DRIP Entity Tag Authentication Formats & Protocols for Broadcast Remote ID

Abstract

This document describes how to add trust into the Broadcast Remote ID (RID) specification discussed in the DRIP Architecture. It defines a few message schemes (sent within the Authentication Message) that can be used to authenticate past messages sent by a unmanned aircraft (UA) and provide proof of UA trustworthiness even in the absence of Internet connectivity at the receiving node.

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1. Introduction

Unmanned Aircraft Systems (UAS) operate usually in a volatile environment when it comes to communication. Unmanned Aircraft (UA) are generally small with little computational (or flying) horsepower to carry standard communication equipment. This limits the mediums of communication to few viable options.

Observer systems (e.g., smartphones and tablets) place further constraints on the communication options. The Remote ID Broadcast messages must be available to applications on these platforms without modifying the devices.

As discussed in [drip-requirements] two communication schemes to a UAS for Remote ID (RID) are considered: Broadcast and Network RID.

This document focuses on adding trust to Broadcast RID (Section 3.2 of [drip-requirements]) via the Authentication Message by combining dynamically signed data with an Attestation of the UA's identity from a Registry.

This authentication approach also provides the missing, but US FAA mandated, Error Correction for the Bluetooth 4 transmissions (see Section 4). This is error correction not only for the authentication message itself, but indirectly, to other messages authenticated via the Manifest method (see Section 5.4).

A summary of addressed DRIP requirempents is provided in Section 7

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. Definitions

This document makes use fo the terms defined in [drip-requirements]. In addition, the following terms are defined:

Legacy Transports: uses broadcast frames (Bluetooth 4).

Extended Transports: uses the extended advertisements (Bluetooth 5), service info (Wi-Fi NaN) or vendor specific element information (Wi-Fi BEACON). Must use ASTM [F3411] Message Pack (Message Type 0xF).

3. Background

3.1. Problem Space and Focus

The current standard for Remote ID does not, in any meaningful capacity, address the concerns of trust in the UA space with communication in the Broadcast RID environment. This is a requirement that will need to be addressed eventually for various different parties that have a stake in the UA industry.

3.1.1. Broadcast RID RF Options

A UA has the option of broadcasting using Bluetooth (4 and 5) or Wi-Fi (BEACON or NAN), see Section 6. With Bluetooth, FAA and other CAA mandate transmitting simultaneously over both 4 and 5. With Wi-Fi, use of BEACON is recommended. Wi-Fi NAN is another option, depending on CAA.

Bluetooth 4 presents a payload size challenge in that it can only transmit 25 bytes of payload where the others all can support 252 byte payloads.

3.2. Reasoning for IETF DRIP Authentication

The ASTM Authentication Message has provisions in [F3411] to allow for other organizations to standardize additional Authentication formats beyond those explicitly in [F3411] that require use of a multi-party online validator system. This has a heavy reliance on

real-time connectivity onto the Internet (specifically into UTM)
that is not always guaranteed.

The standardization of specific formats to support the DRIP
requirements in UAS RID for trustworthy communications over
Broadcast RID is an important part of the chain of trust for a UAS
ID. Per [drip-arch] in Section 5, there is a need to have
Authentication formats to relay information for observers to
determine trust. No existing formats (defined in [F3411] or other
organizations leveraging this feature) provide the functionality to
satisfy this goal resulting in the work reflected in this document.

3.3. ASTM Authentication Message

The ASTM Authentication Message (Message Type 0x2) is a unique
message in the Broadcast [F3411] standard as it is the only one that
is larger than the Bluetooth 4 frame size. To address this, it is
defined as a set of "pages" that each fits into a single Bluetooth 4
broadcast frame. For other media these pages are still used but all
in a single frame.

3.3.1. Authentication Page

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|  Page Header  |                                               |
+---------------+                                               |
|                                                               |
|                                                               |
|                      Authentication Payload                   |
|                                                               |
|                                                               |
+---------------+---------------+---------------+---------------+
```
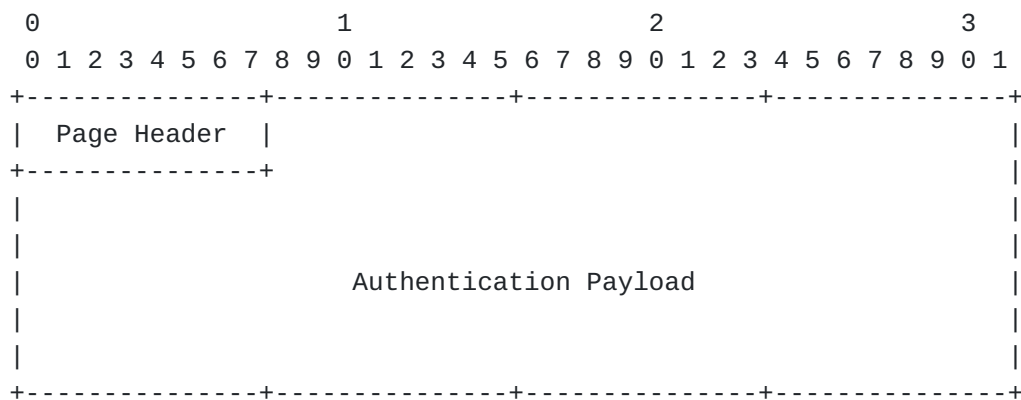
Page Header: (1 byte)
    Authentication Type (4 bits)
    Page Number (4 bits)

Authentication Payload: (23 bytes per page)
    Authentication Payload, including headers. Null padded.

Figure 1: Standard ASTM Authentication Message Page

The Authentication Message is structured as a set of up to 16 pages.
Over Bluetooth 4, these pages are "fragmented" into separate
Bluetooth 4 broadcast frames.

Either as a single Authentication Message or a set of fragmented
Authentication Message Pages the structure(s) is further wrapped by
outer ASTM framing and the specific link framing (Bluetooth or Wi-
Fi).

3.3.1.1. Authentication Type

[F3411] has the following example subset of Authentication Type's
defined and that can be used in the Page Header:

Authentication Type	Description
0x3	Message Set Signature
0x5	Specific Authentication Method

Table 1

3.3.1.1.1. Specific Authentication Method (SAM)

This document leverages Authentication Type 0x5, Specific
Authentication Method (SAM), as the principal authentication
container, defining a set of SAM Types in Section 5. Message Set
Signature (Authentication Type 0x3) is also used in parallel form to
its use in [F3411]. However, the SAM formats provide a more complete
authentication approach.

3.3.1.2. Page Number

There is a technical maximum of 16 pages (indexed 0 to 15 in the
Page Header) that can be sent for a single Authentication Message,
with each page carrying a maximum 23-byte Authentication Payload.
See Section 3.3.2 for more details.

3.3.1.3. Authentication Payload Field

The following is shown in its complete format.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|                     Authentication Headers                    |
|                     +---------------+---------------+
|                     |                               |         |
+---------------+---------------+                               |
.                                                               .
.               Authentication Data / Signature                 .
.                                                               .
|                                                               |
+---------------+---------------+---------------+---------------+
|      ADL      |                                               |
+---------------+                                               |
.                                                               .
.                       Additional Data                         .
.                                                               .
|                                                               |
+---------------+---------------+---------------+---------------+
```
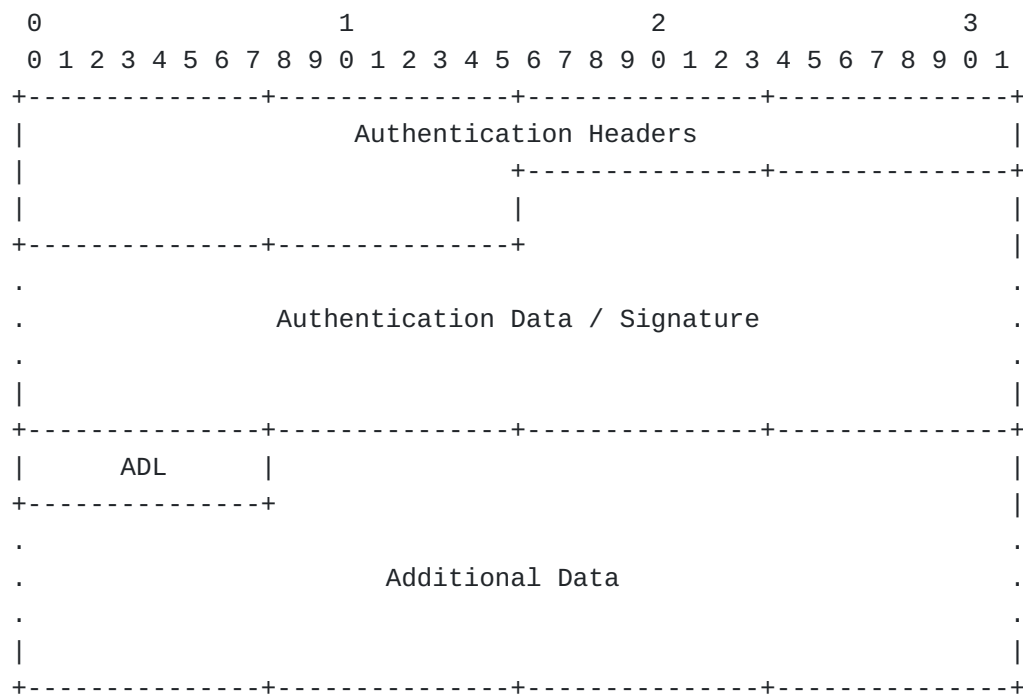
Authentication Headers: (6-bytes)
    As defined in F3411.

Authentication Data / Signature: (255-bytes max)
    Opaque authentication data.

Additional Data Length (ADL): (1-byte - unsigned)
    Length in bytes of Additional Data.

Additional Data: (255-bytes max):
    Data that follows the Authentication Data / Signature but
    is not considered part of the Authentication Data.

        Figure 2: ASTM Authentication Message Fields

Figure 2 is the source data view of the data fields found in the
Authentication Message as defined by [F3411]. This data is placed
into Figure 1's Authentication Payload, spanning multiple pages.

When Additional Data is being sent, a single unsigned byte
(Additional Data Length) directly follows the Authentication Data /
Signature and has the length, in bytes, of the following Additional
Data. For DRIP, this field is used to carry Forward Error Correction
as defined in Section 4.

3.3.2. ASTM Constraints

To keep consistent formatting across the different transports
(Legacy and Extended) and their independent restrictions, the
authentication data being sent is REQUIRED to fit within the page

limit of the most constrained existing transport can support. Under
Broadcast RID the transport that can hold the least amount of
authentication data is Bluetooth 5 and Wi-Fi BEACON at 9-pages.

As such DRIP transmitters are REQUIRED to adhere to the following
when using the Authentication Message:

1. Authentication Data / Signature data MUST fit in the first 9
   pages (Page Numbers 0 through 8).

2. The Length field in the Authentication Headers (which denotes
   the length in bytes of Authentication Data / Signature only)
   MUST NOT exceed the value of 201.

4. Forward Error Correction

For Broadcast RID, Forward Error Correction (FEC) is provided by the
lower layers in Extended Transports (Bluetooth 5, Wi-Fi NaN, and Wi-
Fi BEACON). The Bluetooth 4 Legacy Transport does not have
supporting FEC so with DRIP Authentication the following application
level FEC scheme is used to add FEC. This section is only used for
Bluetooth 4 transmission/reception.

The data added during FEC is not included in the Authentication Data
/ Signature but instead in the Additional Data field of Figure 2.
This may cause the Authentication Message to exceed 9-pages, up to a
maximum of 16-pages.

4.1. Encoding

For any encoding the FEC data MUST start on a new ASTM
Authentication Page. To do this, null padding is added before the
actual FEC data starts and the length of the whole blob (null
padding and FEC) is used as the Additional Data Length. To properly
fit FEC data into an Authentication Page the number of parity-bytes
is limited to 23 or a multiple thereof (size of Authentication data
per page). That is, the Page Header (and anything before it) is
omitted in the FEC process.

4.1.1. Single Page FEC

To generate the parity a simple XOR operation using the previous and
current page is used. Only the 23-byte Authentication Page data is
used in the XOR operation. For Page 0, a 23-byte null pad is used
for the previous page. The resulting parity fills the last 23 bytes
of the Additional Data field of Figure 2 with the Additional Data
Length field being set to 23 or greater (depending on number of null
pad bytes are needed to get onto the next page).

```
Page N-1:
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|  Page Header  |                                               |
+---------------+                                               |
|                  Authentication Data / Signature              |
|                                                               |
|               +---------------+---------------+---------------+
|               |    ADL=33     |                               |
+---------------+---------------+                               |
|                         Null Padding                          |
|                                                               |
+---------------+---------------+---------------+---------------+


Page N:
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|  Page Header  |                                               |
+---------------+                                               |
|                                                               |
|                   Forward Error Correction                    |
|                                                               |
|                                                               |
|                                                               |
+---------------+---------------+---------------+---------------+
```
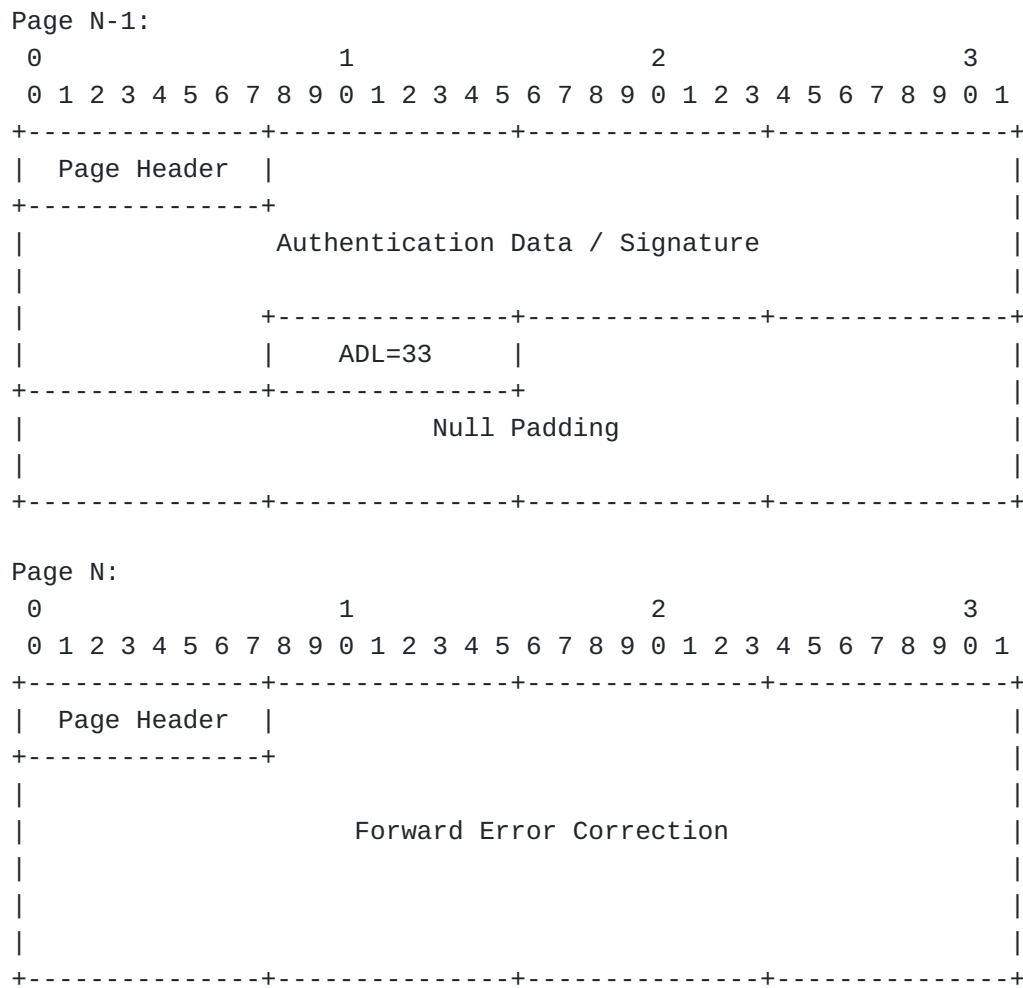
                Figure 3: Example Single Page FEC Encoding

4.1.2. Multiple Page FEC

   For Multiple Page FEC there are two variations: Frame Recovery and
   Page Recovery. Both follow a similar process, but are offset at what
   data is actually protected.

   For DRIP the polynomial to use for Reed Solomon is: $1 + x^2 + x^3 + x^4 + x^8$.

4.1.2.1. Page Recovery

   Take the following example of an Authentication Message with 7 pages
   that 3 pages of parity are to be generated for. The first column is
   just the Page Header with a visual space here to show the boundary.

```
50 098960bf8c05042001001000a00145aac6b00abba268b7
51 2001001000a0014579d8a404d48f2ef9bb9a4470ada5b4
52 ff1352c7402af9d9ebd20034e8d7a12920f4d7e91c1a73
53 dca7d04e776150825863c512c6eb075a206a95c59b297e
54 f2935fd416f27b1b42fd5d9dfaa0dec79f32287f41b454
55 7101415def153a770d3e6c0b17ae560809bc634a822c1f
56 3b1064b80a00000000000000000000000000000000000000
```

For Page Recovery the first column is ignored and the last 23-bytes
of each page are extracted to have Reed Solomon performed on them in
a column wise fashion to produce parity bytes. For the example the
following 3-bytes of parity are generated with the first byte of
each page:

```
dc6c2b = ReedSolomon.encoder(0920ffdcf2713b)
```

Each set of parity is the placed into a pseudo-frame as follows
(each byte in its own message in the same column). Below is an
example of the full parity generated and each 23-bytes of parity
added into the additional pages as Additional Data:

```
57 dc6657acd30b2ec4aa582049f52adf9f922e62c469563a
58 6c636a59145a55417a3895fd543f19e94200be4abc5e94
59 02bba5e28f5896d754caf50016a983993b149b5c9e6eeb
```

4.1.2.2. Frame Recovery

Frame Recovery uses the full ASTM Message and performs Reed Solomon
over each byte. Up to 240 (255 minus 15 pages maximum of FEC data)
messages can be protected using Frame Recovery.

Below is an example of a number of messages. Here the first column
is an additional ASTM Header that contain the Message Type; with a
visual space for clarity. The last 24-bytes are the actual message
contents; be it location information or an Authentication Page.

```
10 42012001001000a0014579d8a404d48f2ef9000000000000
11 249600006efeb019ee111ed37a097a0948081c10ffff0000
12 50098960bf8c05042001001000a00145aac6b00abba268b7
12 512001001000a0014579d8a404d48f2ef9bb9a4470ada5b4
12 52ff1352c7402af9d9ebd20034e8d7a12920f4d7e91c1a73
12 53dca7d04e776150825863c512c6eb075a206a95c59b297e
12 54f2935fd416f27b1b42fd5d9dfaa0dec79f32287f41b454
12 557101415def153a770d3e6c0b17ae560809bc634a822c1f
12 563b1064b80a00000000000000000000000000000000000000
13 0052656372656174696f6e616c2054657374400000000000
14 02c2ffb019322d1ed3010000c008e40700fc080000000000
15 004e2e4f503132333334353600000000000000000000000000
```

A similar process is followed as in [Section 4.1.2.1](). Here every
column of bytes has parity generated for it (even the ASTM Header).
In the below example 5-bytes of parity are generated using the ASTM
Header column:

6c3f42b8a8 = ReedSolomon.encoder(1011121212121212121212131415)

After doing this to all columns the following pseudo-frames would
have been generated:

6c86337bf7ab746f5d62bb7f8de954104b121585d3975f6e92
3f06c1bce165b0e25930d57a63c24f751145e1dd8dc115029b
42e9979580327a6a14d421c12a33aa2e1a2e517daaee581016
b8012a7b3964f7b2720d387bfa77e945556f1831cd477ef3a3
a85bb403aada89926fb8fc2a14a9caacb4ec2f3a6ed2d8e9f9

These 25-byte chunks are now concatenated together and are placed in
Authentication Pages, using the Additional Data, 23-bytes at a time.
In the below figure the first column is the ASTM Header as before,
the second column is the Page Header for each Authentication Page
and then last column is the 23-bytes of data for each page.

12 57 6c86337bf7ab746f5d62bb7f8de954104b121585d3975f
12 58 6e923f06c1bce165b0e25930d57a63c24f751145e1dd8d
12 59 c115029b42e9979580327a6a14d421c12a33aa2e1a2e51
12 5a 7daaee581016b8012a7b3964f7b2720d387bfa77e94555
12 5b 6f1831cd477ef3a3a85bb403aada89926fb8fc2a14a9ca
12 5c acb4ec2f3a6ed2d8e9f90000000000000000000000000000

4.2. Decoding

Due to the nature of Bluetooth 4 and the existing ASTM paging
structure an optimization can be used. If a Bluetooth frame fails
its CRC check, then the frame is dropped without notification to the
upper protocol layers. From the Remote ID perspective this means the
loss of a complete frame/message/page. In Authentication Messages,
each page is already numbered so the loss of a page allows the
receiving application to build a "dummy" page filling the entire
page with nulls.

If Page 0 is being reconstructed an additional check of the Last
Page Index to check against how many pages are actually present,
MUST be performed for sanity. An additional check on the Length
field SHOULD also be performed.

To determine if Single Page FEC or Multiple Page FEC has been used a
simple check of the Last Page Index can be used. If the number of
pages left after the Length of Authentication Data is exhausted than
it is clear that the remaining pages are all FEC. The Additional

Data Length byte can further confirm this; taking into account any null padding needed for page alignment.

4.2.1. Single Page FEC

Using the same methods as encoding, an XOR operation is used between the previous and current page (a 23-byte null pad is used as the start). The resulting 23-bytes should be data of the missing page.

4.2.2. Multiple Page FEC

To determine if Page Recovery or Frame Recovery is used two modulo checks with the ADL after the length of the null-pad is removed are needed. One against the value of 23, and the other against the value of 25. If 23 comes back with a value of 0 then Page Recovery is being used. If 25 comes back with 0 then Frame Recovery is used. Any other combination indicates an error.

4.2.2.1. Page Recovery

To decode Page Recovery, dummy pages (pages with nulls as the data) are needed in the places no page was received. Then Reed Solomon can decode across the columns of the 23-bytes of each page. Erasures can be used as it is known which pages are missing and can improve the Reed Solomon results by specifying them.

4.2.2.2. Frame Recovery

To decode Frame Recovery, the receiver must first extract all FEC data from the pages; concatenate them and then break into 25-byte chunks. This will produce the pseudo-frames. Now Reed Solomon can be used to decode columns, with dummy frames inserted where needed.

4.3. FEC Limitations

The worst case scenario is when the Authentication Data / Signature ends perfectly on a page (Page N-1). This means the Additional Data Length would start the next page (Page N) and have 22-bytes worth of null padding to align the FEC in to the next page (Page N+1). In this scenario an entire page (Page N) is being wasted just to carry the Additional Data Length. This should be be avoided at all costs - in an effort to maintain efficiency.

5. DRIP Authentication Formats

All formats defined in this section are the content for the Authentication Data / Signature field in Figure 2 and uses the Specific Authentication Method (SAM, Authentication Type 0x5). The first byte of the Authentication Data / Signature of Figure 2, is used to multiplex between these various formats.

When sending data over a medium that does not have underlying
Forward Error Correction (FEC), for example Bluetooth 4, then
Section 4 MUST be used.

5.1. DRIP Authentication Field Definitions

ASTM Message (25-bytes): Full ASTM Message as defined in [F3411]
   specifically Message Types 0x0, 0x1, 0x3, 0x4, and 0x5

ASTM Message Hash (12-bytes): Hash of a single full ASTM Message
   using hash operations described in (Section 5.4.2). Multiple
   hashes MUST be in Message Type order.

Attestation Data (0 to 112 bytes): Opaque attestation data that the
   UA is attesting during its flight in Figure 4.

Broadcast Attestation (136-bytes): HDA HI over UA DET/HI. Generated
   by a DRIP Registry during Session ID registration. Used in
   Section 5.2.

Current Manifest Hash (12-bytes): See Section 5.4.3.

Frame Type (1-byte): Sub-type for future different DRIP Frame
   formats. See Section 5.5.1.

Not Before Timestamp by UA (4-bytes): Timestamp denoting
   recommended time to start trusting data in Figure 4. MUST follow
   the format defined in [F3411]. That is a Unix-style timestamp but
   with an epoch of 01/01/2019 00:00:00. MUST be set to the time the
   signature is generated.

Not After Timestamp by UA (4-bytes): Timestamp denoting recommended
   time to stop trusting data in Figure 4. MUST follow the format
   defined in [F3411]. That is a Unix-style timestamp but with an
   epoch of 01/01/2019 00:00:00 with an additional offset is then
   added to push a short time into the future (relative to Not
   Before Timestamp) to avoid replay attacks. The offset used
   against the Unix-style timestamp is not defined in this document.
   Best practice identifying an acceptable offset should be used
   taking into consideration the UA environment, and propagation
   characteristics of the messages being sent and clock differences

between the UA and Observers. A reasonable time would be to set
Not After Timestamp 2 minutes ahead of Not Before Timestamp.

Previous Manifest Hash (12-bytes): See Section 5.4.3.

UA DRIP Entity Tag (16-bytes): The UA DET in byte form (network
byte order) and is part of Figure 4.

UA Signature (64-bytes): Signature over preceding fields of Figure
4 using the HI of the UA.

5.1.1. Broadcast Attestation Structure

Variations of the Attestation Structure format of [drip-registries]
SHOULD be used when running DRIP Authentication under the DRIP SAM
Types (filling the SAM Authentication Data field (Section 5.1.2.2)).
The notable changes of the structure is that the timestamps are set
by the UA and the Attestor Identity Information is set to the DET of
the UA.

When using this structure the UA is minimally self-attesting its
DRIP Entity Tag (DET). It may be attesting the DET registration in a
specific HID (see Appendix B). The Host Identity of the UA DET can
be looked up by mechanisms described in [drip-registries] or by
extracting it from Broadcast Attestation (see Section 5.2 and
Section 6.3).

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                            UA                            |
 |                     DRIP Entity Tag                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 .                                                          .
 .                     Attestation Data                     .
 .                                                          .
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |              Not Before Timestamp by UA                  |
 +--------------+--------------+--------------+--------------+
 |              Not After Timestamp by UA                   |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                      UA Signature                        |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 |                                                          |
 +--------------+--------------+--------------+--------------+
```
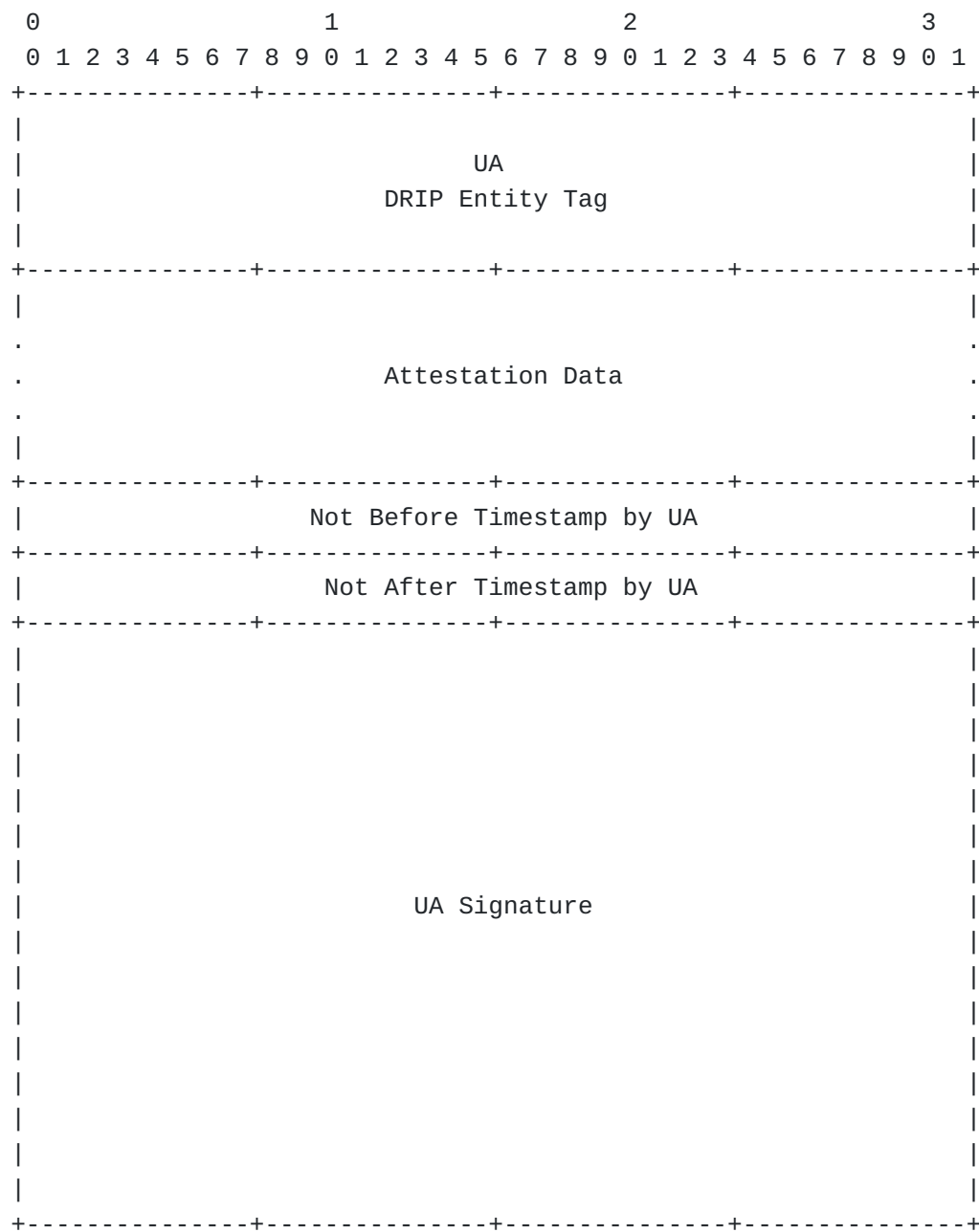
Figure 4: Broadcast Attestation Structure

5.1.2. SAM Data Format

Figure 5 is the general format to hold authentication data when
using SAM and is placed inside the Authentication Data / Signature
field in Figure 2.
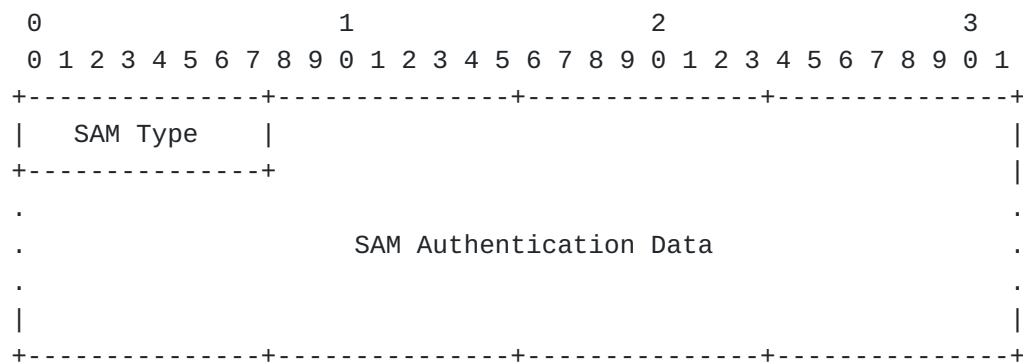
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|   SAM Type    |                                               |
+---------------+                                               |
.                                                               .
.                      SAM Authentication Data                  .
.                                                               .
|                                                               |
+---------------+---------------+---------------+---------------+

    SAM Type (1 byte):
        Byte defined by F3411 to multiplex SAMs

    SAM Authentication Data (0 to 200 bytes):
        Opaque SAM authentication data.
```

                       Figure 5: SAM Data Format

5.1.2.1. SAM Type

The SAM Type field is maintained by the International Civil Aviation
Organization (ICAO) and for DRIP four are planned to be allocated:

SAM Type	Description
0x01	DRIP Link (Section 5.2)
0x02	DRIP Wrapper (Section 5.3)
0x03	DRIP Manifest (Section 5.4)
0x04	DRIP Frame (Section 5.5)

                             Table 2

5.1.2.2. SAM Authentication Data

This field has a maximum size of 200-bytes, as defined by Section
3.3.2. The Broadcast Attestation Structure (Section 5.1.1) SHOULD be
used in this space.

5.2. DRIP Link

This SAM Type is used to transmit Broadcast Attestations. For
example, the Broadcast Attestation of the Registry (HDA) over the UA
is sent (see Section 6.3) as a DRIP Link message. Its structure is
defined in [drip-registries] and an example of it can be found in
Appendix B.

DRIP Link is important as its contents are used to provide trust in
the DET/HI that the UA is currently broadcasting. This message does
not require internet connectivity to perform signature validations
of the contents when the registry DET/HI is in the receivers cache.

It also provides the UA HI so that connectivity is not required when performing validation of other DRIP Authentication Messages.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|                                                               |
.                                                               .
.                     Broadcast Attestation                     .
.                                                               .
|                                                               |
+---------------+---------------+---------------+---------------+
```
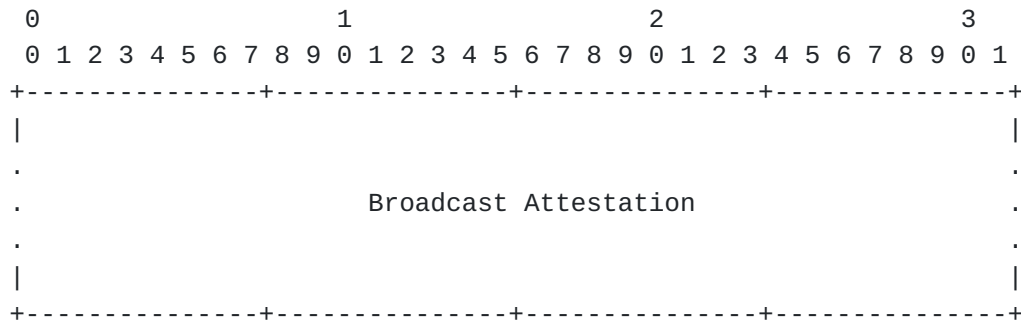
Figure 6: DRIP Link

This DRIP Authentication Message is used in conjunction with other DRIP SAM Types (such as Manifest or Wrapper) that contain data that is guaranteed to be unique and easily cross checked by the receiving device. A good candidate for this is using the DRIP Wrapper to encapsulate a Location Message (Message Type 0x2).

5.3. DRIP Wrapper

This SAM Type is used to wrap and sign over a list of other [F3411] Broadcast RID messages. It MUST use the Broadcast Attestation Structure (Section 5.1.1).

The Attestation Data field is filled with full (25-byte) [F3411] Broadcast RID messages. The minimum number being 1 and the maximum being 4. The encapsulated messages MUST be in Message Type order as defined by [F3411]. All message types except Authentication (Message Type 0x2) and Message Pack (Message Type 0xF) are allowed.

To determine the number of messages wrapped the receiver can check that the length of the Attestation Data field of the DRIP Broadcast Attestation (Section 5.1.1) is a multiple of 25-bytes.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+--------------+--------------+--------------+--------------+
|                                                           |
|                                                           |
|                            UA                             |
|                     DRIP Entity Tag                       |
|                                                           |
+--------------+--------------+--------------+--------------+
|                                                           |
|                                                           |
|                       ASTM Message                        |
|                                                           |
|                                                           |
|                                                           |
+              +--------------+--------------+--------------+
|              |                                            |
+--------------+                                            |
|                                                           |
|                       ASTM Message                        |
|                                                           |
|                                                           |
|                                                           |
+                            +--------------+--------------+
|                            |                             |
+--------------+--------------+                             |
|                                                           |
|                                                           |
|                       ASTM Message                        |
|                                                           |
|                                                           |
+                                          +--------------+
|                                          |               |
+--------------+--------------+--------------+              |
|                                                           |
|                                                           |
|                       ASTM Message                        |
|                                                           |
|                                                           |
|                                                           |
+--------------+--------------+--------------+--------------+
|              Not Before Timestamp by UA                   |
+--------------+--------------+--------------+--------------+
|              Not After Timestamp by UA                    |
+--------------+--------------+--------------+--------------+
|                                                           |
|                                                           |
|                                                           |
|                                                           |
|                                                           |
```

```
|                                                              |
|                                                              |
|                         UA Signature                         |
|                                                              |
|                                                              |
|                                                              |
|                                                              |
|                                                              |
|                                                              |
|                                                              |
|                                                              |
+---------------+---------------+---------------+---------------+
```

Figure 7: Example 4-Message DRIP Wrapper

5.3.1. Wrapper over Extended Transports

To send the DRIP Wrapper over Extended Transports the messages being
wrapped are co-located with the Authentication Message in a Message
Pack (0xF). The ASTM Messages are removed from the DRIP Wrapper
after signing (as they are redundant) leaving the following
structure that is placed into the SAM Authentication Data of Figure
5 and sent in the same Message Pack.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
|                                                               |
|                             UA                                |
|                       DRIP Entity Tag                         |
|                                                               |
+---------------+---------------+---------------+---------------+
|                  Not Before Timestamp by UA                   |
+---------------+---------------+---------------+---------------+
|                  Not After Timestamp by UA                    |
+---------------+---------------+---------------+---------------+
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                        UA Signature                           |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
+---------------+---------------+---------------+---------------+
```

Figure 8: DRIP Wrapper under Extended Transports

To verify the signature the receiver must concatenate all of the
messages in the Message Pack (excluding Authentication Message found
in the same Message Pack) in Message Type order and place the blob
between the UA DRIP Entity Tag and Not Before Timestamp before
performing signature verification.

The functionality of Wrapper in this form is identical to
Authentication Type 0x3 (Message Set Signature) when running over
Extended Transports. What Wrapper provides is the same format but
over both Extended and Legacy Transports allowing the transports to
be similar. Message Set Signature also implies using the ASTM
validator system architecture which relies on Internet connectivity
for verification which the receiver may not have at the time of
receipt of an Authentication Message. This is something Wrapper, and
all DRIP Authentication Formats, avoids when the UA key is obtained
via a DRIP Link Authentication Message.

5.3.2. Wrapper Limitations

The primary limitation of the Wrapper format is the bounding of up
to 4 ASTM Messages that can be sent within it. Another limitation is
that the format can not be used as a surrogate for messages it is
wrapping. This is due to high potential a receiver on the ground
does not support DRIP. Thus when Wrapper is being used the wrapper
data must effectively be sent twice; once as a single framed message
(as specified in [F3411]) and then again wrapped within the Wrapper
format.

5.4. DRIP Manifest

This SAM Type is used to create message manifests. It MUST use the
Broadcast Attestation Structure (Section 5.1.1).

By hashing previously sent messages and signing them we gain trust
in UAs previous reports. An observer who has been listening for any
length of time can hash received messages and cross-check against
listed hashes. This is a way to evade the limitation of a maximum of
4 messages in the Wrapper Format and reduce overhead.

The Attestation Data field is filled with 12-byte hashes of previous
[F3411] Broadcast messages. A receiver does not need to have
received every message in the manifest to verify it. A manifest
SHOULD typically encompass a single transmission cycle of messages
being sent, see Section 6.4.

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                           UA                             |
 |                     DRIP Entity Tag                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                 Previous Manifest Hash                   |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                  Current Manifest Hash                   |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |                                                          |
 |                   ASTM Message Hash                      |
 |                                                          |
 +--------------+--------------+--------------+--------------+
 |              Not Before Timestamp by UA                  |
 +--------------+--------------+--------------+--------------+
 |               Not After Timestamp by UA                  |
 +--------------+--------------+--------------+--------------+
 |                                                          |
```

```
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                           UA Signature                              |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
+---------------+---------------+---------------+---------------+
```

Figure 9: Example DRIP Manifest

5.4.1. Hash Count

The number of hashes in the Manifest can be variable (3-9). An easy way to determine the number of hashes is to take the length of the data between the end of the UA DRIP Entity Tag and Not Before Timestamp by UA and divide it by the hash length (12). If this value is not rational, the message is invalid.

5.4.2. Message Hash Algorithms and Operation

The hash algorithm used for the Manifest Message is the same hash algorithm used in creation of the DET [drip-rid] that is signing the Manifest.

An DET using cSHAKE128 [NIST.SP.800-185] computes the hash as follows:

cSHAKE128(ASTM Message, 96, "", "Remote ID Auth Hash")

> Note: [drip-rid] specifies cSHAKE128 but is open for the expansion of other OGAs.

5.4.2.1. Legacy Transport Hashing

Under this transport DRIP hashes the full ASTM Message being sent over the Bluetooth Advertising frame. For Authentication Messages all the Authentication Message Pages are concatenated together and hashed as one object. For all other Message Types the 25-byte message is hashed.

5.4.2.2. Extended Transport Hashing

Under this transport DRIP hashes the full ASTM Message Pack (Message Type 0xF) - regardless of its content.

5.4.3. Pseudo-Blockchain Hashes

Two special hashes are included in all Manifest messages; a previous manifest hash, which links to the previous manifest message, as well as a current manifest hash. This gives a pseudo-blockchain provenance to the manifest message that could be traced back if the observer was present for extended periods of time.

Creation: During creation and signing of this message format this field MUST be set to 0. So the signature will be based on this field being 0, as well as its own hash. It is an open question of if we compute the hash, then sign or sign then compute.

Cycling:

There a few different ways to cycle this message. We can "roll up" the hash of 'current' to 'previous' when needed or to completely recompute the hash. This mostly depends on the previous note.

5.4.4. Manifest Limitations

A potential limitation to this format is dwell time of the UA. If the UA is not sticking to a general area then most likely the Observer will not obtain many (if not all) of the messages in the manifest. Examples of such scenarios include delivery or survey UA.

5.5. DRIP Frame

This SAM Type is for when the authentication data does not fit in other defined formats under DRIP and is reserved for future expansion under DRIP if required. This SAM Type MUST use the Broadcast Attestation Structure ([Section 5.1.1](#)).

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +--------------+--------------+--------------+--------------+
    |                                                          |
    |                            UA                            |
    |                      DRIP Entity Tag                     |
    |                                                          |
    +--------------+--------------+--------------+--------------+
    |  Frame Type  |                                           |
    +--------------+                                           .
    .                   Frame Attestation Data                 .
    .                                                          .
    |                                                          |
    +--------------+--------------+--------------+--------------+
    |              Not Before Timestamp by UA                  |
    +--------------+--------------+--------------+--------------+
    |              Not After Timestamp by UA                   |
    +--------------+--------------+--------------+--------------+
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                      UA Signature                        |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    |                                                          |
    +--------------+--------------+--------------+--------------+
```
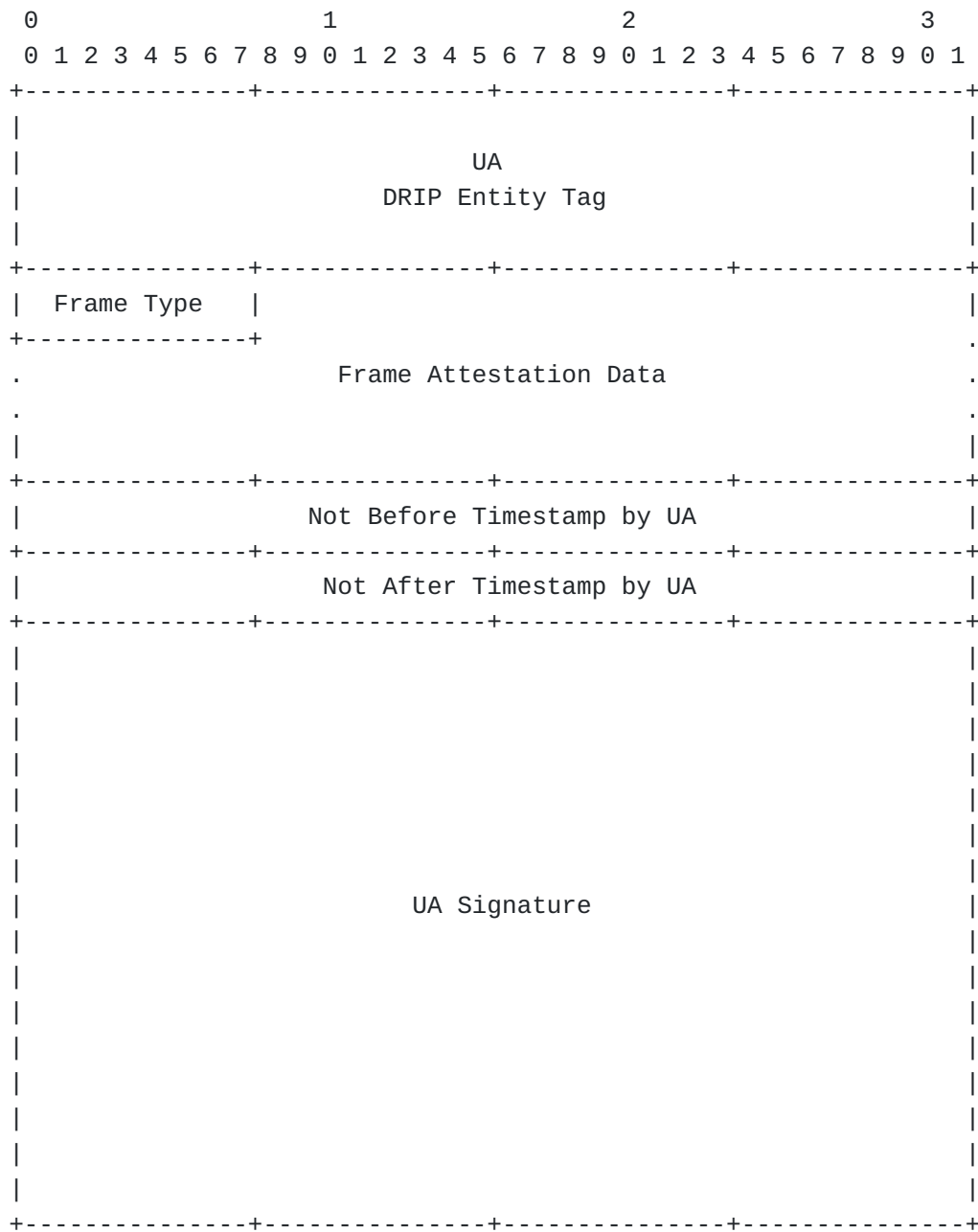
Figure 10: Example DRIP Frame

5.5.1. Frame Type

Byte to sub-type for future different DRIP Frame formats. It takes
the first byte of Attestation Data in Section 5.1.1 leaving 111-
bytes for Frame Attestation Data.

Frame Type	Name	Description
0x00	Reserved	Reserved
0xC0-0xFF	Experimental	Experimental Use

Table 3

6. Requirements & Recommendations

6.1. Legacy Transports

With Legacy Advertisements the goal is to attempt to bring reliable receipt of the paged Authentication Message. FEC ([Section 4](#)) MUST be used, per mandated Remote ID rules (for example the US FAA Remote ID Rule [[faa-rid](#)]), when using Legacy Advertising methods (such as Bluetooth 4).

Under ASTM Bluetooth 4 rules, transmission of dynamic messages are at least every 1 second. DRIP Authentication Messages typically contain dynamic data (such as the DRIP Manifest or DRIP Wrapper) and must be sent at the dynamic rate of 1 per second.

6.2. Extended Transports

Under the ASTM specification, Bluetooth 5, Wi-Fi NaN, and Wi-Fi BEACON transport of Remote ID is to use the Message Pack (Message Type 0xF) format for all transmissions. Under Message Pack messages are sent together (in Message Type order) in a single Bluetooth 5 extended frame (up to 9 single frame equivalent messages under Bluetooth 4). Message Packs are required by ASTM to be sent at a rate of 1 per second (like dynamic messages).

Without any fragmentation or loss of pages with transmission Forward Error Correction ([Section 4](#)) MUST NOT be used as it is impractical.

6.3. Authentication

It is REQUIRED that a UA send the following Authentication Formats to fulfill the [[drip-requirements](#)]:

1. DRIP Link using the Broadcast Attestation of HDA and the UA (satisfying GEN-1 and GEN-3)

2. Any other DRIP Authentication Format (RECOMMENDED: DRIP Manifest or DRIP Wrapper) where the UA is dynamically signing data that is guaranteed to be unique and easily cross checked by the receiving device (satisfying GEN-1 and GEN-2)

It is RECOMMENDED the following set of Authentication Formats are sent for support of offline Observers:

1. DRIP Link using the Broadcast Attestation of HID Root and the RAA (CAA) (satisfies GEN-3)

2. DRIP Link using the Broadcast Attestation of RAA (CAA) and the HDA (USS) (satisfies GEN-3)

3. DRIP Link using the Broadcast Attestation of HDA (USS) and the UA (satisfies GEN-1 and GEN-3)

4. Any other DRIP Authentication Format (RECOMMENDED: DRIP Manifest or DRIP Wrapper) where the UA is dynamically signing data that is guaranteed to be unique and easily cross checked by the receiving device (satisfying GEN-1 and GEN-2)

6.4. Operational

UAS operation may impact the frequency of sending DRIP Authentication messages. Where a UA is dwelling in one location, and the channel is heavily used by other devices, "occasional" message authentication may be sufficient for an observer. Contrast this with a UA traversing an area, and then every message should be authenticated as soon as possible for greatest success as viewed by the receiver.

Thus how/when these DRIP authentication messages are sent is up to each implementation. Further complication comes in contrasting Legacy and Extended Transports. In Legacy, each message is a separate hash within the Manifest. So, again in dwelling, may lean toward occasional message authentication. In Extended Transports, the hash is over the Message Pack so only few hashes need to be in a Manifest. A single Manifest can handle a potential two Message Packs (for a full set of messages) and a DRIP Link Authentication Message for the HDA UA assertion.

A separate issue is the frequency of transmitting the DRIP Link Authentication Message for the HDA UA assertion when using a Manifest Message. This message content is static; its hash never changes radically. The only change is the 4-byte timestamp in the Authentication Message headers. Thus, potentially, in a dwelling operation it can be sent once per minute, where its hash is in every Manifest. A receiver can cache all DRIP Link Authentication Message for the HDA UA assertion to mitigate potential packet loss.

The preferred mode of operation is to send the HDA UA assertion every 3 seconds and Manifest messages immediately after a set of UA operation messages (e.g. Basic, Location, and System messages).

6.4.1. DRIP Wrapper

The DRIP Wrapper MUST NOT be used in place of sending the ASTM messages as is. All receivers MUST be able to process all the messages specified in [F3411]. Sending them within the DRIP Wrapper makes them opaque to receivers lacking support for DRIP authentication messages. Thus messages within a Wrapper are sent twice: in the clear, and authenticated within the Wrapper. The DRIP

Manifest format would seem to be a more efficient use of the transport channel.

The DRIP Wrapper has a specific use case for DRIP aware receivers. For receiver plotting received Location Messages (Message Type 0x2) on a map display an embedded Location Message in a DRIP Wrapper can be colored differently to signify trust in the Location data - be it current or previous Location reports that are wrapped.

7. Summary of Addressed DRIP Requirements

The following [drip-requirements] are addressed in this document:

GEN-1: Provable Ownership This will be addressed using the DRIP Link and DRIP Wrapper or DRIP Manifest.

GEN-2: Provable Binding This requirement is addressed using the DRIP Wrapper or DRIP Manifest.

GEN-3: Provable Registration This requirement is addressed using the DRIP Link.

8. ICAO Considerations

DRIP requests the following SAM Type's to be allocated:

1. DRIP Link

2. DRIP Wrapper

3. DRIP Manifest

4. DRIP Frame

9. IANA Considerations

9.1. IANA DRIP Registry

This document requests a new subregistry for Frame Type under the DRIP registry.

DRIP Frame Type: This 8-bit valued subregistry is for Frame Types in DRIP Frame Authentication Messages. Future additions to this subregistry are to be made through Expert Review (Section 4.5 of [RFC8126]). The following values are defined:

Frame Type	Name	Description
0x00	Reserved	Reserved
0xC0-0xFF	Experimental	Experimental Use

Table 4

10. Security Considerations

10.1. Replay Attacks

The astute reader may note that the DRIP Link messages, which are
recommended to be sent, are static in nature and contain various
timestamps. These Attestation Link messages can easily be replayed
by an attacker who has copied them from previous broadcasts. There
are two things to mitigate this in DRIP:

   1. If an attacker (who is smart and spoofs more than just the UAS
      ID/data payloads) willing replays an Attestation Link message
      they have in principle actually helped by ensuring the message
      is sent more frequently and be received by potential Observers.

   2. It is RECOMMENDED to send more than just DRIP Link messages,
      specifically those that sign over changing data using the
      current session keypair, and those messages are sent more
      frequently. An UA beaconing these messages then actually
      signing other messages using the keypair validates the data
      receiver by an Observer. An UA who does not either run DRIP
      themselves or does not have possession of the same private key,
      would be clearly exposed upon signature verification.

10.2. Trust Timestamp Offsets

Note the discussion of Trust Timestamp Offsets here is in context of
the DRIP Wrapper (Section 5.3) and DRIP Manifest (Section 5.4)
messages. For DRIP Link (Section 5.2) messages these offsets are set
by the Attestor (typically a registry) and have their own set of
considerations as seen in [drip-registries].

The offset of the Trust Timestamp (defined as a very short
Expiration Timestamp) is one that needs careful consideration for
any implementation. The offset should be shorter than any given
flight duration (typically less than an hour) but be long enough to
be received and processed by Observers (larger than a few seconds).
It recommended that 3-5 minutes should be sufficient to serve this
purpose in any scenario, but is not limited by design.

11. Acknowledgments

of data (9 Authentication pages) - this drove the requirement for
maximum page length of Authentication Data itself.

*Many thanks to Rick Salz for the secdir review.

12. References

12.1. Normative References

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12.2. Informative References

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            Gurtov, "UAS Remote ID", Work in Progress, Internet-

Draft, draft-ietf-drip-uas-rid-01, 9 September 2020,
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Appendix A. Authentication State Diagrams & Color Scheme

ASTM Authentication has only 3 states: None, Invalid or Valid. This
is because under ASTM the idea is that Authentication is done by an
external service hosted somewhere on the Internet so it is assumed
you will always get some sort of answer back. With DRIP this
classification becomes more complex with the support of "offline"
scenarios where the receiver does not have Internet connectivity.
With the use of asymmetric keys this means the public key (PK) must
somehow be obtained - [drip-registries] gets more into detail how
these keys are stored on DNS and one reason for DRIP Authentication
is to send PK's over Broadcast RID.

There are two keys of interest: the PK of the UA and the PK of the
HDA (or Registry). This document gives a clear way to send the PK of
the UA over the Broadcast RID messages. The key of the HDA can be
sent over Broadcast RID using the same mechanisms (see Section 5.2
and Section 6.3) but is not required due to potential operational
constraints of sending multiple DRIP Link messages. As such there
are scenarios where you may have part of the key-chain but not all
of it.

The intent of this appendix is to give some kind of recommended way
to classify these various states and convey it to the user through
colors and state names/text.

A.1. State Colors

The table below lays out the RECOMMENDED colors to associate with
state.

State	Color	Details
None	Black	No Authentication being received
Partial	Gray	Authentication being received but missing pages
Unsupported	Brown	Authentication Type/SAM Type of received message not supported
Unverifiable	Yellow	Data needed for verification missing
Verified	Green	Valid verification results
Trusted	Blue	Valid verification results and HDA is marked as trusted

State	Color	Details
Questionable	Orange	Inconsistent verification results
Unverified	Red	Invalid verification results
Conflicting	Purple	Inconsistent verification results and HDA is marked as trusted

<div align="center">Table 5</div>

A.2. State Diagrams

This section gives some RECOMMENDED state flows that DRIP should
follow. Note that the state diagrams do not have all error
conditions mapped.

A.2.1. Notations

```
          o--------------o
          |    PROCESS    |
          o--------------o


          +--------------+
          |     STATE     |
          +--------------+


           ooooo
          o  N  o     Transition N
           ooooo


          +----->    Transition Option False/No


          ----->     Transition Option True/Yes
```
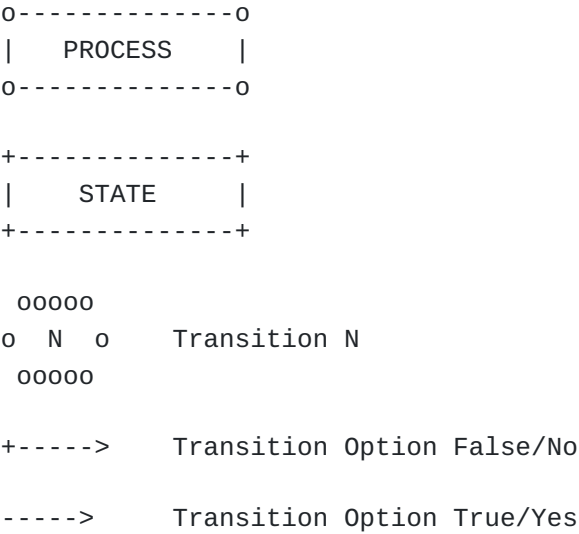
<div align="center">Figure 11: Diagram Notations</div>

A.2.2. General

```
O--------------------O      OOOOO         +------+
|      Start         |---->o  1  o+----->| None |
O--------------------O      OOOOO         +------+
                              |
                              v
                            OOOOO         +-------------+
                          o  2  o+----->| Unsupported |
                            OOOOO         +-------------+
                              |                 ^
                              v                 |
         +---------+        OOOOO               |
         | Partial |<-----+o  3  o              |
         +---------+        OOOOO               |
                              |                 |
                              v                 +
                            OOOOO      OOOOO            O-------------O
                          o  4  o------>o  5  o------>| SAM Decoder |
                            OOOOO      OOOOO            O-------------O
                              +
                              |
                              v
                   O-----------------O
                   | AuthType Decoder |
                   O-----------------O
```
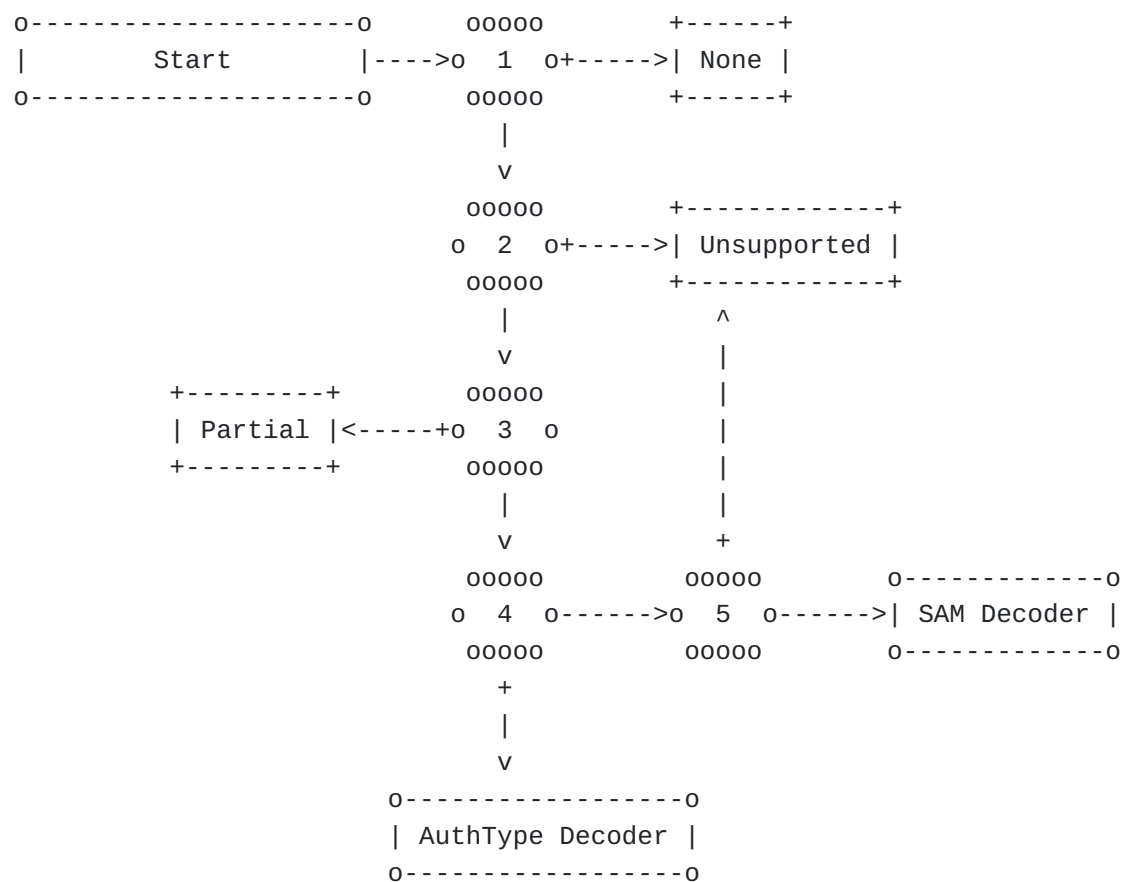
Figure 12: Standard Authentication Colors/State

Transition	Transition Query	Next State/Process/ Transition (Yes, No)
1	Receiving Authentication Pages?	2, None
2	Authentication Type Supported?	3, Unsupported
3	All Pages of Authentication Message Received?	4, Partial
4	Is Authentication Type received 5?	5, AuthType Decoder
5	Is SAM Type Supported?	SAM Decoder, Unsupported

Table 6

A.2.3. DRIP SAM

```
O-------------O       OOOOO         O-----------------------------O
| SAM Decoder |---->o  6  o------>| DRIP Wrapper/Manifest/Frame |
O-------------O       OOOOO         O-----------------------------O
       +                      |                    ^
       |                      |                    |
       v                      v                    |
   O-----------O       O-------------------O  |
   | DRIP Link |--->| Update State Cache |  |
   O-----------O       O-------------------O  |
                              |                    |
                              v                    |
  O--------------O       OOOOO       O---------------------O
  | NOP / Return |<------+o  7  o----->| Extract Message from |
  O--------------O       OOOOO       | Verification Queue   |
                                     O---------------------O
```

                    Figure 13: DRIP SAM Decoder

Transition	Transition Query	Next State/Process/Transition (Yes, No)
6	Is SAM Type DRIP Link?	DRIP Link, DRIP Wrapper/Manifest/Frame
7	Messages in Verification Queue?	Extract Message from Verification Queue, NOP / Return

                           Table 7

A.2.4. DRIP Link

```
     O-----------O        OOOOO          OOOOO         +--------------+
     | DRIP Link |----->o  8  o+----->o  9  o+----->| Unverifiable |
     O-----------O        OOOOO          OOOOO         +--------------+
                            |              |
                            |-------------'
                            v
                          OOOOO          +-----------+
                        o  10 o+----->| Unverified |
                          OOOOO          +-----------+
                            |
                            v
                  O--------------------O
                  | Add UA DET/PK      |
                  | to Key Cache       |
                  O--------------------O
                            |
                            v
                          OOOOO           +----------+
                        o  11 o+------>| Verified |
                          OOOOO           +----------+
                            |                 ^
                            v                 |
                  O------------------------O
                  | Mark UA DET/PK         |
                  | as Trusted in Key Cache |
                  O------------------------O
```

Figure 14: DRIP Link State Decoder

Transition	Transition Query	Next State/Process/ Transition (Yes, No)
8	Registry DET/PK in Key Cache?	10, 9
9	Registry PK found Online?	10, Unverifiable
10	Registry Signature Verified?	Add UA DET/PK to Key Cache, Unverified
11	Registry DET/PK marked as Trusted in Key Cache?	Mark UA DET/PK as Trusted in Key Cache, Verified

Table 8

A.2.5. DRIP Wrapper/Manifest/Frame

```
     o-----------------------------o          +--------------+
     | DRIP Wrapper/Manifest/Frame |          | Unverifiable |
     o-----------------------------o          +--------------+
                   |                                  ^
                   v                                  |
             ooooo          ooooo      o-------------------o
           o  12 o+----->o  13 o+----->| Add Message to    |
             ooooo          ooooo      | Verification Queue |
               |              |        o-------------------o
               |              |
               |-------------'
               v
             ooooo          ooooo          ooooo       +------------+
           o  14 o+----->o  15 o+----->o  16 o+----->| Unverified |
             ooooo          ooooo          ooooo       +------------+
               |              |              |
               v              v              |
             ooooo       +--------------+     |
           o  17 o+----->| Conflicting |     |
             ooooo       +--------------+     |
               |                              |
               v                              v
             ooooo                   +--------------+
           o  18 o---------------->| Questionable |
             ooooo                   +--------------+
               +
               |
               v
             ooooo       +----------+
           o  19 o+----->| Verified |
             ooooo       +----------+
               |
               v
          +---------+
          | Trusted |
          +---------+
```
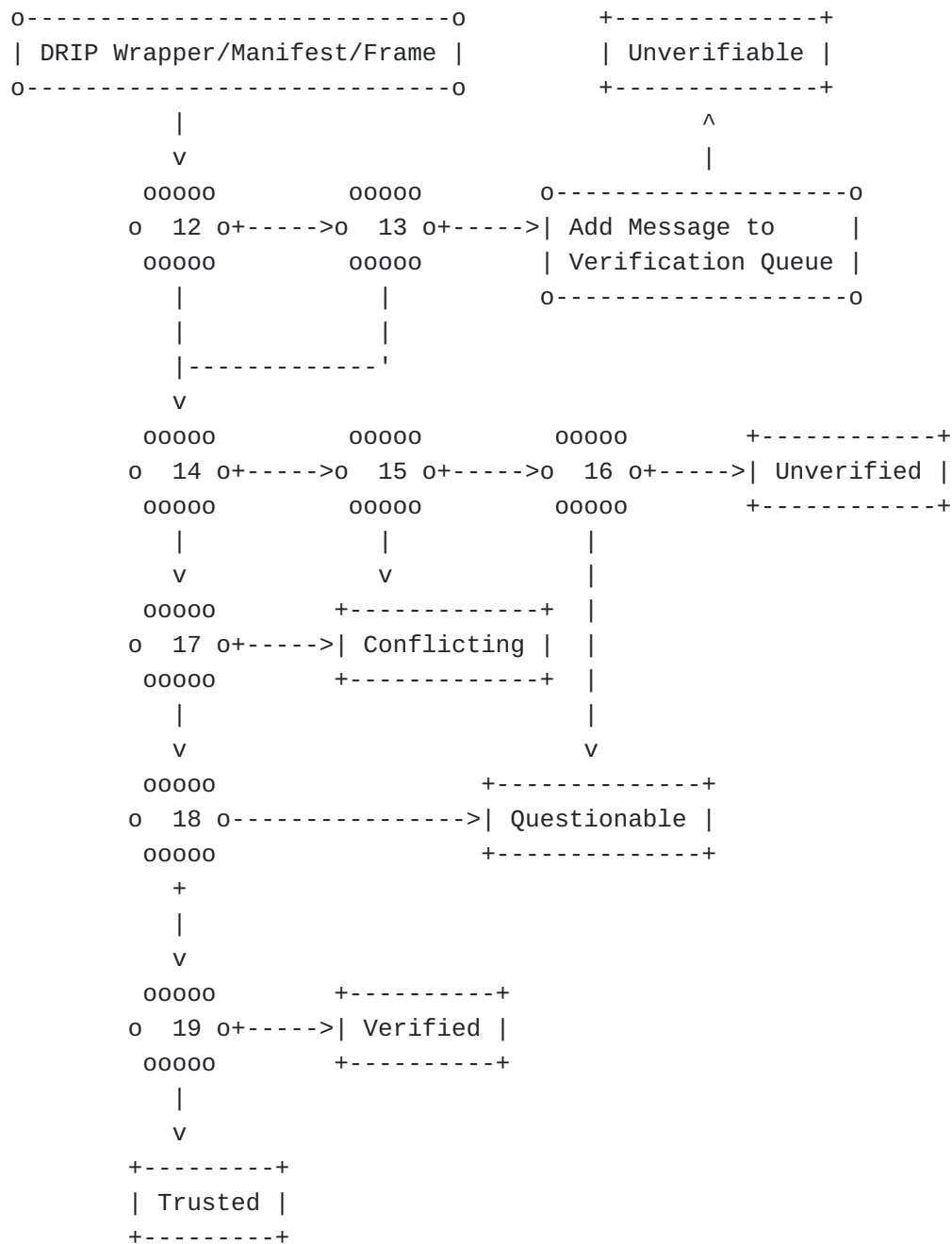
Figure 15: DRIP Wrapper/Manifest/Frame State Decoder

Transition	Transition Query	Next State/Process/ Transition (Yes, No)
12	UA DET/PK in Key Cache?	14, 13
13	UA PK found Online?	14, Add Message to Verification Queue
14	UA Signature Verified?	17, 15
15	Has past Messages of this type been marked as Trusted?	Conflicting, 16
16		Questionable, Unverified

Transition	Transition Query	Next State/Process/ Transition (Yes, No)
	Has past Messages of this type been marked as Questionable or Verified?	
17	Has past Messages of this type been marked as Conflicting?	Conflicting, 18
18	Has past Messages of this type been marked as Questionable or Unverified?	Questionable, 19
19	Is UA DET/PK marked as Trusted in Key Cache?	Trusted, Verified

Table 9

Appendix B. HDA-UA Broadcast Attestation
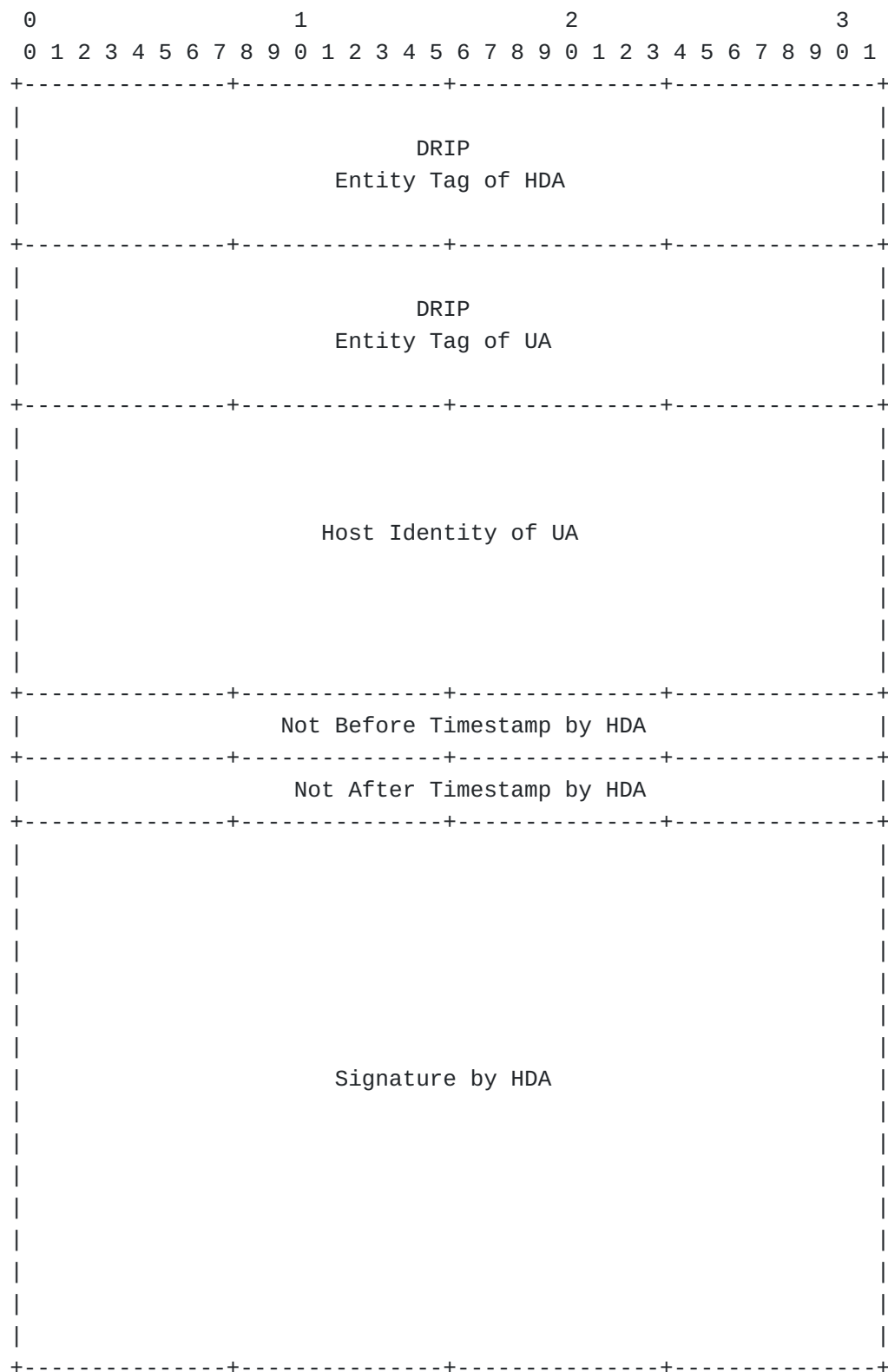
```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +---------------+---------------+---------------+---------------+
    |                                                               |
    |                             DRIP                              |
    |                       Entity Tag of HDA                       |
    |                                                               |
    +---------------+---------------+---------------+---------------+
    |                                                               |
    |                             DRIP                              |
    |                       Entity Tag of UA                        |
    |                                                               |
    +---------------+---------------+---------------+---------------+
    |                                                               |
    |                                                               |
    |                                                               |
    |                       Host Identity of UA                     |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    +---------------+---------------+---------------+---------------+
    |                 Not Before Timestamp by HDA                   |
    +---------------+---------------+---------------+---------------+
    |                 Not After Timestamp by HDA                    |
    +---------------+---------------+---------------+---------------+
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                       Signature by HDA                        |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    |                                                               |
    +---------------+---------------+---------------+---------------+

DRIP Entity Tag of HDA: (16-bytes)
     DET of HDA.

DRIP Entity Tag of UA: (16-bytes)
     DET of UA.
```

```
Host Identity of UA: (32-bytes)
     HI of UA

Expiration Timestamp by HDA (4 bytes):
     Timestamp denoting recommended time to trust data to.

Signing Timestamp by HDA (4 bytes):
     Current time at signing.

HDA Signature (64 bytes):
     Signature over preceding fields using the keypair of
     the HDA.
```

Figure 16: Example DRIP HDA-UA Broadcast Attestation

Appendix C. Example TX/RX Flow

   In this example the UA is sending all DRIP Authentication Message
   formats (DRIP Link, DRIP Wrapper and DRIP Manifest) during flight,
   along with standard ASTM Messages. The objective is to show the
   combinations of messages that must be received to properly validate
   a DRIP equipped UA and examples of their various states (Appendix
   A).

```
        +-------------------+
  .-----| Unmanned Aircraft |-----.
  |     +-------------------+     |
  | 1       | 2         | 3       | 4
  |         |           |         |

   O         O           O         O
--|--      --|--       --|--     --|--
 / \        / \         / \       / \
  A          B           C         D
```

Broadcast Paths: Messages Received
1: DRIP Link
2: DRIP Link and DRIP Wrapper or DRIP Manifest
3: DRIP Wrapper or DRIP Manifest
4: None

Observers: Authentication State
A: Unverifiable
B: Verified, Trusted, Unverified, Questionable, or Conflicting
C: Unverifiable
D: None

   As the above example shows to properly authenticate both a DRIP Link
   and a DRIP Wrapper or DRIP Manifest are required.

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