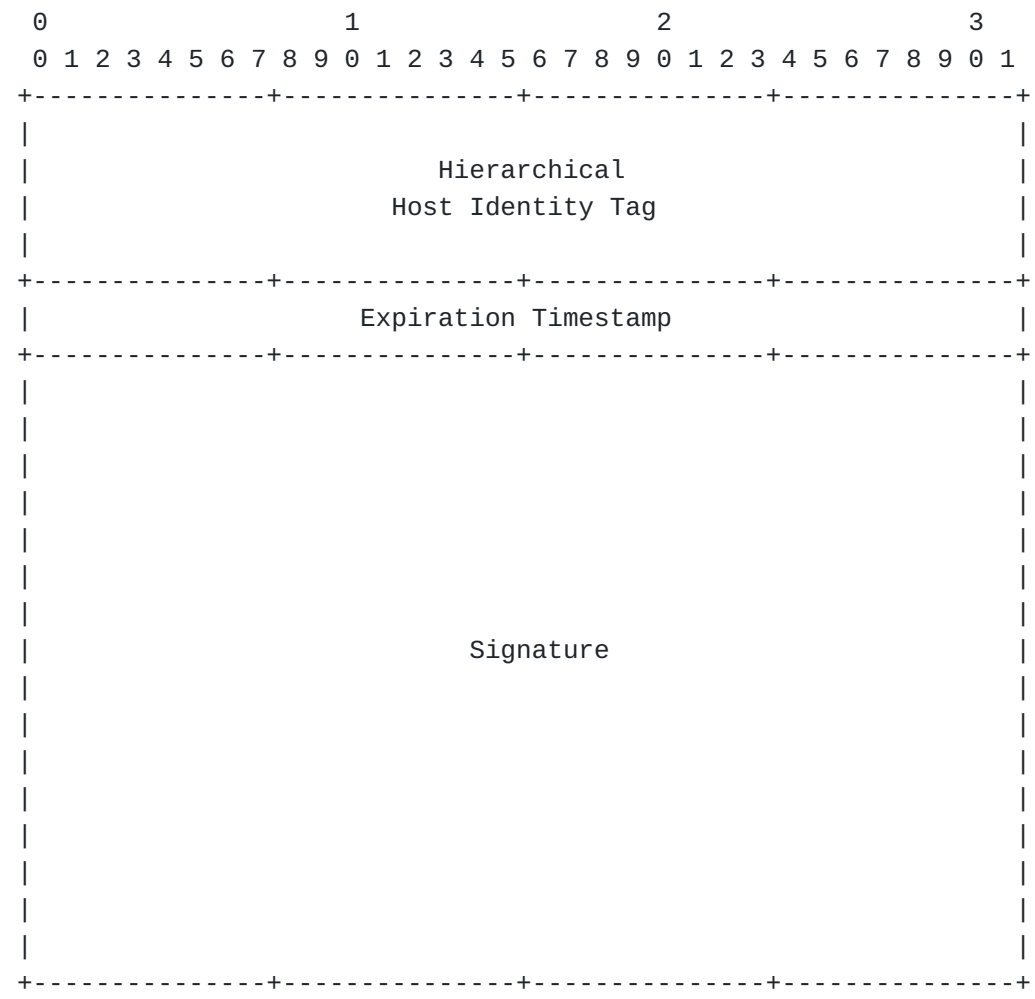
- *Attestation(Manufacturer, Manufacturer)
- *Attestation(RAA, RAA)
- *Attestation(HDA, HDA) or Attestation(Registry, Registry)
- *Attestation(Operator, Operator)
- *Attestation(Aircraft, Aircraft)

This is not an exhaustive list as any entity with the DRIP UAS system SHOULD have a Self-Attestation for itself.

The Timestamp formatting is covered in Section 6.5.

6.2.1. Concise Self-Attestation: Attestation(X, ConciseX)

A smaller version of Attestation(X, X) exists where the Host Identity is removed allowing a claim to be made in 84 bytes.



HHIT	The HHIT of the entity, derived from the HI and other information.
Expiration Timestamp	A timestamp signaling the expiration of the attestation.
Signature	Generated using the asymmetric keypair of the entity.

Figure 2: Concise Self-Attestation: Attestation(X, ConciseX)

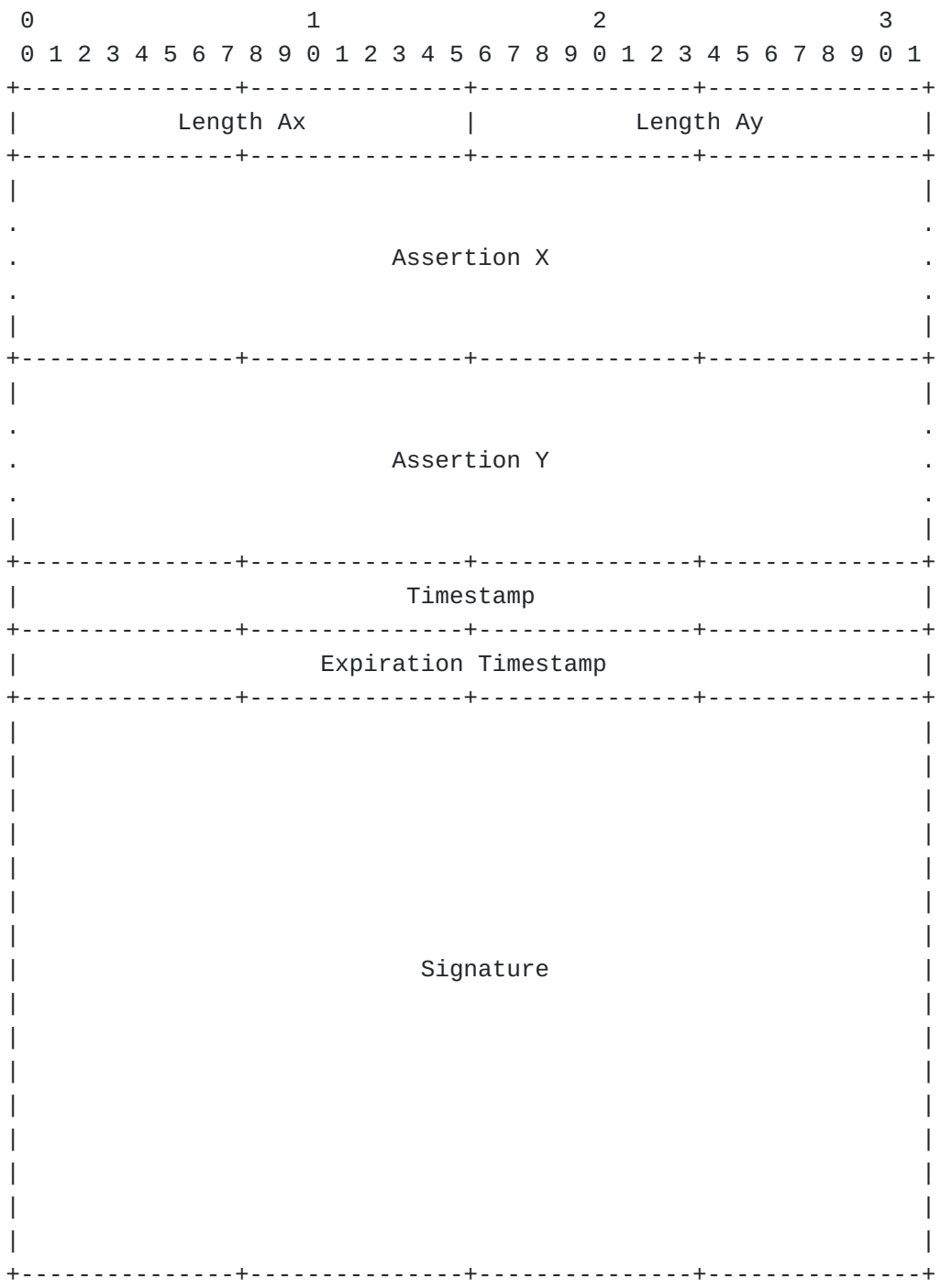
This form would require that the Host Identity associated with the HHIT be in a public Registry to be requested (nominally with a DNS lookup using a HIP RR type) and checked against.

The Timestamp formatting is covered in Section 6.5.

6.3. Certificate(X, Y)

This DRIP Proof is an attestation where Entity X asserts trust in the binding claimed by Entity Y (in Assertion Y) and signs this asserting

with a timestamp and an expiration of when the binding is no longer asserted by Entity X.



Length Ax	Length in bytes of Assertion(X). Encoded as an unsigned integer.
Length Ay	Length in bytes of Assertion(Y). Encoded as an unsigned integer.
Assertion(X)	The attestation/certificate of entity X.
Assertion(Y)	The attestation/certificate of entity Y.

Timestamp	A timestamp signaling the current time at signing of the certificate.
Expiration Timestamp	A timestamp signaling the expiration of the attestation.
Signature	Generated using the asymmetric keypair of the entity.

Figure 3: Certificate(X, Y)

Cxy Form wraps both Self-Attestations of the entities and is signed by Entity X. Two timestamps, one taken at the time of signing and one as an expiration time are used to set boundaries to the assertion. Care should be given to how far into the future the Expiration Timestamp is set, but is left up to system policy.

Most attestations of this form have a length of 304 bytes; some may be 84 or 116 bytes. Certificate(Registry, Certificate(Operator,Aircraft)) is unique in that is 680 bytes long, binding of two Cxy forms (in this specific case Certificate(Registry, Operator) with Certificate(Operator, Aircraft).

The Timestamp formatting is covered in Section 6.5.

6.3.1. Concise Certificate(X, Concise Y)

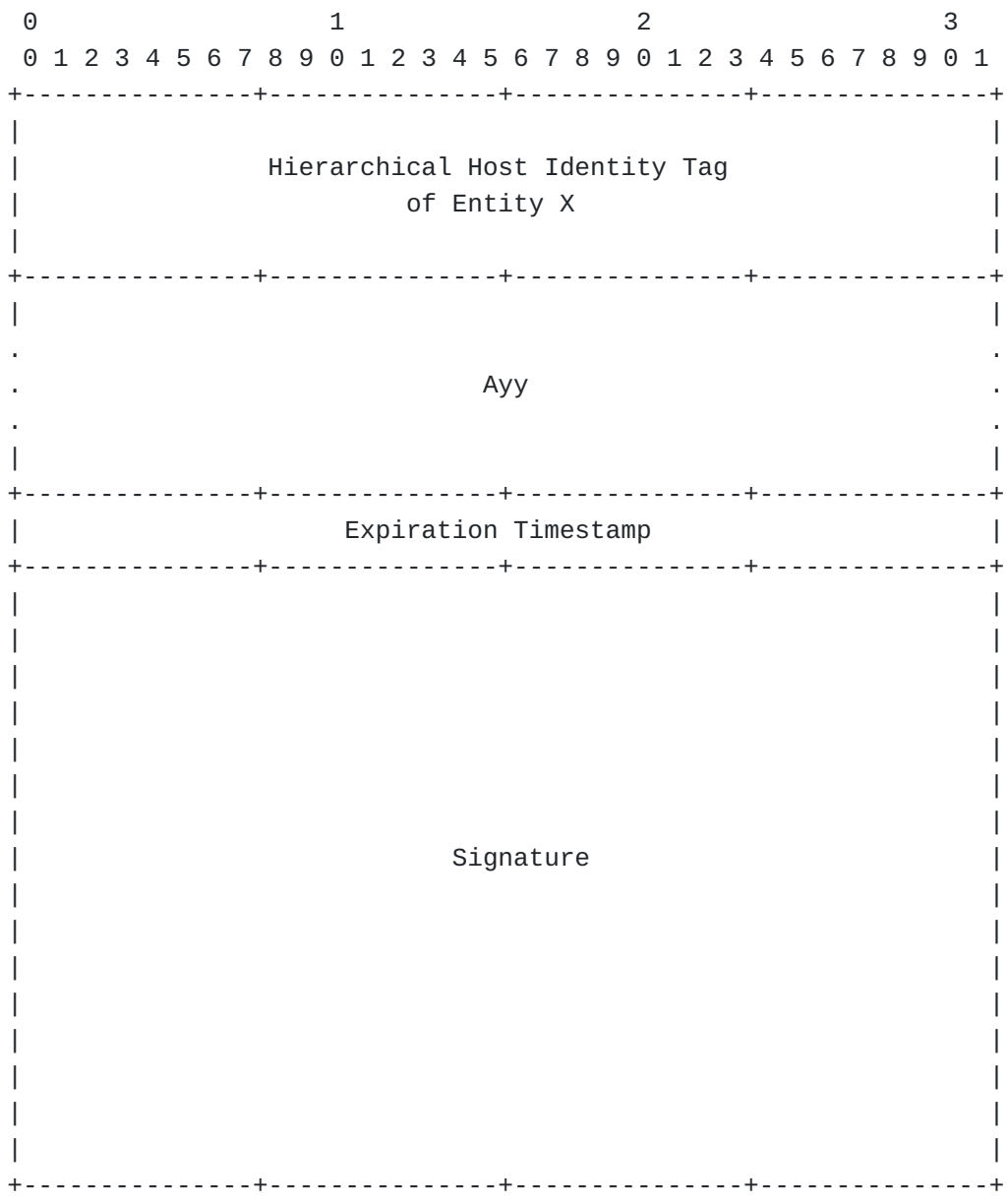


Figure 4: Concise Certificate(X, Concise Y)

The short form of the Cxy this attestation is 200 bytes long and is designed to fit inside the framing of the ASTM F3411 Authentication Message. The HHIT of Entity X is used in place of the full Axx (see Section 11.3 for comments). The timestamp is removed and only an expiration timestamp is present. Ayy MUST NOT be the in Concise Form.

During creation the Expiration Timestamp MUST be no later than the Expiration Timestamp found in Ayy.

6.4. Offline Broadcast Attestation: Attestation(X, Offline Y)

A special attestation that is the basis for a certificate finalized onboard the aircraft during flight. It is used in Broadcast RID to provide the trustworthiness of the Aircraft without the need of the Observer to be connected to the Internet.

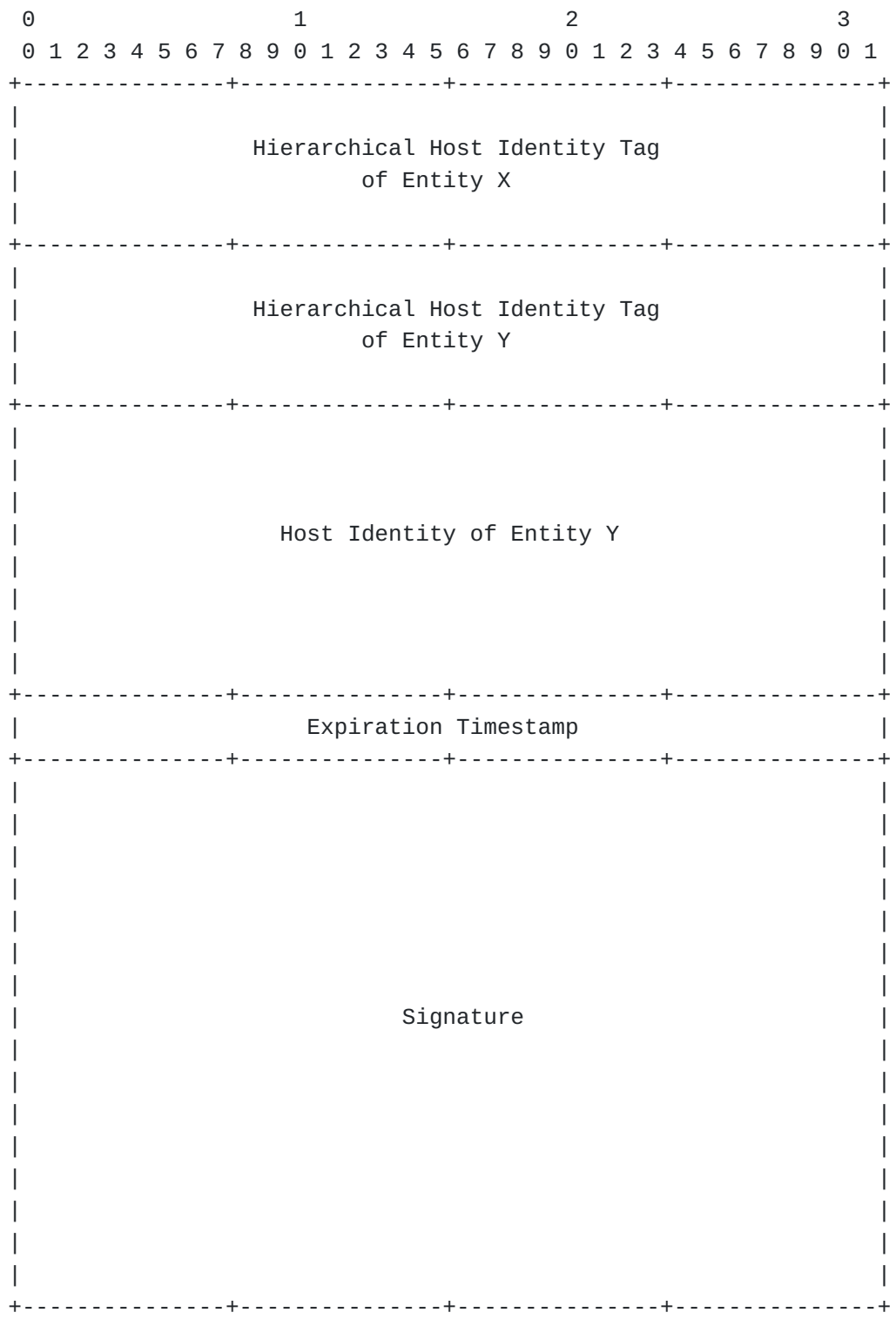


Figure 5: Offline Form: Attestation(X, Offline Y)

The signature is generated using Entity X's keypair.

6.5. Timestamps

Timestamps MAY be the standard UNIX time or a protocol specific timestamp, to avoid programming complexities. For example [F3411-19] uses a 00:00:00 01/01/2019 offset. When a Expiration Timestamp is required a desired offset is added, setting the timestamp into the future. The amount of offset for specific timestamps is left to best practice.

6.6. Signatures

Signatures are ALWAYS taken over the preceding fields in the certificate/attestation. For DRIP the EdDSA25519 algorithm from [RFC8032] is used.

7. Other UTM uses of HHITs

HHITs might be used within the UTM architecture beyond UA ID (and USS in UA ID registration and authentication). This includes a GCS HHIT ID. The GCS may use its HIIT if it is the source of Network Remote ID for securing the transport and for secure C2 transport (e.g. [drip-secure-nrid-c2]).

Observers may have their own HHITs to facilitate UAS information retrieval (e.g., for authorization to private UAS data). They could also use their HHIT for establishing a HIP connection with the UA Pilot for direct communications per authorization (this use is currently outside the scope). Further, they can be used by FINDER observers, (e.g. [crowd-sourced-rid]).

8. DRIP Requirements addressed

This document in the previous sections provides the details to solutions for GEN 1 - 3, ID 1 - 5, and REG 1 - 2 as described in [drip-requirements].

9. ASTM Considerations

ASTM will need to make the following additional value to the "UA ID" in the Basic Message (Msg Type 0x0):

Type 4:
This document UA ID of Hierarchical HITs (see Section 4).

The HHIT RID authors will participate in ASTM to enact this change.

10. IANA Considerations

This document requests IANA to make the following changes to the IANA "Host Identity Protocol (HIP) Parameters" registry:

Host ID:
This document defines the new EdDSA Host ID with value TBD1 (suggested: 13) (see Section 3.4.1) in the "HI Algorithm" subregistry of the "Host Identity Protocol (HIP) Parameters" registry.

EdDSA Curve Label:
This document specifies a new algorithm-specific subregistry named "EdDSA Curve Label". The values for this subregistry are defined in Section 3.4.1.

HIT Suite ID:
This document defines the new HIT Suite of EdDSA/cSHAKE with value TBD2 (suggested: 5) (see Section 3.4.2) in the "HIT Suite ID" subregistry of the "Host Identity Protocol (HIP) Parameters" registry.

HIT Suite ID eight-bit encoding:
This document defines the first eight-bit encoded HIT Suite IDs as defined in Section 5.2.10 of [RFC7401]. These are the new HDA domain HIT Suites with values TBD3 and TBD4 (suggested: 0x0E and 0x0F) (see Section 3.2.1). IANA is requested to expand the "HIT Suite ID" subregistry of the "Host Identity Protocol (HIP) Parameters" registry to show both the four-bit and eight-bit values as shown in Section 5.2.10 of [RFC7401] and add these new values that only have eight bit representations.

10.1. New IPv6 prefix needed for HHITs

Because HHIT format is not compatible with [RFC7343], IANA is requested to allocated a new 28-bit prefix out of the IANA IPv6 Special Purpose Address Block, namely 2001:0000::/23, as per [RFC6890] (suggested: 2001:30::/28).

11. Security Considerations

A 64-bit hash space presents a real risk of second pre-image cryptographic hash attack Section 11.2. The HHIT Registry services effectively block attempts to "take over" or "hijack" a HHIT. It does not stop a rogue attempting to impersonate a known HHIT. This attack can be mitigated by the receiver of the HHIT using DNS to find the HI for the HHIT. As such, use of DNSSEC by the HHIT registries is recommended.

Another mitigation of HHIT hijacking is if the HI owner (UA) supplies an object containing the HHIT and signed by the HI private key of the HDA such as Appendix B.1 as discussed in Section 4.6.

The two risks with hierarchical HITs are the use of an invalid HID and forced HIT collisions. The use of a DNS zone (e.g. "hhit.arpa.")

is a strong protection against invalid HIDs. Querying an HDA's RVS for a HIT under the HDA protects against talking to unregistered clients. The Registry service [drip-registries], through its HHIT uniqueness enforcement, provides against forced or accidental HIT hash collisions.

Cryptographically Generated Addresses (CGAs) provide an assurance of uniqueness. This is two-fold. The address (in this case the UAS ID) is a hash of a public key and a Registry hierarchy naming. Collision resistance (more important that it implied second-preimage resistance) makes it statistically challenging to attacks. A registration process ([drip-registries]) within the HDA provides a level of assured uniqueness unattainable without mirroring this approach.

The second aspect of assured uniqueness is the digital signing (attestation) process of the HHIT by the HI private key and the further signing (attestation) of the HI public key by the Registry's key. This completes the ownership process. The observer at this point does not know WHAT owns the HHIT, but is assured, other than the risk of theft of the HI private key, that this UAS ID is owned by something and is properly registered.

11.1. Hierarchical HIT Trust

The HHIT UAS RID in the ASTM Basic Message (Msg Type 0x0, the actual Remote ID message) does not provide any assertion of trust. The best that might be done within this Basic Message is 4 bytes truncated from a HI signing of the HHIT (the UA ID field is 20 bytes and a HHIT is 16). This is not trustable. Minimally, it takes 84 bytes, Appendix B, to prove ownership of a HHIT.

The ASTM Authentication Messages (Msg Type 0x2) as shown in Section 4.6 can provide practical actual ownership proofs. These attestations include timestamps to defend against replay attacks. But in themselves, they do not prove which UA actually sent the message. They could have been sent by a dog running down the street with a Broadcast Remote ID device strapped to its back.

Proof of UA transmission comes when the Authentication Message includes proofs for the ASTM Location/Vector Message (Msg Type 0x1) and the observer can see the UA or that information is validated by ground multilateration [crowd-sourced-rid]. Only then does an observer gain full trust in the HHIT Remote ID.

HHIT Remote IDs obtained via the Network Remote ID path provides a different approach to trust. Here the UAS SHOULD be securely communicating to the USS (see [drip-secure-nrid-c2]), thus asserting HHIT RID trust.

11.2. Collision risks with Hierarchical HITs

The 64 bit hash size does have an increased risk of collisions over the 96 bit hash size used for the other HIT Suites. There is a 0.01% probability of a collision in a population of 66 million. The probability goes up to 1% for a population of 663 million. See Appendix C for the collision probability formula.

However, this risk of collision is within a single "Additional Information" value, i.e. a RAA/HDA domain. The UAS/USS registration process should include registering the HHIT and MUST reject a collision, forcing the UAS to generate a new HI and thus HHIT and reapplying to the registration process.

11.3. Proofs Considerations

A major consideration is the optimization done in Certificate: X on Y (Concise Form) to get its length down to 200 bytes. The truncation of Certificate: HDA on HDA down to just its HHIT is one that could be used against the system to act as a false Registry. For this to occur an attacker would need to find a hash collision on that Registry HHIT and then manage to spoof all of DNS being used in the system.

The authors believe that the probability of such an attack is low when Registry operators are using best practices in security. If such an attack can occur (especially in the time frame of "one-time use IDs") then there are more serious issues present in the system.

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Appendix A. EU U-Space RID Privacy Considerations

EU is defining a future of airspace management known as U-space within the Single European Sky ATM Research (SESAR) undertaking. Concept of Operation for EuROpean UTM Systems (CORUS) project proposed low-level Concept of Operations [corus] for UAS in EU. It introduces strong requirements for UAS privacy based on European GDPR regulations. It suggests that UAs are identified with agnostic IDs, with no information about UA type, the operators or flight trajectory. Only authorized persons should be able to query the details of the flight with a record of access.

Due to the high privacy requirements, a casual observer can only query U-space if it is aware of a UA seen in a certain area. A general observer can use a public U-space portal to query UA details based on the UA transmitted "Remote identification" signal. Direct remote identification (DRID) is based on a signal transmitted by the UA directly. Network remote identification (NRID) is only possible for UAs being tracked by U-Space and is based on the matching the current UA position to one of the tracks.

The project lists "E-Identification" and "E-Registrations" services as to be developed. These services can follow the privacy mechanism proposed in this document. If an "agnostic ID" above refers to a completely random identifier, it creates a problem with identity resolution and detection of misuse. On the other hand, a classical HIT has a flat structure which makes its resolution difficult. The Hierarchical HITs provide a balanced solution by associating a registry with the UA identifier. This is not likely to cause a major conflict with U-space privacy requirements, as the registries are typically few at a country level (e.g. civil personal, military, law enforcement, or commercial).

Appendix B. Example HHIT Self Attestation

This section shows example uses of HHIT RID to prove trustworthiness of the RID and attestation of registration to the RAA|HDA. These are examples only and other documents will provide fully specified attestations. Care has been taken in the example design to minimize the risk of replay attacks.

This ownership/attestation of a HHIT can be proved in 84 bytes via the following HHIT Self Attestation following Section 6.2.1 format:

- 4 byte Signing Timestamp
- 16 byte HHIT
- 64 byte Signature (EdDSA25519 signature)

The Timestamp MAY be the standard UNIX time at the time of signing. A protocol specific timestamp may be used to avoid programming complexities. For example, [F3411-19] uses a 00:00:00 01/01/2019 offset.

To minimize the risk of replay, the UA SHOULD create a new Self Attestation, with a new timestamp, at least once a minute. The UA MAY precompute these attestations and transmit during the appropriate 1 minute window. 1 minute is chosen as a balance between attestation compute time against risk. A shorter window of use lessens the risk of replay.

The signature is over the 20 byte Timestamp + HHIT.

The receiver of such an attestation would need access to the underlying public key (HI) to validate the signature. This may be obtained via a DNS query using the HHIT. A larger (116 bytes) Self Attestation could include the EdDSA25519 HI. This larger 116 attestation allows for signature validation before HHIT lookup to prove registration attestation.

B.1. HHIT Offline Self Attestation

Ownership and RAA|HDA registration of a HHIT can be proved in 200 bytes without Internet access and a small cache via the following HHIT Offline Self Attestation Section 6.2 format:

- *16 byte UA HHIT
- *32 byte UA EdDSA25519 HI
- *4 byte HDA Signing Expiry Timestamp
- *16 byte HDA HHIT
- *64 byte HDA Signature (EdDSA25519 signature)
- *4 byte UA Signing Timestamp
- *64 byte UA Signature (EdDSA25519 signature)

The Timestamps MAY be the standard UNIX time at the time of signing. A protocol specific timestamp may be used to avoid programming complexities. For example, [F3411-19] uses a 00:00:00 01/01/2019 offset.

The HDA signature is over the 68 byte UA HHIT + UA HI + HDA Expiry Timestamp + HDA HHIT. During the UA Registration process, the UA would provide a Self Attestation to the HDA. The HDA would construct its attestation of registry with an Expiry Timestamp, its own HHIT, and its signature, returning a 132 byte HDA Registry Attestation to the UA. The UA would use this much the same way as its HHIT only in the Self Attestation above, creating a 200 byte Offline Self Attestation.

The receiver of such an attestation would need a cache of RAA ID, HDA ID, HDA HHIT, and HDA HI (min 80 bytes per RAA/HDA).

Appendix C. Calculating Collision Probabilities

The accepted formula for calculating the probability of a collision is:

```
p = 1 - e^{-k^2/(2n)}
```

```
P   Collision Probability
n   Total possible population
k   Actual population
```

The following table provides the approximate population size for a collision for a given total population.

Total Population	Deployed Population With Collision Risk of .01%	1%
2^96	4T	42T
2^72	1B	10B
2^68	250M	2.5B
2^64	66M	663M
2^60	16M	160M

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