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Abstract

This document describes using the ASTM Broadcast Remote ID (B-RID) specification in a "crowd sourced" smart phone environment to provide much of the ASTM and FAA envisioned Network Remote ID (N-RID) functionality. This crowd sourced B-RID data will use multilateration to add a level of reliability in the location data on the Unmanned Aircraft (UA). The crowd sourced environment will also provide a monitoring coverage map to authorized observers.

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Table of Contents

1.	Introduction	3
1.1.	Draft Status	4
2.	Terms and Definitions	4
2.1.	Requirements Terminology	4
2.2.	Definitions	4
3.	Problem Space	6
3.1.	Meeting the needs of Network Remote ID	6
3.2.	Advantages of Broadcast Remote ID	6
3.3.	Trustworthiness of Proxied Data	7
3.4.	Defense against fraudulent RID Messages	7
4.	The Finder - SDSP Security Relationship	7
4.1.	The Finder Map	8
4.2.	Managing Finders	8
5.	UA location via multilateration	8
5.1.	GPS Inaccuracy	9
6.	The CS-RID Messages	9
6.1.	CS-RID MESSAGE TYPE	10
6.1.1.	CDDL description for CS-RID message type	10
6.2.	The CS-RID B-RID Proxy Message	11
6.2.1.	CS-RID ID	12
6.2.2.	CDDL description for CS-RID B-RID Proxy Message	12
6.3.	CS-RID Finder Registration	13
6.3.1.	CDDL description for Finder Registration	14
6.4.	CS-RID SDSP Response	14
6.4.1.	CDDL description for SDSP Response	15
6.5.	CS-RID Location Update	15
6.5.1.	CDDL description for Location Update	16
7.	The Full CS-RID CDDL specification	16
8.	IANA Considerations	19
9.	Security Considerations	19
9.1.	Privacy Concerns	19
10.	References	19
10.1.	Normative References	19
10.2.	Informative References	19
	Appendix A. Using LIDAR for UA location	21
	Acknowledgments	21

Authors' Addresses 21

1. Introduction

This document defines a mechanism to capture the ASTM Broadcast Remote ID messages (B-RID) [F3411-19] on any Internet connected device that receives them and can forward them to the SDSP(s) responsible for the geographic area the UA and receivers are in. This will create an ecosystem that will meet most if not all data collection requirements that CAAs are placing on Network Remote ID (N-RID).

These Internet connected devices are herein called "Finders", as they find UAs by listening for B-RID messages. The Finders are B-RID forwarding proxies. Their potentially limited spacial view of RID messages could result in bad decisions on what messages to send to the SDSP and which to drop. The SDSP will make any filtering decisions in what it forwards to the UTM(s).

Finders can be smartphones, tablets, connected cars, or any computing platform with Internet connectivity that can meet the requirements defined in this document. It is not expected, nor necessary, that Finders have any information about a UAS beyond the content in the B-RID messages.

Finders MAY only need a loose association with the SDSP(s). They may only have the SDSP's Public Key and FQDN. It would use these, along with the Finder's Public Key to use ECIES, or other security methods, to send the messages in a secure manner to the SDSP. The SDSP MAY require a stronger relationship to the Finders. This may range from the Finder's Public Key being registered to the SDSP with other information so that the SDSP has some level of trust in the Finders to requiring transmissions be sent over long-lived transport connections like ESP or DTLS.

This document has minimal information about the actions of SDSPs. In general the SDSP is out of scope of this document. That said, the SDSPs should not simply proxy B-RID messages to the UTM(s). They should perform some minimal level of filtering and content checking before forwarding those messages that pass these tests in a secure manner to the UTM(s).

The SDSPs are also capable of maintaining a monitoring map, based on location of active Finders. UTMs may use this information to notify authorized observers of where there is and there is not monitoring coverage. They may also use this information of where to place proactive monitoring coverage.

An SDSP SHOULD only forward Authenticated B-RID messages like those defined in [tmrid-auth] to the UTM(s). Further, the SDSP SHOULD validate the Remote ID (RID) and the Authentication signature before forwarding anything from the UA. The SDSP MAY forward all B-RID messages to the UTM, leaving all decision making on B-RID messages veracity to the UTM.

When 3 or more Finders are reporting to an SDSP on a specific UA, the SDSP is in a unique position to perform multilateration on these messages and compute the Finder's view of the UA location to compare with the UA Location/Vector messages. This check against the UA's location claims is both a validation on the UA's reliability as well as the trustworthiness of the Finders. Other than providing data to allow for multilateration, this SDSP feature is out of scope of this document. This function is limited by the location accuracy for both the Finders and UA.

1.1. Draft Status

This draft is still incomplete. New features are being added as capabilities are researched. The actual message formats also still need work.

2. Terms and Definitions

2.1. Requirements Terminology

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

2.2. Definitions

B-RID:

Broadcast Remote ID. A method of sending RID messages as 1-way transmissions from the UA to any Observers within radio range.

CAA:

Civil Aeronautics Administration. An example is the Federal Aviation Administration (FAA) in the United States of America.

DAA:

Detect and Avoid. The process of a UA detecting obstacles, like other UAs and taking the necessary evasive action.

ECIES:

Elliptic Curve Integrated Encryption Scheme. A hybrid encryption scheme which provides semantic security against an adversary who is allowed to use chosen-plaintext and chosen-ciphertext attacks.

GCS:

Ground Control Station. The part of the UAS that the remote pilot uses to exercise C2 over the UA, whether by remotely exercising UA flight controls to fly the UA, by setting GPS waypoints, or otherwise directing its flight.

Finder:

In Internet connected device that can receive B-RID messages and forward them to a UTM.

Observer:

Referred to in other UAS documents as a "user", but there are also other classes of RID users, so we prefer "observer" to denote an individual who has observed an UA and wishes to know something about it, starting with its RID.

Multilateration:

Multilateration (more completely, pseudo range multilateration) is a navigation and surveillance technique based on measurement of the times of arrival (TOAs) of energy waves (radio, acoustic, seismic, etc.) having a known propagation speed.

NETSP:

Network RID Service Provider. USS receiving Network RID messages from UAS (UA or GCS), storing for a short specified time, making available to NETDP.

NETDP:

Network RID Display Provider. Entity (might be USS) aggregating data from multiple NETSPs to answer query from observer (or other party) desiring Situational Awareness of UAS operating in a specific airspace volume.

N-RID:

Network Remote ID. A method of sending RID messages via the Internet connection of the UAS directly to the UTM.

RID:

Remote ID. A unique identifier found on all UA to be used in communication and in regulation of UA operation.

SDSP:

Supplemental Data Service Provider. Entity providing information that is allowed, but not required to be present in the UTM system.

UA:

Unmanned Aircraft. In this document UA's are typically thought of as drones of commercial or military variety. This is a very strict definition which can be relaxed to include any and all aircraft that are unmanned.

UAS:

Unmanned Aircraft System. Composed of Unmanned Aircraft and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, all required crew members, and C2 links between UA and the control station.

UTM:

UAS Traffic Management. A "traffic management" ecosystem for uncontrolled operations that is separate from, but complementary to, the FAA's Air Traffic Management (ATM) system.

USS:

UAS Service Supplier. Provide UTM services to support the UAS community, to connect Operators and other entities to enable information flow across the USS network, and to promote shared situational awareness among UTM participants. (From FAA UTM ConOps V1, May 2018).

3. Problem Space

3.1. Meeting the needs of Network Remote ID

The Federal (US) Aviation Authority (FAA), in the January 2021 Remote ID Final rule [FAA-FR], has postponed Network Remote ID (N-RID) and focused on Broadcast Remote ID for now. This was in response to the UAS vendors comments that N-RID places considerable demands on currently used UAS.

However, N-RID, or equivalent, is necessary for UTM and knowing what soon may be in an airspace. A method that proxies B-RID into UTM can function as an interim approach to N-RID and continue as a adjunct to N-RID.

3.2. Advantages of Broadcast Remote ID

B-RID has its advantages over N-RID.

- o B-RID can more readily be implemented directly in the UA. N-RID will more frequently be provided by the GCS or a pilot's Internet connected device.

- * If Command and Control (C2) is bi-directional over a direct radio connection, B-RID could be a straight-forward addition.
- * Small IoT devices can be mounted on UA to provide B-RID.
- o B-RID can also be used by the UA to assist in Detect and Avoid (DAA).
- o B-RID is available to observers even in situations with no Internet like natural disaster situations.

3.3. Trustworthiness of Proxied Data

When a proxy is introduced in any communication protocol, there is a risk of corrupted data and DOS attacks.

The Finders, in their role as proxies for B-RID, are authenticated to the SDSP (see Section 4). The SDSP can compare the information from multiple Finders to isolate a Finder sending fraudulent information. SDSPs can additionally verify authenticated messages that follow [tmrid-auth].

The SPDP can manage the number of Finders in an area (see Section 4.2) to limit DOS attacks from a group of clustered Finders.

3.4. Defense against fraudulent RID Messages

The strongest defense against fraudulent RID messages is to focus on [tmrid-auth] conforming messages. Unless this behavior is mandated, SPDPs will have to use assorted algorithms to isolate messages of questionable content.

4. The Finder - SDSP Security Relationship

The SDSP(s) and Finders SHOULD use EDDSA [RFC8032] keys as their trusted Identities. The public keys SHOULD be registered Hierarchical HITS, [hierarchical-hit] and [hhit-registries].

The SDSP uses some process (out of scope here) to register the Finders and their EDDSA Public Key. During this registration, the Finder gets the SDSP's EDDSA Public Key. These Public Keys allow for the following options for authenticated messaging from the Finder to the SDSP.

1. ECIES can be used with a unique nonce to authenticate each message sent from a Finder to the SDSP.

2. ECIES can be used at the start of some period (e.g. day) to establish a shared secret that is then used to authenticate each message sent from a Finder to the SDSP sent during that period.
3. HIPv2 [RFC7401] can be used to establish a session secret that is then used with ESP [RFC4303] to authenticate each message sent from a Finder to the SDSP.
4. DTLS [RFC5238] can be used to establish a secure connection that is then used to authenticate each message sent from a Finder to the SDSP.

4.1. The Finder Map

The Finders are regularly providing their SDSP with their location. This is through the B-RID Proxy Messages and Finder Location Update Messages. With this information, the SDSP can maintain a monitoring map. That is a map of where there Finder coverage.

4.2. Managing Finders

Finder density will vary over time and space. For example, sidewalks outside an urban train station can be packed with pedestrians at rush hour, either coming or going to their commute trains. An SDSP may want to proactively limit the number of active Finders in such situations.

Using the Finder mapping feature, the SDSP can instruct Finders to NOT proxy B-RID messages. These Finders will continue to report their location and through that reporting, the SDSP can instruct them to again take on the proxying role. For example a Finder moving slowly along with dozens of other slow-moving Finders may be instructed to suspend proxying. Whereas a fast-moving Finder at the same location (perhaps a connected car or a pedestrian on a bus) would not be asked to suspend proxying as it will soon be out of the congested area.

5. UA location via multilateration

The SDSP can confirm/correct the UA location provided in the Location/Vector message by using multilateration on data provided by at least 3 Finders that reported a specific Location/Vector message (Note that 4 Finders are needed to get altitude sign correctly). In fact, the SDSP can calculate the UA location from 3 observations of any B-RID message. This is of particular value if the UA is only within reception range of the Finders for messages other than the Location/Vector message.

This feature is of particular value when the Finders are fixed assets around a high value site like an airport or large public venue.

5.1. GPS Inaccuracy

Single-band, consumer grade, GPS on small platforms is not accurate, particularly for altitude. Longitude/latitude measurements can easily be off by 3M based on satellite position and clock accuracy. Altitude accuracy is reported in product spec sheets and actual tests to be 3x less accurate. Altitude accuracy is hindered by ionosphere activity. In fact, there are studies of ionospheric events (e.g. 2015 St. Patrick's day [gps-ionosphere]) as measured by GPS devices at known locations.

Thus where a UA reports it is rarely accurate, but may be accurate enough to map to visual sightings of single UA.

Smartphones and particularly smartwatches are plagued with the same challenge, though some of these can combine other information like cell tower data to improve location accuracy. FCC E911 accuracy, by FCC rules is NOT available to non-E911 applications due to privacy concerns, but general higher accuracy is found on some smart devices than reported for consumer UA. The SDSP MAY have information on the Finder location accuracy that it can use in calculating the accuracy of a multilaterated location value. When the Finders are fixed assets, the SDSP may have very high trust in their location for trusting the multilateration calculation over the UA reported location.

6. The CS-RID Messages

The CS-RID messages between the Finders and the SDSPs primarily support the proxy role of the Finders in forwarding the B-RID messages. There are also Finder registration and status messages.

CS-RID information is represented in CBOR [RFC7049]. The CDDL [RFC8610] specification is used for CS-RID message description

CS-RID MAC and COAP [RFC7252] for the CS-RID protocol.

The following is a general representation of the content in the CS-RID messages.

```
(
  CS-RID MESSAGE TYPE,
  CS-RID MESSAGE CONTENT,
  CS-RID MAC
)
```

The CS-RID MESSAGE CONTENT varies by MESSAGE TYPE.

6.1. CS-RID MESSAGE TYPE

The CS-RID MESSAGE TYPE is defined in Figure 1:

Number	CS-RID Message Type
-----	-----
0	Reserved
1	B-RID Forwarding
2	Finder Registration
3	SDSP Response
4	Finder Location

Figure 1

6.1.1. CDDL description for CS-RID message type

The overall CS-RID CDDL description is structured in Figure 2.

```

CSRID_Object = {
  application-context,
  info           => info_message,
  proxy_message  => broadcast_rid_proxy_message,
  finder_registration => finder_registration_message,
  sdsp_response  => sdsp_response_message,
  location_update  => location_update_message,
}

info_message = {
  common_message_members,
  message_content => tstr,
}

common_message_members = (
  message_type  => message_types,
  mac_address   => #6.37(bstr),
)

message_types = &(amp;
  Reserved      : 0,
  BRD           : 1,
  Finder-Registration : 2,
  SDSP-Response  : 3,
  Finder-Location  : 4,
)

```

Figure 2

The application context rule is defined in Figure 3 for CS-RID application identification and version negotiation.

```
application-context = (
  application => "DRIP-CSRID",
  ? version => uint .size(1..2),
)
```

Figure 3

The predefined CDDL text string labels (author note: for JSON currently, will move to CBOR uint keys in upcoming versions) used in the specification is listed in Figure 4.

```
application          = "application"
version              = "version"
info                 = "message_info"
proxy_message        = "proxy_message-type"
finder_registration = "finder_registration"
sdsp_response        = "sdsp_response"
location_update      = "location_update"
rid                  = "id"
message_type         = "message_type"
mac_address          = "mac_address"
message_content      = "message_content"
timestamp            = "timestamp"
gps                  = "gps"
radio_type           = "radio_type"
broadcast_mac_address = "broadcast_mac_address"
broadcast_message    = "broadcast_message"
sdsp_id              = "sdsp_id"
proxy_status_type    = "proxy_status_type"
update_interval      = "update_interval"
```

Figure 4

6.2. The CS-RID B-RID Proxy Message

The Finders add their own information to the B-RID messages, permitting the SDSP(s) to gain additional knowledge about the UA(s). The RID information is the B-RID message content plus the MAC address. The MAC address is critical, as it is the only field that links a UA's B-RID messages together. Only the ASTM Basic ID Message and possibly the Authentication Message contain the UAS ID field.

The Finders add an SDSP assigned ID, a 64 bit timestamp, GPS information, and type of B-RID media to the B-RID message. Both the timestamp and GPS information are for when the B-RID message(s) were

received, not forwarded to the SDSP. All this content is MACed using a key shared between the Finder and SDSP.

The following is a representation of the content in the CS-RID messages.

```
(
  CS-RID MESSAGE TYPE,
  CS-RID ID,
  RECEIVE TIMESTAMP,
  RECEIVE GPS,
  RECEIVE RADIO TYPE,
  B-RID MAC ADDRESS,
  B-RID MESSAGE,
  CS-RID MAC
)
```

6.2.1. CS-RID ID

The CS-RID ID is the ID recognized by the SDSP. This may be an HHIT Hierarchical HITs [hierarchical-hit], or any ID used by the SDSP.

6.2.2. CDDL description for CS-RID B-RID Proxy Message

The broadcast CS-RID proxy CDDL is defined in Figure 5

```
broadcast_rid_proxy_message = {
    common_message_members,
    rid                => tstr,
    timestamp          => tdate,
    gps                => gps-coordinates,
    radio_type         => radio_types,
    broadcast_mac_address => #6.37(bstr),
    broadcast_message  => #6.37(bstr),
}

radio_types = &(amp;
    EFL : 0,
    VLF : 1,
    LF  : 2,
    MF  : 3,
    HF  : 4,
    HF  : 5,
    VHF : 6,
    UHF : 7,
    SHF : 8,
    EHF : 9,
)

gps-coordinates = [
    latitude : float,
    longitude: float,
]
```

Figure 5

6.3. CS-RID Finder Registration

The CS-RID Finder MAY use HIPv2 [RFC7401] with the SDSP to establish a Security Association and a shared secret to use for the CS-RID MAC generation. In this approach, the HIPv2 mobility functionality and ESP [RFC4303] support are not used.

When HIPv2 is used as above, the Finder Registration is a SDSP "wake up". It is sent prior to the Finder sending any proxied B-RID messages to ensure that the SDSP is able to receive and process the messages.

In this usage, the CS-RID is the Finder HIT. If the SDSP has lost state with the Finder, it initiates the HIP exchange with the Finder to reestablish HIP state and a new shared secret for the CS-RID B-RID Proxy Messages. In this case the Finder Registration Message is:

```
(
  CS-RID MESSAGE TYPE,
  CS-RID ID,
  CS-RID TIMESTAMP,
  CS-RID GPS,
  CS-RID MAC
)
```

6.3.1. CDDL description for Finder Registration

The CDDL for CS-RID Finder Registration is defined in Figure 6

```
finder_registration_message = {
  common_message_members,
  rid      => tstr,
  timestamp => tdate,
  gps      => gps-coordinates,
}

gps-coordinates = [
  latitude : float,
  longitude: float,
]
```

Figure 6

6.4. CS-RID SDSP Response

The SDSP MAY respond to any Finder messages to instruct the Finder on its behavior.

```
(
  CS-RID MESSAGE TYPE,
  SDSP ID,
  CS-RID ID,
  CS-RID PROXY STATUS,
  CS-RID UPDATE INTERVAL,
  CS-RID MAC
)
```

The Proxy Status instructs the Finder if it should actively proxy B-RID messages, or suspend proxying and only report its location.

The Update Interval is the frequency that the Finder SHOULD notify the SDSP of its current location using the Location Update message.

6.4.1. CDDL description for SDSP Response

The CDDL for CS-RID SDSP response is defined in Figure 7

```

sdsp_response_message = {
  common_message_members,
  sdsp_id           => tstr,
  rid               => tstr,
  proxy_status_type => proxy_status_types,
  update_interval  => uint,
}

gps-coordinates = [
  latitude : float,
  longitude: float,
]

proxy_status_types = &(amp;
  0: "forward",
  1: "reverse",
  2: "bi-directional",
)

```

Figure 7

6.5. CS-RID Location Update

The Finder SHOULD provide regular location updates to the SDSP. The interval is based on the Update Interval from Section 6.4 plus a random slew less than 1 second. The Location Update message is only sent when no other CS-RID messages, containing the Finder's GPS location, have been sent since the Update Interval.

If the Finder has not received a SDSP Registration Response, a default of 5 minutes is used for the Update Interval.

```

(
  CS-RID MESSAGE TYPE,
  CS-RID ID,
  CS-RID TIMESTAMP,
  CS-RID GPS,
  CS-RID MAC
)

```

6.5.1. CDDL description for Location Update

The CDDL for CS-RID Location update is defined in Figure 8

```
location_update_message = {
    common_message_members,
    rid          => tstr,
    timestamp    => tdate,
    gps          => gps-coordinates,
}

gps-coordinates = [
    latitude : float,
    longitude: float,
]
```

Figure 8

7. The Full CS-RID CDDL specification

```
<CODE BEGINS>
; CDDL specification for Crowd source RID
; It specifies a collection of CS message types
;
;
; The CSRID overall data structure

CSRID_Object = {
    application-context,
    info => info_message,
    proxy_message => broadcast_rid_proxy_message,
    finder_registration => finder_registration_message,
    sdsp_response => sdsp_response_message,
    location_update => location_update_message,
}

;
; Application context: general information about CSRID message

application-context = (
    application => "DRIP-CSRID", ; TBD: consider CBOR tag
    ? version => uint .size(1..2),
)

; These members are include in every message
common_message_members = (
    message_type => message_types,
```

```
    mac_address => #6.37(bstr),
)
;
; CSRID message general information

info_message = {
    common_message_members,
    message_content => tstr,
}

broadcast_rid_proxy_message = {
    common_message_members,
    rid => tstr,
    timestamp => tdate,
    gps => gps-coordinates,
    radio_type => radio_types,
    broadcast_mac_address => #6.37(bstr)
    broadcast_message => #6.37(bstr)
}

finder_registration_message = {
    common_message_members,
    rid => tstr,
    timestamp => tdate,
    gps => gps-coordinates,
}

sdsp_response_message = {
    common_message_members,
    sdsp_id => tstr,
    rid => tstr,
    proxy_status_type => proxy_status_types,
    update_interval => uint,
}

location_update_message = {
    common_message_members,
    rid => tstr,
    timestamp => tdate,
    gps => gps-coordinates,
}

;
; Common rule definition

message_types = &(
    Reserved          : 0,
```

```
        BRD : 1,
        Finder-Registration : 2,
        SDSP-Response : 3,
        Finder-Location : 4,
    )

gps-coordinates = [
    lat: float,
    long: float,
]

; Radio types, choose from one of radio_types (required)
radio_types = &(amp;
    EFL : 0,
    VLF : 1,
    LF : 2,
    MF : 3,
    HF : 4,
    HF : 5,
    VHF : 6,
    UHF : 7,
    SHF : 8,
    EHF : 9,
)

proxy_status_types = &(amp;
    0: "forward",
    1: "reverse",
    2: "bi",
)

;
; JSON label names

application = "application"
version = "version"
info = "message_info"
proxy_message = "proxy_message-type"
finder_registration = "finder_registration"
sdsp_response = "sdsp_response"
location_update = "location_update"
rid = "id"
message_type = "message_type"
mac_address = "mac_address"
message_content = "message_content"
timestamp = "timestamp"
gps = "gps"
radio_type = "radio_type"
```

```
broadcast_mac_address = "broadcast_mac_address"  
broadcast_message = "broadcast_message"  
sdsp_id = "sdsp_id"  
proxy_status_type = "proxy_status_type"  
update_interval = "update_interval"
```

<CODE ENDS>

8. IANA Considerations

TBD

9. Security Considerations

TBD

9.1. Privacy Concerns

TBD

10. References

10.1. Normative References

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Appendix A. Using LIDAR for UA location

If the Finder has LIDAR or similar detection equipment (e.g. on a connected car) that has full sky coverage, the Finder can use this equipment to locate UAs in its airspace. The Finder would then be able to detect non-participating UAs. A non-participating UA is one that the Finder can "see" with the LIDAR, but not "hear" any B-RID messages.

These Finders would then take the LIDAR data, construct appropriate B-RID messages, and forward them to the SPDP as any real B-RID messages. There is an open issue as what to use for the actual RemoteID and MAC address.

The SDSP would do the work of linking information on a non-participating UA that it has received from multiple Finders with LIDAR detection. In doing so, it would have to select a RemoteID to use.

A seemingly non-participating UA may actually be a UA that is beyond range for its B-RID but in the LIDAR range.

This would provide valuable information to SDSPs to forward to UTMs on potential at-risk situations.

At this time, research on LIDAR and other detection technology is needed. there are full-sky LIDAR for automotive use with ranges varying from 20M to 250M. Would more than UA location information be available? What information can be sent in a CS-RID message for such "unmarked" UAs?

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