DRIP
Internet-Draft
Intended status: Standards Track
Expires: 28 June 2021

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25 December 2020

Secure UAS Network RID and C2 Transport
draft-moskowitz-drip-secure-nrid-c2-02

Abstract

This document provides the mechanisms for secure transport of UAS Network-RemoteID and Command-and-Control messaging. Both HIP and DTLS based methods are described.

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1. Introduction

This document defines mechanisms to provide secure transport for the ASTM Network Remote ID [F3411-19] (N-RID) and UAS Command and Control (C2) messaging.

A secure transport for C2 is critical for UAS Beyond line of sight (BLOS) operations.

Two options for secure transport are provided: HIPv2 [RFC7401] and DTLS [DTLS-1.3-draft]. These options are generally defined and their applicability is compared and contrasted. It is up to N-RID and C2 to select which is preferred for their situation.

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

See [drip-requirements] for common DRIP terms.

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

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.

3. Network RID endpoints

The FAA defines the Network Remote ID endpoints as a USS Network Service Provider (Net-RID SP) and the UAS. Both of these are rather nebulous items and what they actually are will impact how communications flow between them.

The Net-RID SP may be provided by the same entity serving as the UAS Service Provider (USS). This simplifies a number of aspects of the N-RID communication flow. An Operator is expected to register an

operation with the USS. If this is done via the GCS and the GCS is the source (directly acting as a gateway), this could set up the secure connection for N-RID. The Net-RID SP is likely to be stable in the network, that is its IP address will not change during a mission. This simplifies maintaining the N-RID communications.

The UAS component in N-RID may be either the UA, GCS, or the Operator's Internet connected device (e.g. smartphone or tablet). In all cases, mobility MUST be assumed. That is the IP address of this end of the N-RID communication will change during an operation. The N-RID mechanism MUST support this. the UAS Identity for the secure connection may vary based on the UAS endpoint.

3.1. N-RID from the UA

Some UA will be equipped with direct Internet access. These UA will also tend to have multiple radios for their Internet access. Thus multi-homing with "make before break" behavior is needed. This is on top of any IP address changes on any of the interfaces while in use.

3.2. N-RID from the GCS

Many UA will lack direct Internet access, but their GCS may be so connected. There are two sources for the GCS for the RID messages, both from the UA. These are UA B-RID messages, or content from C2 messages that the GCS converts to RID message format. In either case, the GCS may be mobile with changing IP addresses. The GCS may be in a fast moving ground device (delivery van), so it can have as mobility demanding connection needs as the UA.

3.3. N-RID from the Operator

Many UAS will have no Internet connectivity, but the UA is sending B-RID messages and the Operator has an Internet Connected device that is receiving these B-RID messages. The Operator's device can act as the proxy for these messages, turning them into N-RID messages.

3.4. UAS Identity

The UA MAY use its RID private key if the RID is a HHIT [drip-uas-rid]. It may use some other Identity, based on the Net-RID SP policy.

The GCS or Operator smart device may have a copy of the UA credentials and use them in the connection to the Net-RID SP. In this case, they are indistinguishable from the UA as seen from the Net-RID SP. Alternatively, they may use their own credentials with the Net-RID SP which would need some internal mechanism to tie that to the UA.

4. Command and Control

Command and Control (C2) connection is between the UA and GCS. Often this over a direct link radio. Some times, particularly for BLOS, it is via Internet connections. In either case C2 SHOULD be secure from eavesdropping and tampering. For design and implementation consistency it is best to treat the direct link as a local link Internet connection and use constrained networking compression standards.

Both the UA and GCS need to be treated as fully mobile in the IP networking sense. Either one can have its IP address change and both could change at the same time (the double jump problem). It is preferable to use a peer-to-peer (P2P) secure technology like HIPv2 [RFC7401].

Finally UA may also tend to have multiple radios for their C2 communications. Thus multi-homing with "make before break" behavior is needed. This is on top of any IP address changes on any of the interfaces while in use.

5. Secure Transports

The raw RID and C2 messages will be wrapped in UDP. These UDP packets will either be transported in ESP for the HIPv2 approach or DTLS application messages for DTLS. In both cases header compression technologies SHOULD be used and negotiated based on policy.

For IPv6 over both WiFi and Bluetooth (or any other radio link), Robust Header Compression (ROHC) [RFC5795] and/or Generic Header Compression (6LoWAN-HGC) [RFC7400] can significantly reduce the per packet transmission cost of IPv6. For Bluetooth, there is also IPv6

over Bluetooth LE [RFC7668] for more guidance.

Local link (direct radio) C2 security is possible with the link's MAC layer security. Both WiFi and Bluetooth link security can provide appropriate security, but this would not provide trustworthy multi-homed security.

5.1. HIPv2 for Secure Transport

HIP has already been used for C2 mobility, managing the ongoing connectivity over WiFi at start of an operation, switching to LTE once out of WiFi range, and returning to WiFi connectivity at the end of the operation. This functionality is especially important for BLOS. HHITs are already defined for RID, and need only be added to the GCS via a GCS Registration as part of the UAS to USS registration to be usedfor C2 HIP.

When the UA is the UAS endpoint for N-RID, and particularly when HIP is used for C2, HIP for N-RID simplifies protocol use on the UA. The Net-RID SP endpoint may already support HIP if it is also the HHIT Registrar. If the UA lacks any IP ability and the RID HHIT registration was done via the GCS or Operator device, then they may also be set for using HIP for N-RID.

Further, double jump and multi-homing support is mandatory for C2 mobility. This is inherent in the HIP design. The HIP address update can be improved with [hip-fast-mobility].

5.2. DTLS for Secure Transport

DTLS is a good fit for N-RID for any of the possible UAS endpoints. There are challenges in using it for C2. To use DTLS for C2, the GCS will need to be the DTLS server. How does it 'push' commands to the UA? How does it reestablish DTLS security if state is lost? And finally, how is the double jump scenario handled?

All the above DTLS for C2 probably have solutions. None of them are inherent in the DTLS design.

5.3. Ciphers for Secure Transport

The cipher choice for either HIP or DTLS depends, in large measure, on the UAS endpoint. If the endpoint is computationally constrained, the cipher computations become important. If any of the links are constrained or expensive, then the over-the-wire cost needs to be minimized. AES-CCM and AES-GCM are the preferred, modern, AEAD ciphers.

For ESP with HIP [RFC7402], an additional 4 - 8 bytes can be trimmed by using the Implicit IV for ESP option [RFC8750].

NIST is working on selecting a new lightweight cipher that may be the best choice for use on a UA. The Keccak Xoodyak cipher in [new-crypto] is a good "Green Cipher".

5.4. HIP and DTLS contrasted and compared

This document specifies the use of DTLS 1.3 for its 0-RTT mobility feature and improved (over 1.2) handshake. DTLS 1.3 is still an IETF draft, so there is little data available to properly contrast it with HIPv2. This section will be based on the current DTLS 1.2. The basic client-server model is unchanged.

The use of DTLS vs HIPv2 (both over UDP, HIP in IPsec ESP BEET mode) has pros and cons. DTLS is currently at version 1.2 and based on TLS 1.2. It is a more common protocol than HIP, with many different implementations available for various platforms and languages.

DTLS implements a client-server model, where the client initiates the communication. In HIP, two parties are equal and either can be an Initiator or Responder of the Base Exchange. HIP provides separation between key management (base exchange) and secure transport (for example IPsec ESP BEET) while both parts are tightly coupled in DTLS.

DTLS 1.2 still has quite chatty connection establishment taking 3-5 RTTs and 15 packets. HIP connection establishment requires 4 packets

(I1,R1,I2,R2) over 2 RTTs. This is beneficial for constrained environments of UAs. HIPv2 supports cryptoagility with possibility to negotiate cryptography mechanisms during the Base Exchange.

Both DTLS and HIP support mobility with a change of IP address. However, in DTLS only client mobility is well supported, while in HIP either party can be mobile. The double-jump problem (simultaneous mobility) is supported in HIP with a help of Rendezvous Server (RVS) [RFC8004]. HIP can implement secure mobility with IP source address validation in 2 RTTs, and in 1 RTT with fast mobility extension.

One study comparing DTLS and IPsec-ESP performance concluded that DTLS is recommended for memory-constrained applications while IPSec-ESP for battery power-constrained [Vignesh].

6. IANA Considerations

TBD

7. Security Considerations

Designing secure transports is challenging. Where possible, existing technologies SHOULD be used. Both ESP and DTLS have stood "the test of time" against many attack scenarios. Their use here for N-RID and C2 do not represent new uses, but rather variants on existing depoyments.

The same can be said for both key establishment, using HIPv2 and DTLS, and the actual cipher choice for per packet encryption and authentication. N-RID and C2 do not present new challenges, rather new opportunities to provide communications security using well researched technologies.

8. Acknowledgments

Stuart Card and Adam Wiethuechter provivded information on their use of HIP for C2 at the Syracuse NY UAS test corridor. This, in large measure, was the impetus to develop this document.

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