Internet Engineering Task Force (IETF)
Request for Comments: 7360
Category: Experimental
ISSN: 2070-1721

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September 2014

Datagram Transport Layer Security (DTLS) as a Transport Layer for RADIUS

Abstract

The RADIUS protocol defined in RFC 2865 has limited support for authentication and encryption of RADIUS packets. The protocol transports data in the clear, although some parts of the packets can have obfuscated content. Packets may be replayed verbatim by an attacker, and client-server authentication is based on fixed shared secrets. This document specifies how the Datagram Transport Layer Security (DTLS) protocol may be used as a fix for these problems. It also describes how implementations of this proposal can coexist with current RADIUS systems.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for examination, experimental implementation, and evaluation.

This document defines an Experimental Protocol for the Internet community. This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Not all documents approved by the IESG are a candidate for any level of Internet Standard; see Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc7360.

Table of Contents

1. Introduction

The RADIUS protocol as described in [RFC2865], [RFC2866], [RFC5176], and others has traditionally used methods based on MD5 [RFC1321] for per-packet authentication and integrity checks. However, the MD5 algorithm has known weaknesses such as [MD5Attack] and [MD5Break]. As a result, some specifications, such as [RFC5176], have recommended using IPsec to secure RADIUS traffic.

While RADIUS over IPsec has been widely deployed, there are difficulties with this approach. The simplest point against IPsec is that there is no straightforward way for an application to control or monitor the network security policies. That is, the requirement that the RADIUS traffic be encrypted and/or authenticated is implicit in the network configuration, and it cannot be enforced by the RADIUS application.

This specification takes a different approach. We define a method for using DTLS [RFC6347] as a RADIUS transport protocol. This approach has the benefit that the RADIUS application can directly monitor and control the security policies associated with the traffic that it processes.

Another benefit is that RADIUS over DTLS continues to be a UDP-based protocol. The change from RADIUS/UDP is largely to add DTLS support, and make any necessary related changes to RADIUS. This allows implementations to remain UDP based, without changing to a TCP architecture.

This specification does not, however, solve all of the problems associated with RADIUS/UDP. The DTLS protocol does not add reliable or in-order transport to RADIUS. DTLS also does not support fragmentation of application-layer messages, or of the DTLS messages themselves. This specification therefore shares with traditional RADIUS the issues of order, reliability, and fragmentation. These issues are dealt with in RADIUS/TCP [RFC6613] and RADIUS/TLS [RFC6614].

1.1. Terminology

This document uses the following terms:

RADIUS/DTLS
: This term is a shorthand for "RADIUS over DTLS".

RADIUS/DTLS client
: This term refers both to RADIUS clients as defined in [RFC2865] and to Dynamic Authorization clients as defined in [RFC5176] that implement RADIUS/DTLS.

RADIUS/DTLS server
: This term refers both to RADIUS servers as defined in [RFC2865] and to Dynamic Authorization servers as defined in [RFC5176] that implement RADIUS/DTLS.

RADIUS/UDP
: RADIUS over UDP, as defined in [RFC2865].

RADIUS/TLS
: RADIUS over TLS, as defined in [RFC6614].

silently discard
: This means that the implementation discards the packet without further processing.

1.2. Requirements Language

In this document, several words are used to signify the requirements of the specification. 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 [RFC2119].

1.3. Document Status

This document is an Experimental RFC.

It contains one of several approaches to address known cryptographic weaknesses of the RADIUS protocol, such as described in [RFC6614]. This specification does not fulfill all recommendations for an Authentication, Authorization, and Accounting (AAA) transport profile as per [RFC3539]; however, unlike [RFC6614], it is based on UDP and therefore does not have head-of-line blocking issues.

If this specification is indeed selected for advancement to Standards Track, certificate verification options ([RFC6614], Section 2.3, point 2) will need to be refined.

Another experimental characteristic of this specification is the question of key management between RADIUS/DTLS peers. RADIUS/UDP only allowed for manual key management, i.e., distribution of a shared secret between a client and a server. RADIUS/DTLS allows manual distribution of long-term proofs of peer identity, by using TLS-PSK ciphersuites. RADIUS/DTLS also allows the use of X.509 certificates in a PKIX infrastructure. It remains to be seen if one of these methods will prevail or if both will find their place in real-life deployments. The authors can imagine pre-shared keys (PSKs) to be popular in small-scale deployments (Small Office, Home Office (SOHO) or isolated enterprise deployments) where scalability is not an issue and the deployment of a Certification Authority (CA) is considered too much of a hassle; however, the authors can also imagine large roaming consortia to make use of PKIX. Readers of this specification are encouraged to read the discussion of key management issues within [RFC6421] as well as [RFC4107].

It has yet to be decided whether this approach is to be chosen for Standards Track. One key aspect to judge whether the approach is usable on a large scale is by observing the uptake, usability, and operational behavior of the protocol in large-scale, real-life deployments.

2. Building on Existing Foundations

Adding DTLS as a RADIUS transport protocol requires a number of changes to systems implementing standard RADIUS. This section outlines those changes, and defines new behaviors necessary to implement DTLS.

2.1. Changes to RADIUS

The RADIUS packet format is unchanged from [RFC2865], [RFC2866], and [RFC5176]. Specifically, all of the following portions of RADIUS MUST be unchanged when using RADIUS/DTLS:

* Packet format
* Permitted codes
* Request Authenticator calculation
* Response Authenticator calculation
* Minimum packet length
* Maximum packet length
* Attribute format
* Vendor-Specific Attribute (VSA) format
* Permitted data types
* Calculations of dynamic attributes such as CHAP-Challenge, or Message-Authenticator.
* Calculation of "obfuscated" attributes such as User-Password and Tunnel-Password.

In short, the application creates a RADIUS packet via the usual methods, and then instead of sending it over a UDP socket, sends the packet to a DTLS layer for encapsulation. DTLS then acts as a transport layer for RADIUS: hence, the names "RADIUS/UDP" and "RADIUS/DTLS".

The requirement that RADIUS remain largely unchanged ensures the simplest possible implementation and widest interoperability of this specification.

We note that the DTLS encapsulation of RADIUS means that RADIUS packets have an additional overhead due to DTLS. Implementations MUST support sending and receiving encapsulated RADIUS packets of 4096 octets in length, with a corresponding increase in the maximum size of the encapsulated DTLS packets. This larger packet size may cause the packet to be larger than the Path MTU (PMTU), where a RADIUS/UDP packet may be smaller. See Section 5.2, below, for more discussion.

The only changes made from RADIUS/UDP to RADIUS/DTLS are the following two items:

(1) The Length checks defined in [RFC2865], Section 3, MUST use the length of the decrypted DTLS data instead of the UDP packet length. They MUST treat any decrypted DTLS data octets outside the range of the Length field as padding and ignore it on reception.

(2) The shared secret used to compute the MD5 integrity checks and the attribute encryption MUST be "radius/dtls".

All other aspects of RADIUS are unchanged.

2.2. Similarities with RADIUS/TLS

While this specification can be thought of as RADIUS/TLS over UDP instead of the Transmission Control Protocol (TCP), there are some differences between the two methods. The bulk of [RFC6614] applies to this specification, so we do not repeat it here.

This section explains the differences between RADIUS/TLS and RADIUS/DTLS, as semantic "patches" to [RFC6614]. The changes are as follows:

* We replace references to "TCP" with "UDP"

* We replace references to "RADIUS/TLS" with "RADIUS/DTLS"

* We replace references to "TLS" with "DTLS"

Those changes are sufficient to cover the majority of the differences between the two specifications. The next section reviews some more detailed changes from [RFC6614], giving additional commentary only where necessary.

2.2.1. Changes from RADIUS/TLS to RADIUS/DTLS

This section describes how particular sections of [RFC6614] apply to RADIUS/DTLS.

Section 2.1 applies to RADIUS/DTLS, with the exception that the RADIUS/DTLS port is UDP/2083.

Section 2.2 applies to RADIUS/DTLS. Servers and clients need to be pre-configured to use RADIUS/DTLS for a given endpoint.

Most of Section 2.3 applies also to RADIUS/DTLS. Item (1) should be interpreted as applying to DTLS session initiation, instead of TCP connection establishment. Item (2) applies, except for the recommendation that implementations "SHOULD" support TLS_RSA_WITH_RC4_128_SHA. This recommendation is a historical artifact of RADIUS/TLS, and it does not apply to RADIUS/DTLS. Item (3) applies to RADIUS/DTLS. Item (4) applies, except that the fixed shared secret is "radius/dtls", as described above.

Section 2.4 applies to RADIUS/DTLS. Client identities SHOULD be determined from DTLS parameters, instead of relying solely on the source IP address of the packet.

Section 2.5 does not apply to RADIUS/DTLS. The relationship between RADIUS packet codes and UDP ports in RADIUS/DTLS is unchanged from RADIUS/UDP.

Sections 3.1, 3.2, and 3.3 apply to RADIUS/DTLS.

Section 3.4 item (1) does not apply to RADIUS/DTLS. Each RADIUS packet is encapsulated in one DTLS packet, and there is no "stream" of RADIUS packets inside of a TLS session. Implementors MUST enforce the requirements of [RFC2865], Section 3, for the RADIUS Length field, using the length of the decrypted DTLS data for the checks. This check replaces the RADIUS method of using the Length field from the UDP packet.

Section 3.4 items (2), (3), (4), and (5) apply to RADIUS/DTLS.

Section 4 does not apply to RADIUS/DTLS. Protocol compatibility considerations are defined in this document.

Section 6 applies to RADIUS/DTLS.

3. Interaction with RADIUS/UDP

Transitioning to DTLS is a process that needs to be done carefully. A poorly handled transition is complex for administrators and potentially subject to security downgrade attacks. It is not sufficient to just disable RADIUS/UDP and enable RADIUS/DTLS. RADIUS has no provisions for protocol negotiation, so simply disabling RADIUS/UDP would result in timeouts, lost traffic, and network instabilities.

The end result of this specification is that nearly all RADIUS/UDP implementations should transition to using a secure alternative. In some cases, RADIUS/UDP may remain where IPsec is used as a transport, or where implementation and/or business reasons preclude a change.

However, we do not recommend long-term use of RADIUS/UDP outside of isolated and secure networks.

This section describes how clients and servers should use RADIUS/DTLS, and how it interacts with RADIUS/UDP.

3.1. DTLS Port and Packet Types

The default destination port number for RADIUS/DTLS is UDP/2083. There are no separate ports for authentication, accounting, and dynamic authorization changes. The source port is arbitrary. The text in [RFC6614], Section 3.4, describes issues surrounding the use of one port for multiple packet types. We recognize that implementations may allow the use of RADIUS/DTLS over non-standard ports. In that case, the references to UDP/2083 in this document should be read as applying to any port used for transport of RADIUS/DTLS traffic.

3.2. Server Behavior

When a server receives packets on UDP/2083, all packets MUST be treated as being DTLS. RADIUS/UDP packets MUST NOT be accepted on this port.

Servers MUST NOT accept DTLS packets on the old RADIUS/UDP ports. Early versions of this specification permitted this behavior. It is forbidden here, as it depended on behavior in DTLS that may change without notice.

Servers MUST authenticate clients. RADIUS is designed to be used by mutually trusted systems. Allowing anonymous clients would ensure privacy for RADIUS/DTLS traffic, but would negate all other security aspects of the protocol.

As RADIUS has no provisions for capability signaling, there is no way for a server to indicate to a client that it should transition to using DTLS. This action has to be taken by the administrators of the two systems, using a method other than RADIUS. This method will likely be out of band, or manual configuration will need to be used.

Some servers maintain a list of allowed clients per destination port. Others maintain a global list of clients that are permitted to send packets to any port. Where a client can send packets to multiple ports, the server MUST maintain a "DTLS Required" flag per client.

This flag indicates whether or not the client is required to use DTLS. When set, the flag indicates that the only traffic accepted from the client is over UDP/2083. When packets are received from a

client on non-DTLS ports, for which DTLS is required, the server MUST silently discard these packets, as there is no RADIUS/UDP shared secret available.

This flag will often be set by an administrator. However, if a server receives DTLS traffic from a client, it SHOULD notify the administrator that DTLS is available for that client. It MAY mark the client as "DTLS Required".

It is RECOMMENDED that servers support the following Perfect Forward Secrecy (PFS) ciphersuites:

- TLS_DHE_RSA_WITH_AES_128_GCM_SHA256
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256

Allowing RADIUS/UDP and RADIUS/DTLS from the same client exposes the traffic to downbidding attacks and is NOT RECOMMENDED.

4. Client Behavior

When a client sends packets to the assigned RADIUS/DTLS port, all packets MUST be DTLS. RADIUS/UDP packets MUST NOT be sent to this port.

Clients MUST authenticate themselves to servers via credentials that are unique to each client.

It is RECOMMENDED that clients support the following PFS ciphersuites:

- TLS_DHE_RSA_WITH_AES_128_GCM_SHA256
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256

RADIUS/DTLS clients SHOULD NOT probe servers to see if they support DTLS transport. Instead, clients SHOULD use DTLS as a transport layer only when administratively configured. If a client is configured to use DTLS and the server appears to be unresponsive, the client MUST NOT fall back to using RADIUS/UDP. Instead, the client should treat the server as being down.

RADIUS clients often had multiple independent RADIUS implementations and/or processes that originate packets. This practice was simple to implement, but the result is that each independent subsystem must independently discover network issues or server failures. It is therefore RECOMMENDED that clients with multiple internal RADIUS sources use a local proxy as described in Section 6.1, below.

Clients may implement "pools" of servers for fail-over or load-balancing. These pools SHOULD NOT mix RADIUS/UDP and RADIUS/DTLS servers.

5. Session Management

Where [RFC6614] can rely on the TCP state machine to perform session tracking, this specification cannot. As a result, implementations of this specification may need to perform session management of the DTLS session in the application layer. This section describes logically how this tracking is done. Implementations may choose to use the method described here, or another, equivalent method.

We note that [RFC5080], Section 2.2.2, already mandates a duplicate detection cache. The session tracking described below can be seen as an extension of that cache, where entries contain DTLS sessions instead of RADIUS/UDP packets.

[RFC5080], Section 2.2.2, describes how duplicate RADIUS/UDP requests result in the retransmission of a previously cached RADIUS/UDP response. Due to DTLS sequence window requirements, a server MUST NOT retransmit a previously sent DTLS packet. Instead, it should cache the RADIUS response packet, and re-process it through DTLS to create a new RADIUS/DTLS packet, every time it is necessary to retransmit a RADIUS response.

5.1. Server Session Management

A RADIUS/DTLS server MUST track ongoing DTLS sessions for each, based on the following 4-tuple:

* source IP address
* source port
* destination IP address
* destination port

Note that this 4-tuple is independent of IP address version (IPv4 or IPv6).

Each 4-tuple points to a unique session entry, which usually contains the following information:

DTLS Session
: Any information required to maintain and manage the DTLS session.

Last Traffic
: A variable containing a timestamp that indicates when this session last received valid traffic. If "Last Traffic" is not used, this variable may not exist.

DTLS Data
: An implementation-specific variable that may contain information about the active DTLS session. This variable may be empty or nonexistent.

  This data will typically contain information such as idle timeouts, session lifetimes, and other implementation-specific data.

5.1.1. Session Opening and Closing

Session tracking is subject to Denial-of-Service (DoS) attacks due to the ability of an attacker to forge UDP traffic. RADIUS/DTLS servers SHOULD use the stateless cookie tracking technique described in [RFC6347], Section 4.2.1. DTLS sessions SHOULD NOT be tracked until a ClientHello packet has been received with an appropriate Cookie value. Server implementation SHOULD have a way of tracking DTLS sessions that are partially set up. Servers MUST limit both the number and impact on resources of partial sessions.

Sessions (both 4-tuple and entry) MUST be deleted when a TLS Closure Alert ([RFC5246], Section 7.2.1) or a fatal TLS Error Alert ([RFC5246], Section 7.2.2) is received. When a session is deleted due to it failing security requirements, the DTLS session MUST be closed, any TLS session resumption parameters for that session MUST be discarded, and all tracking information MUST be deleted.

Sessions MUST also be deleted when a RADIUS packet fails validation due to a packet being malformed, or when it has an invalid Message-Authenticator or invalid Request Authenticator. There are other cases when the specifications require that a packet received via a DTLS session be "silently discarded". In those cases, implementations MAY delete the underlying session as described above. There are few reasons to communicate with a Network Access Server (NAS) that is not implementing RADIUS.

A session MUST be deleted when non-RADIUS traffic is received over it. This specification is for RADIUS, and there is no reason to allow non-RADIUS traffic over a RADIUS/DTLS session. A session MUST be deleted when RADIUS traffic fails to pass security checks. There is no reason to permit insecure networks. A session SHOULD NOT be deleted when a well-formed, but "unexpected", RADIUS packet is received over it. Future specifications may extend RADIUS/DTLS, and we do not want to forbid those specifications.

The goal of the above requirements is to ensure security, while maintaining flexibility. Any security-related issue causes the connection to be closed. After the security restrictions have been applied, any unexpected traffic may be safely ignored, as it cannot cause a security issue. There is no need to close the session for unexpected but valid traffic, and the session can safely remain open.

Once a DTLS session is established, a RADIUS/DTLS server SHOULD use DTLS Heartbeats [RFC6520] to determine connectivity between the two servers. A server SHOULD also use watchdog packets from the client to determine that the session is still active.

As UDP does not guarantee delivery of messages, RADIUS/DTLS servers that do not implement an application-layer watchdog MUST also maintain a "Last Traffic" timestamp per DTLS session. The granularity of this timestamp is not critical and could be limited to one-second intervals. The timestamp SHOULD be updated on reception of a valid RADIUS/DTLS packet, or a DTLS Heartbeat, but no more than once per interval. The timestamp MUST NOT be updated in other situations.

When a session has not received a packet for a period of time, it is labeled "idle". The server SHOULD delete idle DTLS sessions after an "idle timeout". The server MAY cache the TLS session parameters, in order to provide for fast session resumption.

This session "idle timeout" SHOULD be exposed to the administrator as a configurable setting. It SHOULD NOT be set to less than 60 seconds and SHOULD NOT be set to more than 600 seconds (10 minutes). The minimum useful value for this timer is determined by the application-layer watchdog mechanism defined in the following section.

RADIUS/DTLS servers SHOULD also monitor the total number of open sessions. They SHOULD have a "maximum sessions" setting exposed to administrators as a configurable parameter. When this maximum is reached and a new session is started, the server MUST either drop an old session in order to open the new one or not create a new session.

RADIUS/DTLS servers SHOULD implement session resumption, preferably stateless session resumption as given in [RFC5077]. This practice lowers the time and effort required to start a DTLS session with a client and increases network responsiveness.

Since UDP is stateless, the potential exists for the client to initiate a new DTLS session using a particular 4-tuple, before the server has closed the old session. For security reasons, the server MUST keep the old session active until either it has received secure notification from the client that the session is closed or the server decides to close the session based on idle timeouts. Taking any other action would permit unauthenticated clients to perform a DoS attack, by reusing a 4-tuple and thus causing the server to close an active (and authenticated) DTLS session.

As a result, servers MUST ignore any attempts to reuse an existing 4-tuple from an active session. This requirement can likely be reached by simply processing the packet through the existing session, as with any other packet received via that 4-tuple. Non-compliant, or unexpected packets will be ignored by the DTLS layer.

The above requirement is mitigated by the suggestion in Section 6.1, below, that the client use a local proxy for all RADIUS traffic. That proxy can then track the ports that it uses and ensure that reuse of 4-tuples is avoided. The exact process by which this tracking is done is outside of the scope of this document.

5.2. Client Session Management

Clients SHOULD use PMTU discovery [RFC6520] to determine the PMTU between the client and server, prior to sending any RADIUS traffic. Once a DTLS session is established, a RADIUS/DTLS client SHOULD use DTLS Heartbeats [RFC6520] to determine connectivity between the two systems. RADIUS/DTLS clients SHOULD also use the application-layer watchdog algorithm defined in [RFC3539] to determine server responsiveness. The Status-Server packet defined in [RFC5997] SHOULD be used as the "watchdog packet" in any application-layer watchdog algorithm.

RADIUS/DTLS clients SHOULD proactively close sessions when they have been idle for a period of time. Clients SHOULD close a session when the DTLS Heartbeat algorithm indicates that the session is no longer active. Clients SHOULD close a session when no traffic other than watchdog packets and (possibly) watchdog responses has been sent for three watchdog timeouts. This behavior ensures that clients do not waste resources on the server by causing it to track idle sessions.

When a client fails to implement both DTLS Heartbeats and watchdog packets, it has no way of knowing that a DTLS session has been closed. Therefore, there is the possibility that the server closes the session without the client knowing. When that happens, the client may later transmit packets in a session, and those packets will be ignored by the server. The client is then forced to time out those packets and then the session, leading to delays and network instabilities.

For these reasons, it is RECOMMENDED that all DTLS sessions be configured to use DTLS Heartbeats and/or watchdog packets.

DTLS sessions MUST also be deleted when a RADIUS packet fails validation due to a packet being malformed, or when it has an invalid Message-Authenticator or invalid Response Authenticator. There are other cases when the specifications require that a packet received via a DTLS session be "silently discarded". In those cases, implementations MAY delete the underlying DTLS session.

RADIUS/DTLS clients should not send both RADIUS/UDP and RADIUS/DTLS packets to different servers from the same source socket. This practice causes increased complexity in the client application and increases the potential for security breaches due to implementation issues.

RADIUS/DTLS clients SHOULD implement session resumption, preferably stateless session resumption as given in [RFC5077]. This practice lowers the time and effort required to start a DTLS session with a server and increases network responsiveness.

6. Implementation Guidelines

The text above describes the protocol. In this section, we give additional implementation guidelines. These guidelines are not part of the protocol, but they may help implementors create simple, secure, and interoperable implementations.

Where a TLS-PSK method is used, implementations MUST support keys of at least 16 octets in length. Implementations SHOULD support key lengths of 32 octets and SHOULD allow for longer keys. The key data MUST be capable of being any value (0 through 255, inclusive). Implementations MUST NOT limit themselves to using textual keys. It is RECOMMENDED that the administration interface allow for the keys to be entered as human-readable strings in hex format.

When creating keys for use with PSK ciphersuites, it is RECOMMENDED that keys be derived from a Cryptographically Secure Pseudorandom Number Generator (CSPRNG) instead of administrators inventing keys on their own. If managing keys is too complicated, a certificate-based TLS method SHOULD be used instead.

6.1. Client Implementations

RADIUS/DTLS clients should use connected sockets where possible. Use of connected sockets means that the underlying kernel tracks the sessions, so that the client subsystem does not need to manage multiple sessions on one socket.

RADIUS/DTLS clients should use a single source (IP + port) when sending packets to a particular RADIUS/DTLS server. Doing so minimizes the number of DTLS session setups. It also ensures that information about the home server state is discovered only once.

In practice, this means that RADIUS/DTLS clients with multiple internal RADIUS sources should use a local proxy that arbitrates all RADIUS traffic between the client and all servers. The proxy should accept traffic only from the authorized subsystems on the client machine and should proxy that traffic to known servers. Each authorized subsystem should include an attribute that uniquely identifies that subsystem to the proxy, so that the proxy can apply origin-specific proxy rules and security policies. We suggest using NAS-Identifier for this purpose.

The local proxy should be able to interact with multiple servers at the same time. There is no requirement that each server have its own unique proxy on the client, as that would be inefficient.

The suggestion to use a local proxy means that there is only one process that discovers network and/or connectivity issues with a server. If each client subsystem communicated directly with a server, issues with that server would have to be discovered independently by each subsystem. The side effect would be increased delays in re-routing traffic, error reporting, and network instabilities.

Each client subsystem can include a subsystem-specific NAS-Identifier in each request. The format of this attribute is implementation-specific. The proxy should verify that the request originated from the local system, ideally via a loopback address. The proxy MUST then rewrite any subsystem-specific NAS-Identifier to a NAS-Identifier that identifies the client as a whole, or, remove the NAS-Identifier entirely and replace it with NAS-IP-Address or NAS-IPv6-Address.

In traditional RADIUS, the cost to set up a new "session" between a client and server was minimal. The client subsystem could simply open a port, send a packet, wait for the response, and then close the port. With RADIUS/DTLS, the connection setup is significantly more expensive. In addition, there may be a requirement to use DTLS in order to communicate with a server, as RADIUS/UDP may not be supported by that server. The knowledge of what protocol to use is best managed by a dedicated RADIUS subsystem, rather than by each individual subsystem on the client.

6.2. Server Implementations

RADIUS/DTLS servers should not use connected sockets to read DTLS packets from a client. This recommendation exists because a connected UDP socket will accept packets only from one source IP address and port. This limitation would prevent the server from accepting packets from multiple clients on the same port.

7. Diameter Considerations

This specification defines a transport layer for RADIUS. It makes no other changes to the RADIUS protocol. As a result, there are no Diameter considerations.

8. IANA Considerations

No new RADIUS attributes or packet codes are defined. IANA has updated the "Service Name and Transport Protocol Port Number Registry". The entries corresponding to port service name "radsec", port number "2083", and transport protocol "UDP" have been updated as follows:

- Assignee: IESG
- Contact: IETF Chair
- Reference: This document
- Assignment Notes: The UDP port 2083 was already previously assigned by IANA for "RadSec", an early implementation of RADIUS/TLS, prior to issuance of this RFC.

9. Implementation Status

This section records the status of known implementations of RADIUS/DTLS at the time of writing, and is based on a proposal described in [RFC6982].

The description of implementations in this section is intended to assist the IETF in its decision processes in progressing Internet-Drafts to RFCs.

9.1. Radsecproxy

Organization: Radsecproxy

URL: https://software.uninett.no/radsecproxy/

Maturity: Widely used software based on early versions of this document.
The use of the DTLS functionality is not clear.

Coverage: The bulk of this specification is implemented, based on earlier versions of this document. Exact revisions that were implemented are unknown.

Licensing: Freely distributable with acknowledgment.

Implementation experience: No comments from implementors.

9.2. jradius

Organization: Coova

URL: http://www.coova.org/JRadius/RadSec

Maturity: Production software based on early versions of this document.
The use of the DTLS functionality is not clear.

Coverage: The bulk of this specification is implemented, based on earlier versions of this document. Exact revisions that were implemented are unknown.

Licensing: Freely distributable with requirement to redistribute source.

Implementation experience: No comments from implementors.

10. Security Considerations

The bulk of this specification is devoted to discussing security considerations related to RADIUS. However, we discuss a few additional issues here.

This specification relies on the existing DTLS, RADIUS/UDP, and RADIUS/TLS specifications. As a result, all security considerations for DTLS apply to the DTLS portion of RADIUS/DTLS. Similarly, the TLS and RADIUS security issues discussed in [RFC6614] also apply to this specification. Most of the security considerations for RADIUS apply to the RADIUS portion of the specification.

However, many security considerations raised in the RADIUS documents are related to RADIUS encryption and authorization. Those issues are largely mitigated when DTLS is used as a transport method. The issues that are not mitigated by this specification are related to the RADIUS packet format and handling, which is unchanged in this specification.

This specification also suggests that implementations use a session tracking table. This table is an extension of the duplicate detection cache mandated in [RFC5080], Section 2.2.2. The changes given here are that DTLS-specific information is tracked for each table entry. Section 5.1.1, above, describes steps to mitigate any DoS issues that result from tracking additional information.

The fixed shared secret given above in Section 2.2.1 is acceptable only when DTLS is used with a non-null encryption method. When a DTLS session uses a null encryption method due to misconfiguration or implementation error, all of the RADIUS traffic will be readable by an observer. Therefore, implementations MUST NOT use null encryption methods for RADIUS/DTLS.

For systems that perform protocol-based firewalling and/or filtering, it is RECOMMENDED that they be configured to permit only DTLS over the RADIUS/DTLS port.

10.1. Crypto-Agility

Section 4.2 of [RFC6421] makes a number of recommendations about security properties of new RADIUS proposals. All of those recommendations are satisfied by using DTLS as the transport layer.

Section 4.3 of [RFC6421] makes a number of recommendations about backwards compatibility with RADIUS. Section 3, above, addresses these concerns in detail.

Section 4.4 of [RFC6421] recommends that change control be ceded to the IETF, and that interoperability is possible. Both requirements are satisfied.

Section 4.5 of [RFC6421] requires that the new security methods apply to all packet types. This requirement is satisfied by allowing DTLS to be used for all RADIUS traffic. In addition, Section 3, above, addresses concerns about documenting the transition from legacy RADIUS to crypto-agile RADIUS.

Section 4.6 of [RFC6421] requires automated key management. This requirement is satisfied by using DTLS key management.

10.2. Legacy RADIUS Security

We reiterate here the poor security of the legacy RADIUS protocol. We suggest that RADIUS clients and servers implement either this specification or [RFC6614]. New attacks on MD5 have appeared over the past few years, and there is a distinct possibility that MD5 may be completely broken in the near future. Such a break would mean that RADIUS/UDP was completely insecure.

The existence of fast and cheap attacks on MD5 could result in a loss of all network security that depends on RADIUS. Attackers could obtain user passwords and possibly gain complete network access. We cannot overstate the disastrous consequences of a successful attack on RADIUS.

We also caution implementors (especially client implementors) about using RADIUS/DTLS. It may be tempting to use the shared secret as the basis for a TLS-PSK method and to leave the user interface otherwise unchanged. This practice MUST NOT be used. The administrator MUST be given the option to use DTLS. Any shared secret used for RADIUS/UDP MUST NOT be used for DTLS. Reusing a shared secret between RADIUS/UDP and RADIUS/DTLS would negate all of the benefits found by using DTLS.

RADIUS/DTLS client implementors MUST expose a configuration that allows the administrator to choose the ciphersuite. Where certificates are used, RADIUS/DTLS client implementors MUST expose a configuration that allows an administrator to configure all certificates necessary for certificate-based authentication. These certificates include client, server, and root certificates.

TLS-PSK methods are susceptible to dictionary attacks. Section 6, above, recommends deriving TLS-PSK keys from a Cryptographically Secure Pseudorandom Number Generator (CSPRNG), which makes dictionary attacks significantly more difficult. Servers SHOULD track failed client connections by TLS-PSK ID and block TLS-PSK IDs that seem to be attempting brute-force searches of the keyspace.

The historic RADIUS practice of using shared secrets (here, PSKs) that are minor variations of words is NOT RECOMMENDED, as it would negate all of the security of DTLS.

10.3. Resource Exhaustion

The use of DTLS allows DoS attacks and resource-exhaustion attacks that were not possible in RADIUS/UDP. These attacks are similar to those described in [RFC6614], Section 6, for TCP.

Session tracking, as described in Section 5.1, can result in resource exhaustion. Therefore, servers MUST limit the absolute number of sessions that they track. When the total number of sessions tracked is going to exceed the configured limit, servers MAY free up resources by closing the session that has been idle for the longest time. Doing so may free up idle resources that then allow the server to accept a new session.

Servers MUST limit the number of partially open DTLS sessions. These limits SHOULD be exposed to the administrator as configurable settings.

10.4. Client-Server Authentication with DTLS

We expect that the initial deployment of DTLS will follow the RADIUS/UDP model of statically configured client-server relationships. The specification for dynamic discovery of RADIUS servers is under development, so we will not address that here.

Static configuration of client-server relationships for RADIUS/UDP means that a client has a fixed IP address for a server and a shared secret used to authenticate traffic sent to that address. The server in turn has a fixed IP address for a client and a shared secret used to authenticate traffic from that address. This model needs to be extended for RADIUS/DTLS.

Instead of a shared secret, TLS credentials MUST be used by each party to authenticate the other. The issue of identity is more problematic. As with RADIUS/UDP, IP addresses may be used as a key to determine the authentication credentials that a client will present to a server or which credentials a server will accept from a client. This is the fixed IP address model of RADIUS/UDP, with the shared secret replaced by TLS credentials.

There are, however, additional considerations with RADIUS/DTLS. When a client is configured with a hostname for a server, the server may present to the client a certificate containing a hostname. The client MUST then verify that the hostnames match. Any mismatch is a security violation, and the connection MUST be closed.

A RADIUS/DTLS server MAY be configured with a "wildcard" IP address match for clients, instead of a unique fixed IP address for each client. In that case, clients MUST be individually configured with a unique certificate. When the server receives a connection from a client, it MUST determine client identity from the client certificate, and MUST authenticate (or not) the client based on that certificate. See [RFC6614], Section 2.4, for a discussion of how to match a certificate to a client identity.

However, servers SHOULD use IP address filtering to minimize the possibility of attacks. That is, they SHOULD permit clients only from a limited IP address range or ranges. They SHOULD silently discard all traffic from outside of those ranges.

Since the client-server relationship is static, the authentication credentials for that relationship must also be statically configured. That is, a client connecting to a DTLS server SHOULD be pre-configured with the server’s credentials (e.g., PSK or certificate). If the server fails to present the correct credentials, the DTLS session MUST be closed. Each server SHOULD be pre-configured with sufficient information to authenticate connecting clients.

The requirement for clients to be individually configured with a unique certificate can be met by using a private CA for certificates used in RADIUS/DTLS environments. If a client were configured to use a public CA, then it could accept as valid any server that has a certificate signed by that CA. While the traffic would be secure from third-party observers, the server would, however, have unrestricted access to all of the RADIUS traffic, including all user credentials and passwords.

Therefore, clients SHOULD NOT be pre-configured with a list of known public CAs by the vendor or manufacturer. Instead, the clients SHOULD start off with an empty CA list. The addition of a CA SHOULD be done only when manually configured by an administrator.

This scenario is the opposite of web browsers, where they are pre-configured with many known CAs. The goal there is security from third-party observers, but also the ability to communicate with any unknown site that presents a signed certificate. In contrast, the goal of RADIUS/DTLS is both security from third-party observers and the ability to communicate with only a small set of well-known servers.

This requirement does not prevent clients from using hostnames instead of IP addresses for locating a particular server. Instead, it means that the credentials for that server should be pre-configured on the client, and associated with that hostname. This requirement does suggest that in the absence of a specification for dynamic discovery, clients SHOULD use only those servers that have been manually configured by an administrator.

10.5. Network Address Translation

Network Address Translation (NAT) is fundamentally incompatible with RADIUS/UDP. RADIUS/UDP uses the source IP address to determine the shared secret for the client, and NAT hides many clients behind one source IP address. As a result, RADIUS/UDP clients cannot be located behind a NAT gateway.

In addition, port reuse on a NAT gateway means that packets from different clients may appear to come from the same source port on the NAT. That is, a RADIUS server may receive a RADIUS/DTLS packet from one source IP/port combination, followed by the reception of a RADIUS/UDP packet from that same source IP/port combination. If this behavior is allowed, then the server would have an inconsistent view of the client's security profile, allowing an attacker to choose the most insecure method.

If more than one client is located behind a NAT gateway, then every client behind the NAT MUST use a secure transport such as TLS or DTLS. As discussed below, a method for uniquely identifying each client MUST be used.

10.6. Wildcard Clients

Some RADIUS server implementations allow for "wildcard" clients -- that is, clients with an IPv4 netmask of other than 32 or an IPv6 netmask of other than 128. That practice is not recommended for RADIUS/UDP, as it means multiple clients will use the same shared secret.

The use of RADIUS/DTLS can allow for the safe usage of wildcards. When RADIUS/DTLS is used with wildcards, clients MUST be uniquely identified using TLS parameters, and any certificate or PSK used MUST be unique to each client.

10.7. Session Closing

Section 5.1.1, above, requires that DTLS sessions be closed when the transported RADIUS packets are malformed or fail the authenticator checks. The reason is that the session is expected to be used for transport of RADIUS packets only.

Any non-RADIUS traffic on that session means the other party is misbehaving and is a potential security risk. Similarly, any RADIUS traffic failing authentication vector or Message-Authenticator validation means that two parties do not have a common shared secret, and the session is therefore unauthenticated and insecure.

We wish to avoid the situation where a third party can send well-formed RADIUS packets that cause a DTLS session to close. Therefore, in other situations, the session SHOULD remain open in the face of non-conformant packets.

10.8. Client Subsystems

Many traditional clients treat RADIUS as subsystem-specific. That is, each subsystem on the client has its own RADIUS implementation and configuration. These independent implementations work for simple systems, but break down for RADIUS when multiple servers, fail-over, and load-balancing are required. They have even worse issues when DTLS is enabled.

As noted in Section 6.1, above, clients SHOULD use a local proxy that arbitrates all RADIUS traffic between the client and all servers. This proxy will encapsulate all knowledge about servers, including security policies, fail-over, and load-balancing. All client subsystems SHOULD communicate with this local proxy, ideally over a loopback address. The requirements on using strong shared secrets still apply.

The benefit of this configuration is that there is one place in the client that arbitrates all RADIUS traffic. Subsystems that do not implement DTLS can remain unaware of DTLS. DTLS sessions opened by the proxy can remain open for long periods of time, even when client subsystems are restarted. The proxy can do RADIUS/UDP to some servers and RADIUS/DTLS to others.

Delegation of responsibilities and separation of tasks are important security principles. By moving all RADIUS/DTLS knowledge to a DTLS-aware proxy, security analysis becomes simpler, and enforcement of correct security becomes easier.

11. References

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Acknowledgments

Parts of the text in Section 3 defining the Request and Response Authenticators were taken with minor edits from [RFC2865], Section 3.

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