Remote Procedure Call Encryption By Default

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Abstract

This document describes a mechanism that enables encryption of in-transit Remote Procedure Call (RPC) transactions with minimal administrative overhead and full interoperability with ONC RPC implementations that do not support this mechanism. This document updates RFC 5531.

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Table of Contents

1. Introduction .................................................. 3
2. Requirements Language ...................................... 4
3. Terminology .................................................. 4
4. RPC-Over-TLS in Operation ................................. 4
   4.1. Discovering Server-side TLS Support .................. 5
   4.2. RPC Authentication ..................................... 6
      4.2.1. Server-only Host Authentication .................. 6
      4.2.2. Mutual Host Authentication ........................ 7
      4.2.3. Advanced Forms of RPC Authentication ............ 7
5. TLS Requirements .............................................. 7
   5.1. Connection Types ........................................ 8
      5.1.1. Operation on TCP ................................... 8
      5.1.2. Operation on UDP ................................... 8
      5.1.3. Operation on an RDMA Transport .................... 8
   5.2. TLS Peer Authentication ............................... 8
      5.2.1. X.509 Certificates Using PKIX trust ............. 8
      5.2.2. X.509 Certificates Using Fingerprints ........... 10
      5.2.3. Pre-Shared Keys ................................... 10
      5.2.4. Token Binding ..................................... 10
6. Implementation Status ........................................ 10
   6.1. Linux NFS server and client ............................ 11
   6.2. DESY NFS server ........................................ 11
7. Security Considerations .................................... 11
   7.1. Implications for AUTH_SYS .............................. 12
8. IANA Considerations ......................................... 12
9. References .................................................... 13
   9.1. Normative References .................................. 13
   9.2. Informative References ............................... 14
Acknowledgments ................................................ 15
Authors’ Addresses ............................................. 15
1. Introduction

In 2014 the IETF published [RFC7258] which recognized that unauthorized observation of network traffic had become widespread and was a subversive threat to all who make use of the Internet at large. It strongly recommended that newly defined Internet protocols make a real effort to mitigate monitoring attacks. Typically this mitigation is done by encrypting data in transit.

The Remote Procedure Call version 2 protocol has been a Proposed Standard for three decades (see [RFC5531] and its antecedants). Eisler et al. first introduced an in-transit encryption mechanism for RPC with RPCSEC GSS over twenty years ago [RFC2203]. However, experience has shown that RPCSEC GSS is difficult to deploy:

- Per-client deployment and administrative costs are not scalable. Keying material must be provided for each RPC client, including transient clients.

- Parts of the RPC header remain in clear-text, and can constitute a significant security exposure.

- On-host cryptographic manipulation of data payloads can exact a significant CPU cost on both clients and the server.

- Host identity management and user identity management must be carried out in the same security realm. In certain environments, different authorities might be responsible for provisioning client systems versus provisioning new users.

However strong a privacy service is, it can not provide any security if the difficulties of deploying and using it result in it not being used at all.

An alternative approach is to employ a transport layer security mechanism that can protect the privacy of each RPC connection transparently to RPC and Upper Layer protocols. The Transport Layer Security protocol [RFC8446] (TLS) is a well-established Internet building block that protects many common Internet protocols such as the Hypertext Transport Protocol (http) [RFC2818].

Encrypting at the RPC transport layer enables several significant benefits.

Encryption By Default

In-transit encryption can be enabled without additional administrative actions such as identifying the host system to a
trust authority, generating additional key material, or provisioning a secure network tunnel.

Protection of Existing Protocols
The imposition of encryption at the transport layer protects any Upper Layer protocol that employs RPC, without alteration of that protocol. RPC transport layer encryption can protect recent versions of NFS such as NFS version 4.2 [RFC7862] and indeed legacy NFS versions such as NFS version 3 [RFC1813] and NFS side-band protocols such as the MNT protocol [RFC1813].

Decoupled User and Host Identities
TLS can be used to authenticate hosts using certificates while other security mechanisms can handle user authentication.

Encryption Offload
The use of a well-established transport encryption mechanism that is also employed by other very common network protocols makes it likely that a hardware encryption implementation will be available to offload encryption and decryption.

2. Requirements Language

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.

3. Terminology

This document adopts the terminology introduced in Section 3 of [RFC6973] and assumes a working knowledge of the Remote Procedure Call (RPC) version 2 protocol [RFC5531] and the Transport Layer Security (TLS) version 1.3 protocol [RFC8446].

Note also that the NFS community uses the term "privacy" where other Internet communities use "confidentiality". In this document the two terms are synonymous.

4. RPC-Over-TLS in Operation

In this section we cleave to the convention that a "client" is the peer host that actively initiates a connection, and a "server" is the peer host that passively accepts a connection request.
4.1. Discovering Server-side TLS Support

The mechanism described in this document interoperates fully with RPC implementations that do not support TLS. The use of TLS is automatically disabled in these cases.

To achieve this, we introduce a new RPC authentication flavor called AUTH_TLS. This new flavor is used to signal that the client wants to initiate TLS negotiation if the server supports it. Except for the modifications described in this section, the RPC protocol is largely unaware of security encapsulation.

```c
enum auth_flavor {
    AUTH_NONE       = 0,
    AUTH_SYS        = 1,
    AUTH_SHORT      = 2,
    AUTH_DH         = 3,
    AUTH_KERB       = 4,
    AUTH_RSA        = 5,
    RPCSEC_GSS      = 6,
    AUTH_TLS        = 7,
    /* and more to be defined */
};
```

The length of the opaque data constituting the credential sent in the call message MUST be zero. The verifier accompanying the credential MUST be an AUTH_NONE verifier of length zero.

The flavor value of the verifier received in the reply message from the server MUST be AUTH_NONE. The bytes of the verifier’s string encode the fixed ASCII characters "STARTTLS".

When an RPC client is ready to begin sending traffic to a server, it starts with a NULL RPC request with an auth_flavor of AUTH_TLS. The NULL request is made to the same port as if TLS were not in use.

The RPC server can respond in one of three ways:

- If the RPC server does not recognise the AUTH_TLS authentication flavor, it responds with a reject_stat of AUTH_ERROR. The RPC client then knows that this server does not support TLS.
If the RPC server accepts the NULL RPC procedure, but fails to return an AUTH_NONE verifier containing the string "STARTTLS", the RPC client knows that this server does not support TLS.

If the RPC server accepts the NULL RPC procedure, and returns an AUTH_NONE verifier containing the string "STARTTLS", the RPC client SHOULD proceed with TLS negotiation.

If an RPC client attempts to use AUTH_TLS for anything other than the NULL RPC procedure, the RPC server responds with a reject_stat of AUTH_ERROR. In addition, a client MUST NOT attempt a TLS handshake after the initial exchange.

Once the TLS handshake is complete, the RPC client and server will have established a secure channel for communicating and can proceed to use standard security flavors within that channel, presumably after negotiating down the irrelevant RPCSEC_GSS privacy and integrity services and applying channel binding [RFC7861].

If TLS negotiation fails for any reason -- say, the RPC server rejects the certificate presented by the RPC client, or the RPC client fails to authenticate the RPC server -- the RPC client reports this failure to the calling application the same way it would report an AUTH_ERROR rejection from the RPC server.

4.2. RPC Authentication

Both RPC and TLS have their own variants of authentication, and there is some overlap in capability. The goal of interoperability with implementations that do not support TLS requires that we limit the combinations that are allowed and precisely specify the role that each layer plays. We also want to handle TLS such that an RPC implementation can make the use of TLS invisible to existing RPC consumer applications.

Toward these ends, there are two deployment modes.

4.2.1. Server-only Host Authentication

In a basic deployment, a server possesses a unique global identity (e.g., a certificate that is self-signed or signed by a well-known trust anchor) while its clients are anonymous (i.e., present no identifier). In this situation, the client SHOULD authenticate the server host using the presented TLS identity, but the server cannot authenticate connecting clients. Here, a TLS session is established and the RPC requests in transit carry user and group identities according to the conventions of the RPC protocol.
4.2.2. Mutual Host Authentication

In this type of deployment, both the server and its clients possess unique identities (e.g., certificates). As part of the TLS handshake, both peer hosts SHOULD authenticate using the presented TLS identities. Should authentication of either peer fail, or should authorization based on those identities block access to the server, the connection MAY be rejected. However, once a TLS session is established, the server MUST NOT utilize TLS identity for the purpose of authorizing RPC requests.

In some cases, a client might choose to present a certificate that represents a user rather than one that is bound to the client host. As above, the server MUST NOT utilize this identity for the purpose of authorizing RPC requests. The TLS identities of the peer hosts are fully independent of RPC user identities.

4.2.3. Advanced Forms of RPC Authentication

 RPCSEC GSS can provide integrity or privacy (also known as confidentiality) services. When operating over a TLS session, these services become redundant. Each RPC implementation is responsible for using channel binding for detecting when GSS integrity or privacy is unnecessary and can therefore be disabled. See Section 2.5 of [RFC7861] for details.

Note that a GSS service principal is still required on the server, and mutual GSS authentication of server and client still occurs after the TLS session is established.

5. TLS Requirements

When a TLS session is negotiated for the purpose of transporting RPC, the following restrictions apply:

- Implementations MUST NOT negotiate TLS versions prior to v1.3 [RFC8446]. Support for mandatory-to-implement ciphersuites for the negotiated TLS version is REQUIRED.

- Implementations MUST support certificate-based mutual authentication. Support for TLS-PSK mutual authentication [RFC4279] is OPTIONAL. See Section 4.2 for further details.

- Negotiation of a ciphersuite providing for confidentiality as well as integrity protection is REQUIRED. Support for and negotiation of compression is OPTIONAL.
5.1. Connection Types

5.1.1. Operation on TCP

RPC over TCP is protected by using TLS [RFC8446]. As soon as a client completes the TCP handshake, it uses the mechanism described in Section 4.1 to discover TLS support and then negotiate a TLS session.

5.1.2. Operation on UDP

RPC over UDP is protected using DTLS [RFC6347]. As soon as a client initializes a socket for use with an unfamiliar server, it uses the mechanism described in Section 4.1 to discover DTLS support and then negotiate a DTLS session. Connected operation is RECOMMENDED.

Using a DTLS transport does not introduce reliable or in-order semantics to RPC on UDP. Also, DTLS does not support fragmentation of RPC messages. One RPC message fits in a single DTLS datagram. DTLS encapsulation has overhead which reduces the effective Path MTU (PMTU) and thus the maximum RPC payload size.

5.1.3. Operation on an RDMA Transport

RPC-over-RDMA can make use of Transport Layer Security below the RDMA transport layer [RFC8166]. The exact mechanism is not within the scope of this document.

5.2. TLS Peer Authentication

Peer authentication can be performed by TLS using any of the following mechanisms:

5.2.1. X.509 Certificates Using PKIX trust

Implementations are REQUIRED to support this mechanism. In this mode, an RPC client is uniquely identified by the tuple (serial number of presented client certificate; Issuer).

- Implementations MUST allow the configuration of a list of trusted Certification Authorities for incoming connections.

- Certificate validation MUST include the verification rules as per [RFC5280].

- Implementations SHOULD indicate their trusted Certification Authorities (CAs).
Peer validation always includes a check on whether the locally configured expected DNS name or IP address of the server that is contacted matches its presented certificate. DNS names and IP addresses can be contained in the Common Name (CN) or subjectAltName entries. For verification, only one of these entries is to be considered. The following precedence applies: for DNS name validation, subjectAltName:DNS has precedence over CN; for IP address validation, subjectAltName:iPAddr has precedence over CN. Implementors of this specification are advised to read Section 6 of [RFC6125] for more details on DNS name validation.

Implementations MAY allow the configuration of a set of additional properties of the certificate to check for a peer’s authorization to communicate (e.g., a set of allowed values in subjectAltName:URI or a set of allowed X509v3 Certificate Policies).

When the configured trust base changes (e.g., removal of a CA from the list of trusted CAs; issuance of a new CRL for a given CA), implementations MAY renegotiate the TLS session to reassess the connecting peer’s continued authorization.

Having identified a connecting entity does not mean the RPC server necessarily wants to communicate with that client. For example, if the Issuer is not in a trusted set of Issuers, the RPC server may decline to perform RPC transactions with this client. Implementations that want to support a wide variety of trust models should expose as many details of the presented certificate to the administrator as possible so that the trust model can be implemented by the administrator. As a suggestion, at least the following parameters of the X.509 client certificate should be exposed:

- Originating IP address
- Certificate Fingerprint
- Issuer
- Subject
- all X509v3 Extended Key Usage
- all X509v3 Subject Alternative Name
- all X509v3 Certificate Policies
5.2.2. X.509 Certificates Using Fingerprints

This mechanism is OPTIONAL to implement. In this mode, an RPC client is uniquely identified by the fingerprint of the presented client certificate.

Implementations SHOULD allow the configuration of a list of trusted certificates, identified via fingerprint of the DER encoded certificate octets. Implementations MUST support SHA-1 as the hash algorithm for the fingerprint. To prevent attacks based on hash collisions, support for a more contemporary hash function, such as SHA-256, is RECOMMENDED.

5.2.3. Pre-Shared Keys

This mechanism is OPTIONAL to implement. In this mode, an RPC client is uniquely identified by its TLS identifier. At least the following parameters of the TLS connection should be exposed:

- Originating IP address
- TLS Identifier

5.2.4. Token Binding

This mechanism is OPTIONAL to implement. In this mode, an RPC client is uniquely identified by a token.

Versions of TLS subsequent to TLS 1.2 feature a token binding mechanism which is nominally more secure than using certificates. This is discussed in further detail in [RFC8471].

6. Implementation Status

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs.

Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.
6.1. Linux NFS server and client

Organization: The Linux Foundation

URL: https://www.kernel.org

Maturity: Prototype software based on early versions of this document.

Coverage: The bulk of this specification is implemented. The use of DTLS functionality is not implemented.

Licensing: GPLv2

Implementation experience: No comments from implementors.

6.2. DESY NFS server

Organization: DESY

URL: https://desy.de

Maturity: Prototype software based on early versions of this document.

Coverage: The bulk of this specification is implemented. The use of DTLS functionality is not implemented.

Licensing: Freely distributable with acknowledgment.

Implementation experience: No comments from implementors.

7. Security Considerations

One purpose of the mechanism described in this document is to protect RPC-based applications against threats to the privacy of RPC transactions and RPC user identities. A taxonomy of these threats appears in Section 5 of [RFC6973]. In addition, Section 6 of [RFC7525] contains a detailed discussion of technologies used in conjunction with TLS. Implementers should familiarize themselves with these materials.

The NFS version 4 protocol permits more than one user to use an NFS client at the same time [RFC7862]. Typically that NFS client will conserve connection resources by routing RPC transactions from all of its users over a few or a single connection. In circumstances where the users on that NFS client belong to multiple distinct security
domains, the client MUST establish independent TLS sessions for each distinct security domain.

7.1. Implications for AUTH_SYS

Ever since the IETF NFSv4 Working Group took over the maintenance of the NFSv4 family of protocols (currently specified in [RFC7530], [RFC5661], and [RFC7863], among others), it has encouraged the use of RPCSEC GSS over AUTH_SYS. For various reasons, unfortunately AUTH_SYS continues to be the primary authentication mechanism deployed by NFS administrators. As a result, NFS security remains in an unsatisfactory state.

A deeper purpose of this document is to attempt to address some of the shortcomings of AUTH_SYS so that, where it has been impractical to deploy RPCSEC GSS, better NFSv4 security can nevertheless be achieved.

When AUTH_SYS is used with TLS and no client certificate is available, the RPC server is still acting on RPC requests for which there is no trustworthy authentication. In-transit traffic is protected, but the client itself can still misrepresent user identity without detection. This is an improvement from AUTH_SYS without encryption, but it leaves a critical security exposure.

Therefore, the RECOMMENDED deployment mode is that clients have certificate material configured and used so that servers can have a degree of trust that clients are acting responsibly.

8. IANA Considerations

In accordance with Section 6 of [RFC7301], the authors request that IANA allocate the following value in the "Application-Layer Protocol Negotiation (ALPN) Protocol IDs" registry. The "sunrpc" string identifies SunRPC when used over TLS.

Protocol: SunRPC

Identification Sequence: 0x73 0x75 0x6e 0x72 0x70 0x63 ("sunrpc")

Reference: RFC-TBD
9. References

9.1. Normative References


Myklebust & Lever Expires September 26, 2019 [Page 13]
9.2. Informative References


9.3. URIs

[1] https://www.linuxjournal.com/content/encrypting-nfsv4-stunnel-tls

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