
Stream: Internet Engineering Task Force (IETF)
RFC: [9886](#)
Category: Standards Track
Published: December 2025
ISSN: 2070-1721
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RFC 9886

DRIP Entity Tags (DETs) in the Domain Name System

Abstract

This document defines the Domain Name System (DNS) functionality of a Drone Remote Identification Protocol (DRIP) Identity Management Entity (DIME). It is built around DRIP Entity Tags (DETs) to standardize a hierarchical registry structure and associated processes to facilitate trustable and scalable registration and lookup of information related to Unmanned Aircraft Systems (UAS). The registry system supports issuance, discovery, and verification of DETs, enabling secure identification and association of UAS and their operators. It also defines the interactions between different classes of registries (root, organizational, and individual) and their respective roles in maintaining the integrity of the registration data. This architecture enables decentralized, federated operation while supporting privacy, traceability, and regulatory compliance requirements in the context of UAS Remote Identification and other services.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

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1. Introduction

Registries are fundamental to Unmanned Aircraft System (UAS) Remote Identification (RID). Only very limited operational information can be sent via Broadcast RID, but extended information is sometimes needed. The most essential element of information from RID is the UAS ID, the unique key for lookup of extended information in relevant registries (see [Figure 1](#), which is the same as Figure 4 of [\[RFC9434\]](#)).

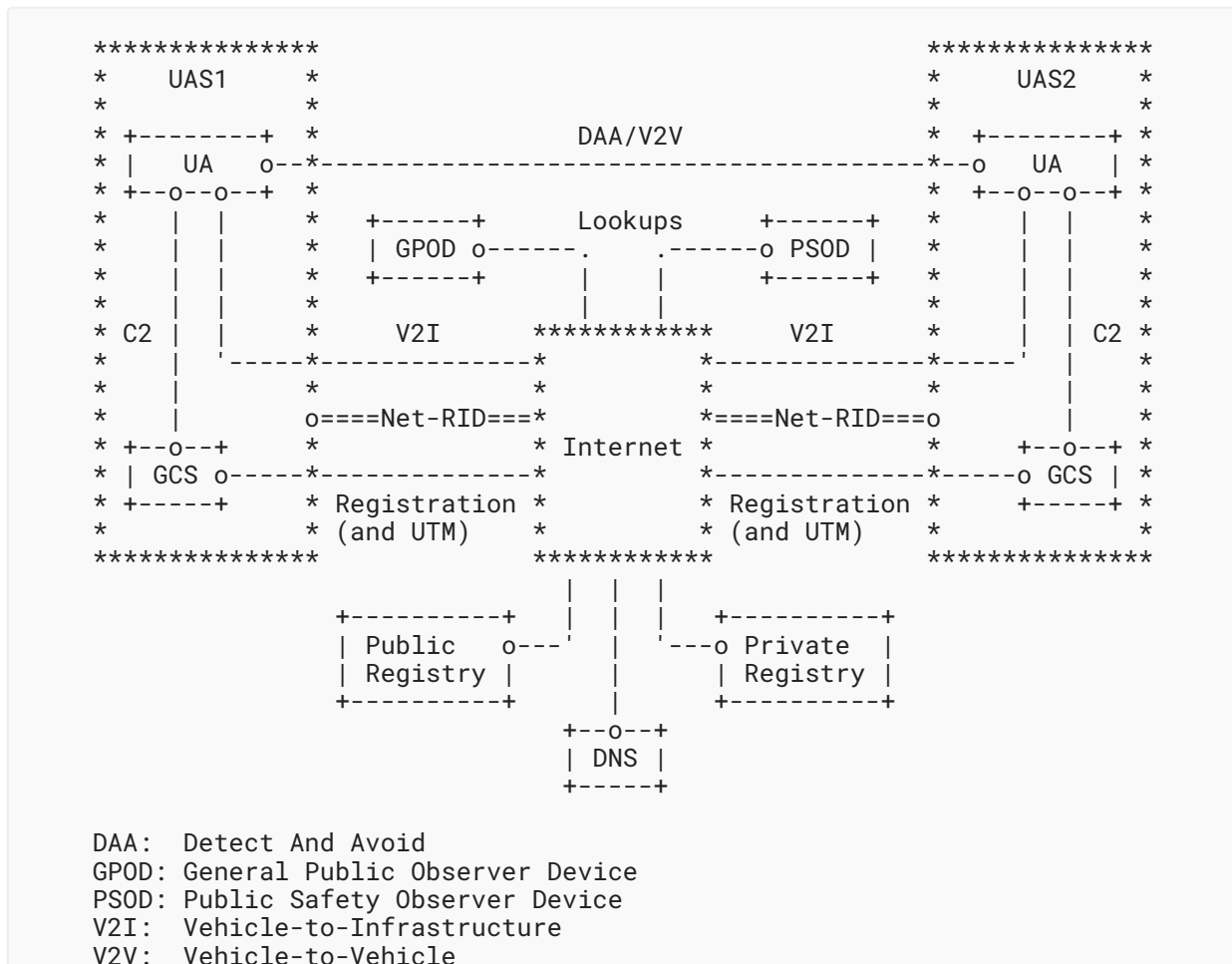


Figure 1: Global UAS RID Usage Scenario (Figure 4 of RFC 9434)

When a DRIP Entity Tag (DET) [RFC9374] is used as the UAS ID in RID, extended information can be retrieved from a DRIP Identity Management Entity (DIME), which manages registration of and associated lookups from DETs. In this document it is assumed the DIME is a function of UAS Service Suppliers (USS) (Appendix A.2 of [RFC9434]), but a DIME can be independent or handled by another entity as well.

1.1. General Concept

DRIP Entity Tags (DETs) embed a hierarchy scheme that is mapped onto the Domain Name System (DNS) [STD13]. DIMEs enforce registration and information access of data associated with a DET while also providing the trust inherited from being a member of the hierarchy. Other identifiers and their methods are out of scope for this document.

Authoritative name servers of the DNS provide the public information such as the cryptographic keys, endorsements and certificates of DETs, and pointers to private information resources. Cryptographic (public) keys are used to authenticate anything signed by a DET, such as in the Authentication Messages defined in [\[RFC9575\]](#) for Broadcast RID. Endorsements and certificates are used to endorse the claim of being part of the hierarchy.

This document does not specify AAA mechanisms used by Private Information Registries to store and protect Personally Identifiable Information (PII).

1.2. Scope

The scope of this document is the DNS registration of DETs with the DNS delegation of the reverse domain of the IPv6 prefix (2001:30::/28 for DETs) and RRsets used to handle DETs.

2. Terminology

2.1. Required 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. Additional Definitions

This document makes use of the terms and abbreviations from previous DRIP documents. Below are subsets, grouped by original document, of terms used this document. Please see those documents for additional context, definitions, and any further referenced material.

From [Section 2.2](#) of [\[RFC9153\]](#), this document uses: AAA, CAA, GCS, ICAO, PII, Observer, Operator, UA, UAS, USS, and UTM.

From [Section 2](#) of [\[RFC9434\]](#), this document uses: Certificate, DIME, and Endorsement.

From [Section 2](#) of [\[RFC9374\]](#), this document uses: HDA, HID, and RAA.

3. DET Hierarchy in DNS

[\[RFC9374\]](#) defines the Hierarchical Host Identity Tags (HHIT) and further specifies an instance of them used for UAS RID called DET. The DET is a 128-bit value that is an IPv6 address intended primarily as an identifier rather than locator. The format is shown in [Figure 2](#) and further information is in [\[RFC9374\]](#).

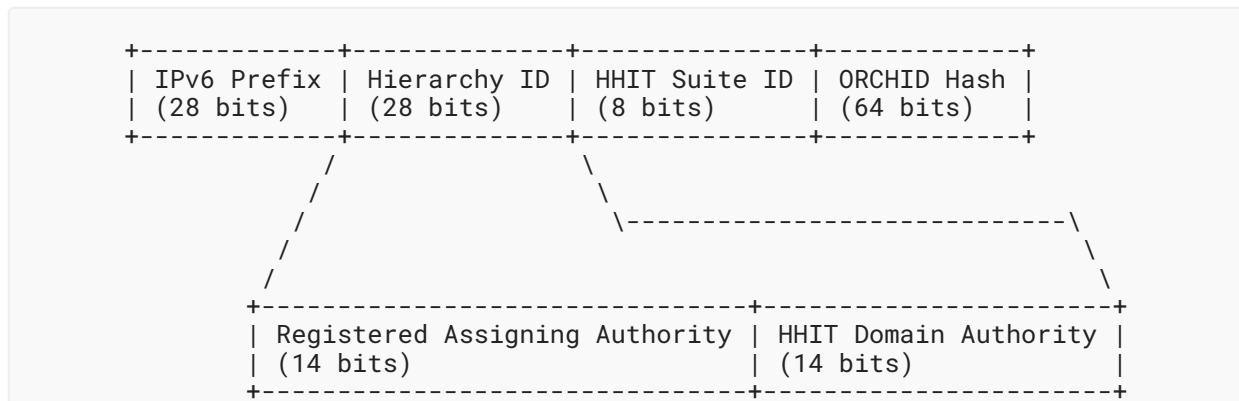


Figure 2: DRIP Entity Tag Breakdown

[RFC9374] assigns the IPv6 prefix `2001:30::/28` for DETs. Its corresponding domain name for reverse lookups is `3.0.0.1.0.0.2.ip6.arpa..` The IAB has administrative control of this domain name.

Due to the nature of the hierarchy split and its relationship to nibble reversing of the IPv6 address (Section 2.5 of RFC 3596 [STD88]), the upper level of the hierarchy (i.e., Registered Assigning Authority (RAA)) "borrows" the upper two bits of their respective HHIT Domain Authority (HDA) space for DNS delegation. As such, the IPv6 prefix of RAAs is `2001:3x:xxx0::/44` and HDAs is `2001:3x:xxxy:yy00::/56` with respective nibble reverse domains of `x.x.x.x.3.0.0.1.0.0.2.ip6.arpa.` and `y.y.y.x.x.x.x.x.3.0.0.1.0.0.2.ip6.arpa..`

This document preallocates a subset of RAAs based on the ISO 3166-1 Numeric Nation Code [ISO3166-1]. This is to support the initial use case of DETs in UAS RID on an international level. See Section 6.2.1 for the RAA allocations.

The HDA values of 0, 4096, 8192, and 12288 are reserved for operational use of an RAA (a by-product of the above mentioned borrowing of bits), in particular to specify when to register with the apex and endorse delegations of HDAs in their namespace.

The administration, management, and policy for the operation of a DIME at any level in the hierarchy (Apex, RAA or HDA) is out of scope for this document. For RAAs or DETs allocated on a per-country basis, these considerations should be determined by the appropriate national authorities, presumably the Civil Aviation Authority (CAA).

3.1. Use of Existing DNS Models

DRIP relies on the DNS and as such roughly follows the registrant-registrar-registry model. In the UAS ecosystem, the registrant would be the end user who owns/controls the Unmanned Aircraft. They are ultimately responsible for the DET and any other information that gets published in the DNS. Registrants use agents known as registrars to manage their interactions with the registry. Registrars typically provide optional additional services such as DNS hosting.

The registry maintains a database of the registered domain names and their related metadata such as the contact details for domain name holder and the relevant registrar. The registry provides DNS service for the zone apex, which contains delegation information for domain names. Registries generally provide services such as the Registration Data Access Protocol (RDAP) [STD95] or equivalent to publish metadata about the registered domain names and their registrants and registrars.

Registrants have contracts with registrars who in turn have contracts with registries. Payments follow this model too: the registrant buys services from a registrar who pays for services provided by the registry.

By definition, there can only be one registry for a domain name. A registry can have an arbitrary number of registrars who compete with each other on price, service, and customer support.

3.1.1. DNS Model Considerations for DIMES

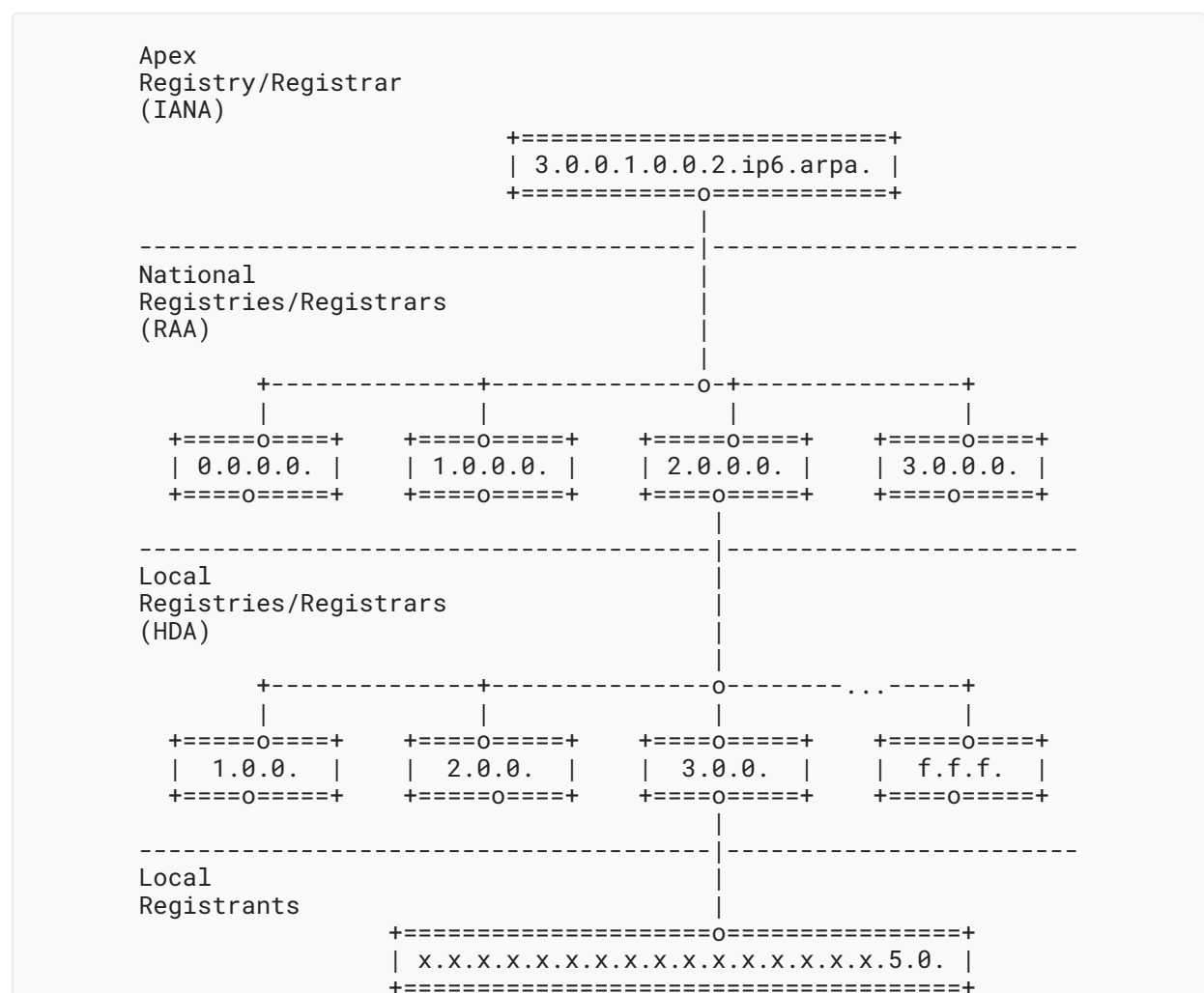


Figure 3: Example DRIP DNS Model

While the registrant-registrar-registry model is mature and well understood, it may not be appropriate for DRIP registrations in some circumstances. It could add costs and complexity to develop policies and contracts as outlined above. On the other hand, registries and registrars offer customer service and support and can provide the supporting infrastructure for reliable DNS and RDAP service.

Another approach could be to handle DRIP registrations in a comparable way to how IP address space gets provisioned. Here, blocks of addresses get delegated to a "trusted" third party, typically an ISP, who then issues IP addresses to its customers. For DRIP, blocks of IP addresses could be delegated from the `3.0.0.1.0.0.2.ip6.arpa.` domain (reverse domain of prefix allocated by [\[RFC9374\]](#)) to an entity chosen by the appropriate Civil Aviation Authority (CAA). This third party would be responsible for the corresponding DNS and RDAP infrastructure for these IP address blocks. They would also provision the HHIT records [\[RFC9374\]](#) for these IP addresses. In principle, a manufacturer or vendor of UAS devices could provide that role. This is shown as an example in [Figure 3](#).

Dynamic DRIP registration is another possible solution, for example when the operator of a UAS device registers its corresponding HHIT record and other resources before a flight and deletes them afterwards. This may be feasible in controlled environments with well-behaved actors. However, this approach may not scale since each device is likely to need credentials for updating the IT infrastructure that provisions the DNS.

Registration policies (pricing, renewals, registrar, and registrant agreements, etc.) will need to be developed. These considerations should be determined by the CAA, perhaps in consultation with local stakeholders to assess the cost-benefits of these approaches (and others). All of these are out of scope for this document. The specifics for the UAS RID use case are detailed in the rest of document.

4. Public Information Registry

Per [\[RFC9434\]](#), all information classified as public is stored in the DNS, specifically authoritative name servers, to satisfy REG-1 from [\[RFC9153\]](#).

Authoritative name servers use domain names as identifiers and data is stored in Resource Records (RRs) with associated RRTypes. This document defines two new RRTypes, one for HHIT metadata (HHIT, [Section 5.1](#)) and another for UAS Broadcast RID information (BRID, [Section 5.2](#)). The former RRTYPE is particularly important as it contains a URI (as part of the certificate) that points to Private Information resources.

DETs, being IPv6 addresses, are to be under `ip6.arpa.` (nibble reversed per [Section 2.5](#) of RFC 3596 [\[STD88\]](#)) and **MUST** resolve to an HHIT RRTYPE. Depending on local circumstances or additional use cases, other RRTypes **MAY** be present (for example the inclusion of the DS RRTypes or equivalent when using DNSSEC). For UAS RID, the BRID RRTYPE **MUST** be present to provide the Broadcast Endorsements (BEs) defined in [Section 3.1.2.1](#) of [\[RFC9575\]](#).

DNSSEC **MUST** be used for apex entities (those which use a self-signed Canonical Registration Certificate) and is **RECOMMENDED** for other entities. When a DIME decides to use DNSSEC, they **SHOULD** define a framework for cryptographic algorithms and key management [RFC6841]. This may be influenced by the frequency of updates, size of the zone, and policies.

UAS-specific information, such as physical characteristics, may also be stored in DNS but is out of scope for this document.

[illegible]

The HHIT RRTYPE provides the public key for signature verification and URIs via the certificate. The BRID RRTYPE provides static Broadcast RID information such as the Broadcast Endorsements sent as described in [RFC9575].

5. Resource Records

5.1. HHIT Resource Record

The HHIT Resource Record (HHIT, RRTYPE 67) [RFC8005] is a metadata record for various bits of HHIT-specific information that isn't available in the pre-existing HIP RRTYPE. The HHIT RRTYPE does not replace the HIP RRTYPE. The primary advantage of the HHIT RRTYPE over the existing RRTYPE is the mandatory inclusion of the Canonical Registration Certificate containing an entity's public key signed by the registrar, or other trust anchor, to confirm registration.

The data **MUST** be encoded in the Concise Binary Object Representation (CBOR) [RFC8949] bytes. The Concise Data Definition Language (CDDL) [RFC8610] of the data is provided in Figure 4.

5.1.1. Text Representation

The data are represented in base64 [RFC4648] and may be divided into any number of white-space-separated substrings, down to single base64 digits, which are concatenated to obtain the full object. These substrings can span lines using the standard parenthesis. Note that the data has internal subfields but these do not appear in the zone file representation; only a single logical base64 string will appear.

5.1.1.1. Presentation Representation

The data **MAY**, for display purposes only, be represented using the Extended Diagnostic Notation as defined in [Appendix G](#) of [RFC8610].

5.1.2. Field Descriptions

```
hhit-rr = [  
    hhit-entity-type: uint,  
    hid-abbreviation: tstr .size(15),  
    canonical-registration-cert: bstr  
]
```

Figure 4: HHIT Wire Format CDDL

All fields of the HHIT RRTYPE **MUST** be included to be properly formed.

HHIT Entity Type: The HHIT Entity Type field is a number with values defined in [Section 6.2.2](#). It is envisioned that there may be many types of HHITs in use. In some cases, it may be helpful to understand the role of the HHITs in the ecosystem, like that described in [\[drip-dki\]](#). This field provides such context. This field **MAY** provide a signal of additional information and/or different handling of the data beyond what is defined in this document.

HID Abbreviation: The HID Abbreviation field is a string that provides an abbreviation to the HID (Hierarchy ID) structure of a DET for display devices. The convention for such abbreviations is a matter of local policy. Absent of such a policy, this field **MUST** be filled with the four character hexadecimal representations of the RAA and HDA (in that order) with a separator character, such as a space, in between. For example, a DET with an RAA value of 10 and HDA value of 20 would be abbreviated as: 000A 0014.

Canonical Registration Certificate: The Canonical Registration Certificate field is for a certificate-endorsing registration of the DET. It **MUST** be encoded as X.509 DER [\[RFC5280\]](#). This certificate **MAY** be self-signed when the entity is acting as a root of trust (i.e., an apex). Such self-signed behavior is defined by policy, such as in [\[drip-dki\]](#), and is out of scope for this document. This certificate is part of a chain of certificates that can be used to validate inclusion in the hierarchy.

5.2. UAS Broadcast RID Resource Record

The UAS Broadcast RID Resource Record (BRID, RRTYPE 68) is a format to hold information typically sent over UAS Broadcast RID that is static. It can act as a data source if information is not received over Broadcast RID or for cross validation. The primary function for DRIP is to include one or more Broadcast Endorsements as defined in [\[RFC9575\]](#) in the auth field. These Endorsements are generated by the registrar upon successful registration and broadcast by the entity.

The data **MUST** be encoded in CBOR [\[RFC8949\]](#) bytes. The CDDL [\[RFC8610\]](#) of the data is provided in [Figure 5](#).

5.2.1. Text Representation

The data are represented in base64 [[RFC4648](#)] and may be divided into any number of white-space-separated substrings, down to single base64 digits, which are concatenated to obtain the full object. These substrings can span lines using the standard parenthesis. Note that the data has internal subfields but these do not appear in the zone file representation; only a single logical base64 string will appear.

5.2.1.1. Presentation Representation

The data **MAY**, for display purposes only, be represented using the Extended Diagnostic Notation as defined in [Appendix G](#) of [[RFC8610](#)]. All byte strings longer than a length of 20 **SHOULD** be displayed as base64 when possible.

5.2.2. Field Descriptions

```

bcast-rr = {
    uas_type => nibble-field,
    uas_ids => [+ uas-id-grp],
    ? auth => [+ auth-grp],
    ? self_id => self-grp,
    ? area => area-grp,
    ? classification => classification-grp,
    ? operator_id => operator-grp
}
uas-id-grp = [
    id_type: &uas-id-types,
    uas_id: bstr .size(20)
]
auth-grp = [
    a_type: &auth-types,
    a_data: bstr .size(1..362)
]
area-grp = [
    area_count: 1..255,
    area_radius: float, # in decameters
    area_floor: float, # wgs84-hae in meters
    area_ceiling: float # wgs84-hae in meters
]
classification-grp = [
    class_type: 0..8,
    class: nibble-field,
    category: nibble-field
]
self-grp = [
    desc_type: 0..255,
    description: tstr .size(23)
]
operator-grp = [
    operator_id_type: 0..255,
    operator_id: bstr .size(20)
]
uas-id-types = (none: 0, serial: 1, session_id: 4)
auth-types = (none: 0, specific_method: 5)
nibble-field = 0..15
uas_type = 0
uas_ids = 1
auth = 2
self_id = 3
area = 4
classification = 5
operator_id = 6

```

Figure 5: BRID Wire Format CDDL

The field names and their general typing are taken from the ASTM data dictionary (Tables 1 and 2) [F3411]. See that document for additional context and background information on aviation application-specific interpretation of the field semantics. The explicitly enumerated values

included in the CDDL above are relevant to DRIP for its operation. Other values may be valid but are outside the scope of DRIP operation. Application-specific fields, such as UAS Type, are transported and authenticated by DRIP but are regarded as opaque user data to DRIP.

6. IANA Considerations

6.1. DET Prefix Delegation

The reverse domain for the DET Prefix, i.e., `3.0.0.1.0.0.2.ip6.arpa.`, is managed by IANA. IANA will liaise, as needed, with the International Civil Aviation Organization (ICAO) to verify the authenticity of delegations to CAAs (see [Section 6.2.1.4](#)).

6.2. IANA DRIP Registry

6.2.1. DRIP RAA Allocations

IANA has created the registry for RAA Allocations under the ["Drone Remote ID Protocol" registry group](#).

RAA Allocations: a 14-bit value used to represent RAAs. Future additions to this registry are to be made based on the following range and policy table:

RAA Range	Allocation	Policy
0 - 3	Reserved	
4 - 3999	ISO 3166-1 Countries	IESG Approval (Section 4.10 of [RFC8126]), Section 6.2.1.4
4000 - 8191	Reserved	
8192 - 15359	Unassigned	First Come First Served (Section 4.4 of [RFC8126])
15360 - 16383	Private Use	Private Use (Section 4.1 of [RFC8126]), Section 6.2.1.5

Table 1: RAA Ranges

6.2.1.1. RAA Allocation Fields

- Value: The RAA value delegated for this entry.
- Name: Name of the delegated RAA. For the ISO 3166-1 Countries ([Section 6.2.1.4](#)), this should be the name of the country.
- Reference: A publicly accessible link to the policy requirements for prospective HDA operators to register under this RAA. This field is **OPTIONAL**.

Contact: Contact details of the administrator of this RAA that prospective HDA operators can make informational queries to.

6.2.1.2. RAA Registration Form

```
Value:
Name:
Reference:
Contact:
NS RRTYPE Content (HDA=0):
NS RRTYPE Content (HDA=4096):
NS RRTYPE Content (HDA=8192):
NS RRTYPE Content (HDA=12288):
```

Figure 6: RAA Delegation Request Form

The NS RRTYPE Content (HDA=X) fields are used by IANA to perform the DNS delegations under 3.0.0.1.0.0.2.ip6.arpa.. See [Section 6.2.1.3](#) for technical details.

6.2.1.3. Handling Nibble Split

To support DNS delegation in `3.0.0.1.0.0.2.ip6.arpa.`, a single RAA is given 4 delegations by borrowing the upper two bits of HDA space (see [Figure 7](#) for an example). This enables a clean nibble boundary in the DNS to delegate from (i.e., the prefix `2001:3x:xx00::/44`). These HDAs (0, 4096, 8192 and 12288) are reserved for the RAA.

[illegible]

Figure 7: Example Bit Borrowing of $RAA=16376$

6.2.1.4. ISO 3166-1 Countries Range

The mapping between ISO 3166-1 Numeric Nation Codes and RAAs is specified and documented by IANA. Each Nation is assigned 4 RAAs that are left to the national authority for their purpose. For RAAs under this range, a shorter prefix of 2001:3x:xx00::/40 **MAY** be delegated to each CAA, which covers all 4 RAAs (and reserved HDAs) assigned to them.

The registration policy for this range is set to IESG Approval (Section 4.10 of [RFC8126]) and IANA will liaise with the ICAO to verify the authenticity of delegation requests (using Figure 6) by CAAs.

6.2.1.5. Private Range

If nibble-reversed lookup in DNS is desired, it can only be provided by private DNS servers as zone delegations from the global root will not be performed for this address range. Thus the RAAs (with its subordinate HDAs) in this range may be used in like manner and IANA will not delegate any value in this range to any party (as per Private Use, [Section 4.1](#) of [\[RFC8126\]](#)).

One anticipated acceptable use of the private range is for experimentation and testing prior to request allocation or assignment from IANA.

6.2.2. HHIT Entity Types

This document requests a new registry for HHIT Entity Types under the ["Drone Remote ID Protocol"](#) registry group.

HHIT Entity Type: Numeric, field of the HHIT RRTYPE to encode the HHIT Entity Type. All entries in this registry are under the First Come First Served policy ([Section 4.4](#) of [\[RFC8126\]](#)).

6.2.2.1. HHIT Type Registry Fields

Value: HHIT Type value of the entry.

HHIT Type: Name of the entry and an optional abbreviation.

Reference: Public document allocating the value and any additional information such as semantics. This can be a URL pointing to an Internet-Draft, IETF RFC, or web page among others.

6.2.2.2. HHIT Type Registration Form

Value:

HHIT Type:

Reference:

Figure 8: HHIT Type Registration Form

6.2.2.3. Initial Values

The following values are defined by this document:

Value	HHIT Type	Reference
0	Not Defined	RFC 9886
1	DRIP Identity Management Entity (DIME)	RFC 9886
5	Apex	RFC 9886

Value	HHIT Type	Reference
9	Registered Assigning Authority (RAA)	RFC 9886
13	HHIT Domain Authority (HDA)	RFC 9886
16	Unmanned Aircraft (UA)	RFC 9886
17	Ground Control Station (GCS)	RFC 9886
18	Unmanned Aircraft System (UAS)	RFC 9886
19	Remote Identification (RID) Module	RFC 9886
20	Pilot	RFC 9886
21	Operator	RFC 9886
22	Discovery & Synchronization Service (DSS)	RFC 9886
23	UAS Service Supplier (USS)	RFC 9886
24	Network RID Service Provider (SP)	RFC 9886
25	Network RID Display Provider (DP)	RFC 9886
26	Supplemental Data Service Provider (SDSP)	RFC 9886
27	Crowd Sourced RID Finder	RFC 9886

Table 2: HHIT Entity Type Initial Values

7. Security Considerations

7.1. DNS Operational and Registration Considerations

The Registrar and Registry are commonly used concepts in the DNS. These components connect the DIME with the DNS hierarchy and thus operation **SHOULD** follow best common practices, specifically in security (such as running DNSSEC) as appropriate except when national regulations prevent it. [BCP237] provides suitable guidance.

If DNSSEC is used, a DNSSEC Practice Statement **SHOULD** be developed and published. It **SHOULD** explain how DNSSEC has been deployed and what security measures are in place. [RFC6841] documents a framework for DNSSEC policies and DNSSEC Practice Statements. A self-signed entity (i.e., an entity that self-signed its certificate as part of the HHIT RRTYPE) **MUST** use DNSSEC.

The interfaces and protocol specifications for registry-registrar interactions are intentionally not specified in this document. These will depend on nationally defined policy and prevailing local circumstances. It is expected that registry-registrar activity will use the Extensible Provisioning Protocol (EPP) [STD69] or equivalent. The registry **SHOULD** provide a lookup service such as RDAP [STD95] or equivalent to publish public information about registered domain names.

Decisions about DNS or registry best practices and other operational matters that influence security **SHOULD** be made by the CAA, ideally in consultation with local stakeholders.

The guidance above is intended to reduce the likelihood of interoperability problems and minimize security and stability concerns. For instance, validation and authentication of DNS responses depends on DNSSEC. If this is not used, entities using DRIP will be vulnerable to DNS spoofing attacks and could be exposed to bogus data. DRIP DNS responses that have not been validated by DNSSEC could contain bogus data that have the potential to create serious security problems and operational concerns for DRIP entities. These threats include denial-of-service attacks, replay attacks, impersonation or cloning of UAVs, hijacking of DET registrations, injection of corrupt metadata, and compromising established trust architecture/relationships. Some regulatory and legal considerations are expected to be simplified by providing a lookup service for access to public information about registered domain names for DETs.

When DNSSEC is not in use, due to the length of the ORCHID hash selected for DETs (Section 3.5 of [RFC9374]), clients **MUST** "walk" the tree of certificates locating each certificate by performing DNS lookups of HHIT RRTypes for each DET verifying inclusion into the hierarchy. The collection of these certificates (which provide both signature protection from the parent entity and the public key of the entity) is the only way without DNSSEC to prove valid registration.

The contents of the BRID RRTYPE auth key, containing Endorsements as described in Section 4.2 of [RFC9575], are a shadow of the X.509 certificate found in the HHIT RRTYPE. The validation of these Endorsements follow the guidelines written in Section 6.4.2 of [RFC9575] for Broadcast RID Observers and when present **MUST** also be validated.

7.2. DET and Public Key Exposure

DETs are built upon asymmetric keys. As such the public key must be revealed to enable clients to perform signature verifications. [RFC9374] security considerations cover various attacks on such keys. While unlikely, the forging of a corresponding private key is possible if given enough time (and computational power).

When practical, it is **RECOMMENDED** that no RRTypes under a DET's specific domain name be published unless and until it is required for use by other parties. Such action would cause at least the HHIT RRTYPE to not be in the DNS, protecting the public key in the certificate from being exposed before its needed. The combination of this "just in time" publishing mechanism and DNSSEC is out of scope for this document.

Optimally this requires that the UAS somehow signal to the DIME that a flight using a Specific Session ID will soon be underway or complete. It may also be facilitated under UTM if the USS (which may or may not be a DIME) signals when a given operation using a Session ID goes active.

8. References

8.1. Normative References

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-
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-

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Blanchet, M., "Finding the Authoritative Registration Data Access Protocol (RDAP) Service", STD 95, RFC 9224, DOI 10.17487/RFC9224, March 2022, <<https://www.rfc-editor.org/info/rfc9224>>.

Appendix A. Example Zone Files and RRType Contents

An example zone file `ip6.arpa.`, run by IANA, is not shown. It would contain NS RRTypes to delegate to a respective RAA. To avoid any future collisions with production deployments an apex of `ip6.example.com.` is used instead of `ip6.arpa.` All hexadecimal strings in the examples are broken into the lengths of a word, for document formatting purposes.

An RAA with a HID of `RAA=16376`, `HDA=0` and HDA with a the HID `RAA=16376`, `HDA=10` were used in the examples.

A.1. Example RAA

A.1.1. Authentication HHIT

```
$ORIGIN 5.0.0.0.0.e.f.f.3.0.0.1.0.0.2.ip6.example.com.
7.b.0.a.1.9.e.1.7.5.1.a.0.6.e.5. IN HHIT (
  gwppM2Zm0CAwMDAwWQFGMIIBQjCB9aAD
  AgECAgE1MAUGAytlcDArMSkwJwYDVQQD
  DCAYMDAxMDAzZmZlMDAwMDA1NWU2MGEx
  NTcxZTkxYTBiNzAeFw0yNTA0MDkyMDU2
  MjZaFw0yNTA0MDkyMTU2MjZaMB0xGzAZ
  BgNVBAMMEkRSSVAtUkFBLUEtMTYzNzYt
  MDAqMAUGAytlcAMhAJmQ1bBLcGZtQJ
  K1LH1JlPt8Fr1+jB9ED/qNBP8eE/o0ww
  SjAPBgNVHRMBAf8EBTADAQH/MdcGA1Ud
  EQEB/wQtMCuHECABAD/+AAAFxmChVx6R
  oLeGF2h0dHBzOi8vcmlmV4YW1wbGUu
  Y29tMAUGAytlcANBALUPjhIB3rwqXQep
  r9/VDB+hhtwuWZIW10UkEuDrF6DCkgc7
  5widXnXa5/uDfdKL7dZ83mPHm2Tf32Dv
  b8AzEw8=
)
```

Figure 9: RAA Auth HHIT RRType Example

Figure 10 shows the CBOR decoded RDATA in the HHIT RRType found in Figure 9.

```
[
  10, # Reserved (RAA Auth from DKIM)
  "3ff8 0000",
  h'308201423081F5A00302010202013530
0506032B6570302B312930270603550403
0C20323030313030336666653030303030
3535653630613135373165393161306237
301E170D3235303430393230353632365A
170D3235303430393231353632365A301D
311B301906035504030C12445249502D52
41412D412D31363337362D30302A300506
032B6570321009990D5B04B72A18066D4
092B52C7D4994FB7C16BD7E8C1F440FFA8
D04FF1E13FA34C304A300F0603551D1301
01FF040530030101FF30370603551D1101
01FF042D302B87102001003FFE0000055E
60A1571E91A0B7861768747470733A2F2F
7261612E6578616D706C652E636F6D3005
06032B657034100B50F8E1201DEBC2A5D
07A9AFDFD50C1FA186DC2E599230D4E524
12E0EB17A0C292073BE7089D5E75DAE7FB
837DD28BEDD67CDE63C79B64DFDF60EF6F
C033130F'
]
```

Figure 10: 2001:3f:fe00:5:5e60:a157:1e91:a0b7 Decoded HHIT RRType CBOR

Figure 11 shows the decoded DER X.509 found in Figure 10.

```

Certificate:
  Data:
    Version: 3 (0x2)
    Serial Number: 53 (0x35)
    Signature Algorithm: ED25519
    Issuer: CN = 2001003ffe0000055e60a1571e91a0b7
    Validity
      Not Before: Apr  9 20:56:26 2025 GMT
      Not After : Apr  9 21:56:26 2025 GMT
    Subject: CN = DRIP-RAA-A-16376-0
    Subject Public Key Info:
      Public Key Algorithm: ED25519
      ED25519 Public-Key:
        pub:
          99:90:d5:b0:4b:72:a1:80:66:d4:09:2b:52:c7:d4:
          99:4f:b7:c1:6b:d7:e8:c1:f4:40:ff:a8:d0:4f:f1:
          e1:3f
    X509v3 extensions:
      X509v3 Basic Constraints: critical
      CA:TRUE
      X509v3 Subject Alternative Name: critical
      IP Address:2001:3F:FE00:5:5E60:A157:1E91:A0B7,
      URI:https://raa.example.com
    Signature Algorithm: ED25519
    Signature Value:
      b5:0f:8e:12:01:de:bc:2a:5d:07:a9:af:df:d5:0c:1f:a1:86:
      dc:2e:59:92:30:d4:e5:24:12:e0:eb:17:a0:c2:92:07:3b:e7:
      08:9d:5e:75:da:e7:fb:83:7d:d2:8b:ed:d6:7c:de:63:c7:9b:
      64:df:df:60:ef:6f:c0:33:13:0f

```

Figure 11: 2001:3f:fe00:5:5e60:a157:1e91:a0b7 Decoded Certificate

A.1.2. Delegation of HDA

```

$ORIGIN c.d.f.f.3.0.0.1.0.0.2.ip6.example.com.
a.0.0. IN NS ns1.hda-10.example.com

```

Figure 12: HDA Delegation Example

A.2. Example HDA

A.2.1. Authentication and Issue HHITs

```

$ORIGIN 5.0.a.0.0.0.e.f.f.3.0.0.1.0.0.2.ip6.example.com.
0.a.9.0.7.2.4.d.5.4.e.e.5.1.6.6.5.0. IN HHIT (
  gw5pM2ZmOCAwMDBhWQFHMIIBQzCB9qAD
  AgECAgFfMAUGAytlcDArMSkwJwYDVQQD
  DCAYMDAxMDAzZmZlMDAwMDA1NWU2MGEx
  NTcxZTkxYTBiNzAeFw0yNTA0MDkyMTAz
  MTlaFw0yNTA0MDkyMjAzMTlaMB4xHDAa
  BgNVBAMME0RSSVAtSERBLUEtMTYzNzYt
  MTAwKjAFBgMrZXADIQD0aB424RQa61YN
  bna8eWt7fLRU5GPMsfEt4wo4AQGAP6NM
  MEowDwYDVR0TAQH/BAUwAwEB/zA3BgNV
  HREBAf8ELTArhxAgAQA//gAKBWYV7kXU
  JwmghhdodHRwczovL3JhYS5leGFtcGx1
  LmNvbTAFBgMrZXADQQAjMjY0MDkxY1
  f+B9nTgawUjK4YEERBtczMknHdK0owX0
  ynbaLN60TYe9hqN6+CJ3SN8brJke3hpM
  gorvhDkJ
)
8.2.e.6.5.2.b.6.7.3.4.d.e.0.6.2.5.0. IN HHIT (
  gw9pM2ZmOCAwMDBhWQFHMIIBQzCB9qAD
  AgECAgFYMAUGAytlcDArMSkwJwYDVQQD
  DCAYMDAxMDAzZmZlMDAwYTA1NjYxNWVl
  NDVkdDI3MDIhMDAeFw0yNTA0MDkyMTA1
  MTRaFw0yNTA0MDkyMjA1MTRaMB4xHDAa
  BgNVBAMME0RSSVAtSERBLUktMTYzNzYt
  MTAwKjAFBgMrZXADIQCCM/2utQaLwUhZ
  0R0g7fz43AeBTj3Sd15rW4LgTQcF16NM
  MEowDwYDVR0TAQH/BAUwAwEB/zA3BgNV
  HREBAf8ELTArhxAgAQA//gAKBSY01Ddr
  JW4ohhdodHRwczovL2hkYS5leGFtcGx1
  LmNvbTAFBgMrZXADQQAjMjY0MDkxY1
  Vgv4Rt+cMUmc8aQwet4UZd03yQ0B9uq4
  sLVAScaZCWjC0nmerkgVRhize1esfyi3
  RRU44IAE
)

```

Figure 13: HDA Auth/Issue HHIT RRType Example

Figure 14 shows the CBOR decoded RDATA in the HHIT RRType found in Figure 13.


```
[
  14, # Reserved (HDA Auth from DK1)
  "3ff8 000a",
  h'308201433081F6A00302010202015F30
  0506032B6570302B312930270603550403
  0C20323030313030336666653030303030
  3535653630613135373165393161306237
  301E170D3235303430393231303331395A
  170D3235303430393232303331395A301E
  311C301A06035504030C13445249502D48
  44412D412D31363337362D3130302A3005
  06032B6570032100CE681E36E1141AEB56
  0D6E76BC796B7B7CB454E463CCB1F12DE3
  0A380101803FA34C304A300F0603551D13
  0101FF040530030101FF30370603551D11
  0101FF042D302B87102001003FFE000A05
  6615EE45D42709A0861768747470733A2F
  2F7261612E6578616D706C652E636F6D30
  0506032B6570034100213293923A680C90
  96357FE07D9D381AC148CAE18104441B5C
  CCC9271C390EA305F4CA76DA2CDEB44D87
  BD86A37AF8227748DF1BAC991EDE1A4C82
  8AEF843909'
]
```

Figure 14: 2001:3f:fe00:a05:6615:ee45:d427:9a0 Decoded HHIT RRType CBOR

Figure 15 shows the decoded DER X.509 found in Figure 14.

```
Certificate:
  Data:
    Version: 3 (0x2)
    Serial Number: 95 (0x5f)
    Signature Algorithm: ED25519
    Issuer: CN = 2001003ffe0000055e60a1571e91a0b7
    Validity
      Not Before: Apr  9 21:03:19 2025 GMT
      Not After : Apr  9 22:03:19 2025 GMT
    Subject: CN = DRIP-HDA-A-16376-10
    Subject Public Key Info:
      Public Key Algorithm: ED25519
      ED25519 Public-Key:
        pub:
          ce:68:1e:36:e1:14:1a:eb:56:0d:6e:76:bc:79:6b:
          7b:7c:b4:54:e4:63:cc:b1:f1:2d:e3:0a:38:01:01:
          80:3f
    X509v3 extensions:
      X509v3 Basic Constraints: critical
      CA:TRUE
      X509v3 Subject Alternative Name: critical
      IP Address:2001:3F:FE00:A05:6615:EE45:D427:9A0,
      URI:https://raa.example.com
    Signature Algorithm: ED25519
    Signature Value:
      21:32:93:92:3a:68:0c:90:96:35:7f:e0:7d:9d:38:1a:c1:48:
      ca:e1:81:04:44:1b:5c:cc:c9:27:1c:39:0e:a3:05:f4:ca:76:
      da:2c:de:b4:4d:87:bd:86:a3:7a:f8:22:77:48:df:1b:ac:99:
      1e:de:1a:4c:82:8a:ef:84:39:09
```

Figure 15: 2001:3f:fe00:a05:6615:ee45:d427:9a0 Decoded Certificate

Figure 16 shows the CBOR decoded RDATA in the HHIT RRType found in Figure 13.

```
[
  15, # Reserved (HDA Issue from DK1)
  "3ff8 000a",
  h'308201433081F6A00302010202015830
  0506032B6570302B312930270603550403
  0C20323030313030336666653030306130
  3536363135656534356434323730396130
  301E170D3235303430393231303531345A
  170D3235303430393232303531345A301E
  311C301A06035504030C13445249502D48
  44412D492D31363337362D3130302A3005
  06032B65700321008233FDAEB5068BC148
  59D113A0EDFCF8DC07814E3DD2765E6B5B
  82E04D070597A34C304A300F0603551D13
  0101FF040530030101FF30370603551D11
  0101FF042D302B87102001003FFE000A05
  260ED4376B256E28861768747470733A2F
  2F6864612E6578616D706C652E636F6D30
  0506032B65700341005AF256727EDC4726
  A0C5560BF846DF9C31499CF1A4307ADE14
  65D3B7C90381F6EAB8B0B54049C6990968
  C2D2799E4648154618B37B57AC7F28B745
  1538E08004'
]
```

Figure 16: 2001:3ffe00:a05:260e:d437:6b25:6e28 Decoded HHIT RRType CBOR

Figure 17 shows the decoded DER X.509 found in Figure 16.

```
Certificate:
  Data:
    Version: 3 (0x2)
    Serial Number: 88 (0x58)
    Signature Algorithm: ED25519
    Issuer: CN = 2001003ffe000a056615ee45d42709a0
    Validity
      Not Before: Apr  9 21:05:14 2025 GMT
      Not After : Apr  9 22:05:14 2025 GMT
    Subject: CN = DRIP-HDA-I-16376-10
    Subject Public Key Info:
      Public Key Algorithm: ED25519
      ED25519 Public-Key:
        pub:
          82:33:fd:ae:b5:06:8b:c1:48:59:d1:13:a0:ed:fc:
          f8:dc:07:81:4e:3d:d2:76:5e:6b:5b:82:e0:4d:07:
          05:97
    X509v3 extensions:
      X509v3 Basic Constraints: critical
      CA:TRUE
      X509v3 Subject Alternative Name: critical
      IP Address:2001:3F:FE00:A05:260E:D437:6B25:6E28,
      URI:https://hda.example.com
    Signature Algorithm: ED25519
    Signature Value:
      5a:f2:56:72:7e:dc:47:26:a0:c5:56:0b:f8:46:df:9c:31:49:
      9c:f1:a4:30:7a:de:14:65:d3:b7:c9:03:81:f6:ea:b8:b0:b5:
      40:49:c6:99:09:68:c2:d2:79:9e:46:48:15:46:18:b3:7b:57:
      ac:7f:28:b7:45:15:38:e0:80:04
```

Figure 17: 2001:3f:fe00:a05:260e:d437:6b25:6e28 Decoded Certificate

A.2.2. Registrant HHIT and BRID

```

$ORIGIN 5.0.a.0.0.0.e.f.f.3.0.0.1.0.0.2.ip6.example.com.
2.b.6.c.b.4.a.9.9.6.4.2.8.0.3.1. IN HHIT (
  gxJpM2ZmOCAwMDBhWQEYMIIBFDCBx6AD
  AgECAgFUMAUGAyt1cDArMSkwJwYDVQQD
  DCAyMDAxMDAzZmZlMDAwYTA1MjYwZWQ0
  Mzc2YjI1NmUyODAEFw0yNTA0MDkyMTEz
  MDBaFw0yNTA0MDkyMjEzMDBaMAAwKjAF
  BgMrZXADIQDJLi+d1+iWD5tfF1T4sJA5
  +drcW88GHqxPD0p560h3+qM7MDkwNwYD
  VR0RAQH/BC0wK4cQIAEAP/4ACgUTCCRp
  mkvGsoYXaHR0cHM6Ly9oZGEuZXhhbXBs
  ZS5jb20wBQYDK2VwA0EA0DbcdngC7/BB
  /aLjZmLio0ZFCDbd/KIxAy+3X2KtT4J
  todVxRMPAkN6o008gacbNfTG8p9npEcD
  eYhesl2jBQ==
)
2.b.6.c.b.4.a.9.9.6.4.2.8.0.3.1. IN BRID (
  owAAAYIEUQEgAQA//gAKBRMIJGmaS8ay
  AogFWIkB+t72Zwrt9mcgAQA//gAABV5g
  oVcekaC3mZDVSEtyoYBm1AkrUsfUmU+3
  wWvX6MH0QP+o0E/x4T8gAQA//gAABV5g
  oVcekaC3vC9m1JguvXt7W2o4wxPumaT1
  IP3TQN3fQP28hpInSIIsSwq8UCNjm2ad
  7pdTvm2Eqf0JQNPkClvRZm4qT05FDAVY
  iQGX4PZnp+72ZyABAD/+AAoFZhXuRdQn
  CaD0aB424RQa61YNbna8eWt7fLRU5GPM
  sfEt4wo4AQGAPyABAD/+AAAFxmChVx6R
  oLfv3q+mLRB3ya5TmjY8+3CzdoDZT9RZ
  +XpN5hDiA6JyyxBJvUewxLzPNhTXQp8v
  ED71XAE82tMmt3fB4zbzWNQLBViJAQrh
  9mca7/ZnIAEAP/4ACgUmDtQ3ayVuKIIZ
  /a61BovBSFnRE6Dt/PjcB4FOPdJ2Xmtb
  guBNBwWXIAEAP/4ACgVmFe5F1CcJoIjy
  CriJCxAyAWTOHPm1HL02MKSPsHviiTze
  qwBH9K/Rrz41CYix9HazAIOAZ08FcfU5
  M+WLLJJZoaQWBHnMbTQwFWIkB30L2Z+zw
  9mcgAQA//gAKBRMIJGmaS8ayyS4vnZfo
  lg+bXxZU+LCQ0fna3FvPBh6sTwzqeejo
  d/ogAQA//gAKBSY01DdrJW4ogOfc8jTi
  mYLMt00yFZoUx2j00wtB1jnqUJr6bYaw
  MoPrR3M1KGBGWSvz1yXNqUURoCqYdwsY
  e61vd5i6YJqnAQ==
)

```

Figure 18: Registrant HHIT/BRID RRTYPE Example

Figure 19 shows the CBOR decoded RDATA in the HHIT RRTYPE found in Figure 18.

```
[
  18, # Uncrewed Aircraft System (UAS)
  "3ff8 000a",
  h'308201143081C7A00302010202015430
  0506032B6570302B312930270603550403
  0C20323030313030336666653030306130
  3532363065643433373662323536653238
  301E170D3235303430393231313330305A
  170D3235303430393232313330305A3000
  302A300506032B6570032100C92E2F9D97
  E8960F9B5F1654F8B09039F9DADC5BCF06
  1EAC4F0CEA79E8E877FAA33B3039303706
  03551D110101FF042D302B87102001003F
  FE000A05130824699A4BC6B28617687474
  70733A2F2F6864612E6578616D706C652E
  636F6D300506032B6570034100D036DC76
  7802EFF041FDA2E36662E27A8D191420DB
  77F288C40CBEDD7D8AB53E09B68755C513
  0F02437AA34D3C81A71B35F4C6F29F67A4
  470379885EB25DA305'
]
```

Figure 19: 2001:3f:fe00:a05:1308:2469:9a4b:c6b2 Decoded HHIT RRType CBOR

Figure 20 shows the decoded DER X.509 found in [Figure 19](#).

```
Certificate:
  Data:
    Version: 3 (0x2)
    Serial Number: 84 (0x54)
    Signature Algorithm: ED25519
    Issuer: CN = 2001003ffe000a05260ed4376b256e28
    Validity
      Not Before: Apr  9 21:13:00 2025 GMT
      Not After : Apr  9 22:13:00 2025 GMT
    Subject:
      Subject Public Key Info:
        Public Key Algorithm: ED25519
        ED25519 Public-Key:
          pub:
            c9:2e:2f:9d:97:e8:96:0f:9b:5f:16:54:f8:b0:90:
            39:f9:da:dc:5b:cf:06:1e:ac:4f:0c:ea:79:e8:e8:
            77:fa
      X509v3 extensions:
        X509v3 Subject Alternative Name: critical
        IP Address:2001:3F:FE00:A05:1308:2469:9A4B:C6B2,
        URI:https://hda.example.com
    Signature Algorithm: ED25519
    Signature Value:
      d0:36:dc:76:78:02:ef:f0:41:fd:a2:e3:66:62:e2:7a:8d:19:
      14:20:db:77:f2:88:c4:0c:be:dd:7d:8a:b5:3e:09:b6:87:55:
      c5:13:0f:02:43:7a:a3:4d:3c:81:a7:1b:35:f4:c6:f2:9f:67:
      a4:47:03:79:88:5e:b2:5d:a3:05
```

Figure 20: 2001:3f:fe00:a05:1308:2469:9a4b:c6b2 Decoded Certificate

[Figure 21](#) shows the CBOR decoded RDATA of the BRID RRType in [Figure 18](#).

```

{
  0: 0,
  1: [4, h'012001003FFE000A05130824699A4BC6B2' ],
  2: [
    5,
    h'01FADEF6670AEDF6672001003FFE0000
    055E60A1571E91A0B79990D5B04B72A180
    66D4092B52C7D4994FB7C16BD7E8C1F440
    FFA8D04FF1E13F2001003FFE0000055E60
    A1571E91A0B7BC2F66D4982EBD7B7B5B6A
    38C313EE99A4F520FDD340DDDF40FDBC86
    922748896C4B0ABC5023639B669DEE9753
    BE6D84A9F38940D3CA0A5BD1666E2A4CEE
    450C',
    5,
    h'0197E0F667A7EEF6672001003FFE000A
    056615EE45D42709A0CE681E36E1141AEB
    560D6E76BC796B7B7CB454E463CCB1F12D
    E30A380101803F2001003FFE0000055E60
    A1571E91A0B7EFDEAFA62D1077C9AE539A
    363CFB70B37680D94FD459F97A4DE610E2
    03A272CB1049BD47B0C4BCCF3614D7429F
    2F103EF55C013CDAD326B777C1E336F358
    D40B',
    5,
    h'010AE1F6671AEFF6672001003FFE000A
    05260ED4376B256E288233FDAEB5068BC1
    4859D113A0EDFCF8DC07814E3DD2765E6B
    5B82E04D0705972001003FFE000A056615
    EE45D42709A088F20AB8890B10320164CE
    1CF9A51CBD3630A4A9B07BE2893CDEAB00
    47F4AFD1AF3E350988B1F476B300838064
    EF0571F53933E58B2C96686905811E731B
    4D0C',
    5,
    h'01DCE2F667ECF0F6672001003FFE000A
    05130824699A4BC6B2C92E2F9D97E8960F
    9B5F1654F8B09039F9DADC5BCF061EAC4F
    0CEA79E8E877FA2001003FFE000A05260E
    D4376B256E2880E7DCF234E29982E64CE3
    B2159A14C768CE3B0B41D639EA509AFA6D
    86B03283EB4773252860465AC573D725CD
    A94511A02A98770B187BAD6F7798BA609A
    A701'
  ]
}

```

Figure 21: 2001:3ffe00:a05:1308:2469:9a4b:c6b2 Decoded BRID RRType CBOR

Acknowledgements

Thanks to Stuart Card (AX Enterprize, LLC) and Bob Moskowitz (HTT Consulting, LLC) for their early work on the DRIP registries concept. Their early contributions laid the foundation for the content and processes of this architecture and document. The authors would also like to thank the DRIP chairs and AD, the reviewers from the various Directorates, and the members of the IESG at time of publication.

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