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Recommendations for Secure Use of TLS and DTLS
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Abstract

Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS) are widely used to protect data exchanged over application protocols such as HTTP, SMTP, IMAP, POP, SIP, and XMPP. Over the last few years, several serious attacks on TLS have emerged, including attacks on its most commonly used cipher suites and their modes of operation. This document provides recommendations for improving the security of deployed services that use TLS and DTLS. The recommendations are applicable to the majority of use cases.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on August 24, 2015.

Table of Contents

1. Introduction

Transport Layer Security (TLS) [RFC5246] and Datagram Transport Security Layer (DTLS) [RFC6347] are widely used to protect data exchanged over application protocols such as HTTP, SMTP, IMAP, POP, SIP, and XMPP. Over the last few years, several serious attacks on TLS have emerged, including attacks on its most commonly used cipher suites and their modes of operation. For instance, both the AES-CBC [RFC3602] and RC4 [RFC7465] encryption algorithms, which together have been the most widely deployed ciphers, have been attacked in the context of TLS. A companion document [RFC7457] provides detailed information about these attacks and will help the reader understand the rationale behind the recommendations provided here.

Because of these attacks, those who implement and deploy TLS and DTLS need updated guidance on how TLS can be used securely. This document provides guidance for deployed services as well as for software implementations, assuming the implementer expects his or her code to be deployed in environments defined in Section 5. In fact, this document calls for the deployment of algorithms that are widely implemented but not yet widely deployed. Concerning deployment, this document targets a wide audience, namely all deployers who wish to add authentication (be it one-way only or mutual), confidentiality, and data integrity protection to their communications.

The recommendations herein take into consideration the security of various mechanisms, their technical maturity and interoperability, and their prevalence in implementations at the time of writing. Unless it is explicitly called out that a recommendation applies to TLS alone or to DTLS alone, each recommendation applies to both TLS and DTLS.

It is expected that the TLS 1.3 specification will resolve many of the vulnerabilities listed in this document. A system that deploys TLS 1.3 should have fewer vulnerabilities than TLS 1.2 or below. This document is likely to be updated after TLS 1.3 gets noticeable deployment.

These are minimum recommendations for the use of TLS in the vast majority of implementation and deployment scenarios, with the exception of unauthenticated TLS (see Section 5). Other specifications that reference this document can have stricter requirements related to one or more aspects of the protocol, based on their particular circumstances (e.g., for use with a particular application protocol); when that is the case, implementers are advised to adhere to those stricter requirements. Furthermore, this document provides a floor, not a ceiling, so stronger options are always allowed (e.g., depending on differing evaluations of the importance of cryptographic strength vs. computational load).

Community knowledge about the strength of various algorithms and feasible attacks can change quickly, and experience shows that a security BCP is a point-in-time statement. Readers are advised to seek out any errata or updates that apply to this document.

2. Terminology

A number of security-related terms in this document are used in the sense defined in [RFC4949].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

3. General Recommendations

This section provides general recommendations on the secure use of TLS. Recommendations related to cipher suites are discussed in the following section.

3.1. Protocol Versions

3.1.1. SSL/TLS Protocol Versions

It is important both to stop using old, less secure versions of SSL/TLS and to start using modern, more secure versions; therefore, the following are the recommendations concerning TLS/SSL protocol versions:

- Implementations MUST NOT negotiate SSL version 2.

  Rationale: Today, SSLv2 is considered insecure [RFC6176].

- Implementations MUST NOT negotiate SSL version 3.

Rationale: SSLv3 [RFC6101] was an improvement over SSLv2 and plugged some significant security holes, but did not support strong cipher suites. SSLv3 does not support TLS extensions, some of which (e.g., renegotiation_info) are security-critical. In addition, with the emergence of the POODLE attack [POODLE], SSLv3 is now widely recognized as fundamentally insecure. See [I-D.ietf-tls-sslv3-diediedie] for further details.

- Implementations SHOULD NOT negotiate TLS version 1.0 [RFC2246] unless no higher version is available in the negotiation.

  Rationale: TLS 1.0 (published in 1999) does not support many modern, strong cipher suites. In addition, TLS 1.0 lacks a per-record IV for CBC-based cipher suites and does not warn against common padding errors.

- Implementations SHOULD NOT negotiate TLS version 1.1 [RFC4346] unless no higher version is available in the negotiation.

  Rationale: TLS 1.1 (published in 2006) is a security improvement over TLS 1.0, but still does not support certain stronger cipher suites.

- Implementations MUST support TLS 1.2 [RFC5246] and MUST prefer to negotiate TLS version 1.2 over earlier versions of TLS.

  Rationale: Several stronger cipher suites are available only with TLS 1.2 (published in 2008). In fact, the cipher suites recommended by this document (Section 4.2 below) are only available in TLS 1.2.

This BCP applies to TLS 1.2, and also to earlier versions. It is not safe for readers to assume that the recommendations in this BCP apply to any future version of TLS.

3.1.2. DTLS Protocol Versions

DTLS, an adaptation of TLS for UDP datagrams, was introduced when TLS 1.1 was published. The following are the recommendations with respect to DTLS:

- Implementations SHOULD NOT negotiate DTLS version 1.0 [RFC4347].

  Version 1.0 of DTLS correlates to version 1.1 of TLS (see above).

- Implementations MUST support, and prefer to negotiate, DTLS version 1.2 [RFC6347].

Version 1.2 of DTLS correlates to Version 1.2 of TLS (see above). (There is no Version 1.1 of DTLS.)

3.1.3. Fallback to Lower Versions

Clients that "fall back" to lower versions of the protocol after the server rejects higher versions of the protocol MUST NOT fall back to SSLv3 or earlier.

Rationale: Some client implementations revert to lower versions of TLS or even to SSLv3 if the server rejected higher versions of the protocol. This fallback can be forced by a man in the middle (MITM) attacker. TLS 1.0 and SSLv3 are significantly less secure than TLS 1.2, the version recommended by this document. While TLS 1.0-only servers are still quite common, IP scans show that SSLv3-only servers amount to only about 3% of the current Web server population. (At the time of this writing, an explicit method for preventing downgrade attacks is being defined in [I-D.ietf-tls-downgrade-scsv].)

3.2. Strict TLS

The following recommendations are provided to help prevent SSL Stripping (the attack is summarized in Section 2.1 of [RFC7457]):

- In cases where an application protocol allows implementations or deployments a choice between strict TLS configuration and dynamic upgrade from unencrypted to TLS-protected traffic (such as STARTTLS), clients and servers SHOULD prefer strict TLS configuration.

- Application protocols typically provide a way for the server to offer TLS during an initial protocol exchange, and sometimes also provide a way for the server to advertise support for TLS (e.g., through a flag indicating that TLS is required); unfortunately, these indications are sent before the communication channel is encrypted. A client SHOULD attempt to negotiate TLS even if these indications are not communicated by the server.

- HTTP client and server implementations MUST support the HTTP Strict Transport Security (HSTS) header [RFC6797], in order to allow Web servers to advertise that they are willing to accept TLS-only clients.

- Web servers SHOULD use HSTS to indicate that they are willing to accept TLS-only clients, unless they are deployed in such a way that using HSTS would in fact weaken overall security (e.g., it can be problematic to use HSTS with self-signed certificates, as described in Section 11.3 of [RFC6797]).

Rationale: Combining unprotected and TLS-protected communication opens the way to SSL Stripping and similar attacks, since an initial part of the communication is not integrity protected and therefore can be manipulated by an attacker whose goal is to keep the communication in the clear.

3.3. Compression

In order to help prevent compression-related attacks (summarized in Section 2.6 of [RFC7457]), implementations and deployments SHOULD disable TLS-level compression ([RFC5246], Section 6.2.2), unless the application protocol in question has been shown not to be open to such attacks.

Rationale: TLS compression has been subject to security attacks, such as the CRIME attack.

Implementers should note that compression at higher protocol levels can allow an active attacker to extract cleartext information from the connection. The BREACH attack is one such case. These issues can only be mitigated outside of TLS and are thus out of scope of the current document. See Section 2.6 of [RFC7457] for further details.

3.4. TLS Session Resumption

If TLS session resumption is used, care ought to be taken to do so safely. In particular, when using session tickets [RFC5077], the resumption information MUST be authenticated and encrypted to prevent modification or eavesdropping by an attacker. Further recommendations apply to session tickets:

- A strong cipher suite MUST be used when encrypting the ticket (as least as strong as the main TLS cipher suite).

- Ticket keys MUST be changed regularly, e.g., once every week, so as not to negate the benefits of forward secrecy (see Section 7.3 for details on forward secrecy).

- For similar reasons, session ticket validity SHOULD be limited to a reasonable duration (e.g., half as long as ticket key validity).

Rationale: session resumption is another kind of TLS handshake, and therefore must be as secure as the initial handshake. This document (Section 4) recommends the use of cipher suites that provide forward secrecy, i.e. that prevent an attacker who gains momentary access to the TLS endpoint (either client or server) and its secrets from reading either past or future communication. The tickets must be managed so as not to negate this security property.

3.5. TLS Renegotiation

Where handshake renegotiation is implemented, both clients and servers MUST implement the renegotiation_info extension, as defined in [RFC5746].

The most secure option for countering the Triple Handshake attack is to refuse any change of certificates during renegotiation. In addition, TLS clients SHOULD apply the same validation policy for all certificates received over a connection. The [triple-handshake] document suggests several other possible countermeasures, such as binding the master secret to the full handshake (see [I-D.ietf-tls-session-hash]) and binding the abbreviated session resumption handshake to the original full handshake. Although the latter two techniques are still under development and thus do not qualify as current practices, those who implement and deploy TLS are advised to watch for further development of appropriate countermeasures.

3.6. Server Name Indication

TLS implementations MUST support the Server Name Indication (SNI) extension defined in Section 3 of [RFC6066] for those higher level protocols which would benefit from it, including HTTPS. However, unlike implementation, the use of SNI in particular circumstances is a matter of local policy.

Rationale: SNI supports deployment of multiple TLS-protected virtual servers on a single address, and therefore enables fine-grained security for these virtual servers, by allowing each one to have its own certificate.

4. Recommendations: Cipher Suites

TLS and its implementations provide considerable flexibility in the selection of cipher suites. Unfortunately, some available cipher suites are insecure, some do not provide the targeted security services, and some no longer provide enough security. Incorrectly configuring a server leads to no or reduced security. This section includes recommendations on the selection and negotiation of cipher suites.

4.1. General Guidelines

Cryptographic algorithms weaken over time as cryptanalysis improves: algorithms that were once considered strong become weak. Such algorithms need to be phased out over time and replaced with more secure cipher suites. This helps to ensure that the desired security

properties still hold. SSL/TLS has been in existence for almost 20 years and many of the cipher suites that have been recommended in various versions of SSL/TLS are now considered weak or at least not as strong as desired. Therefore this section modernizes the recommendations concerning cipher suite selection:

- Implementations MUST NOT negotiate the cipher suites with NULL encryption.

  Rationale: The NULL cipher suites do not encrypt traffic and so provide no confidentiality services. Any entity in the network with access to the connection can view the plaintext of contents being exchanged by the client and server. (Nevertheless, this document does not discourage software from implementing NULL cipher suites, since they can be useful for testing and debugging.)

- Implementations MUST NOT negotiate RC4 cipher suites.

  Rationale: The RC4 stream cipher has a variety of cryptographic weaknesses, as documented in [RFC7465]. Note that DTLS specifically forbids the use of RC4 already.

- Implementations MUST NOT negotiate cipher suites offering less than 112 bits of security, including so-called "export-level" encryption (which provide 40 or 56 bits of security).

  Rationale: Based on [RFC3766], at least 112 bits of security is needed. 40-bit and 56-bit security are considered insecure today. TLS 1.1 and 1.2 never negotiate 40-bit or 56-bit export ciphers.

- Implementations SHOULD NOT negotiate cipher suites that use algorithms offering less than 128 bits of security.

  Rationale: Cipher suites that offer between 112-bits and 128-bits of security are not considered weak at this time, however it is expected that their useful lifespan is short enough to justify supporting stronger cipher suites at this time. 128-bit ciphers are expected to remain secure for at least several years, and 256-bit ciphers until the next fundamental technology breakthrough. Note that, because of so-called "meet-in-the-middle" attacks [Multiple-Encryption] some legacy cipher suites (e.g., 168-bit 3DES) have an effective key length which is smaller than their nominal key length (112 bits in the case of 3DES). Such cipher suites should be evaluated according to their effective key length.

- Implementations SHOULD NOT negotiate cipher suites based on RSA key transport, a.k.a. "static RSA".

  Rationale: These cipher suites, which have assigned values starting with the string "TLS_RSA_WITH_*", have several drawbacks, especially the fact that they do not support forward secrecy.

- Implementations MUST support and prefer to negotiate cipher suites offering forward secrecy, such as those in the Ephemeral Diffie-Hellman and Elliptic Curve Ephemeral Diffie-Hellman ("DHE" and "ECDHE") families.

  Rationale: Forward secrecy (sometimes called "perfect forward secrecy") prevents the recovery of information that was encrypted with older session keys, thus limiting the amount of time during which attacks can be successful. See Section 7.3 for a detailed discussion.

4.2. Recommended Cipher Suites

Given the foregoing considerations, implementation and deployment of the following cipher suites is RECOMMENDED:

- TLS_DHE_RSA_WITH_AES_128_GCM_SHA256
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256
- TLS_DHE_RSA_WITH_AES_256_GCM_SHA384
- TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384

These cipher suites are supported only in TLS 1.2 because they are authenticated encryption (AEAD) algorithms [RFC5116].

Typically, in order to prefer these suites, the order of suites needs to be explicitly configured in server software (see [BETTERCRYPTO] for helpful deployment guidelines, but note that its recommendations differ from the current document in some details). It would be ideal if server software implementations were to prefer these suites by default.

Some devices have hardware support for AES-CCM but not AES-GCM, so they are unable to follow the foregoing recommendations regarding cipher suites. There are even devices that do not support public key cryptography at all, but they are out of scope entirely.

4.2.1. Implementation Details

Clients SHOULD include TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 as the first proposal to any server, unless they have prior knowledge that the server cannot respond to a TLS 1.2 client_hello message.

Servers MUST prefer this cipher suite over weaker cipher suites whenever it is proposed, even if it is not the first proposal.

Clients are of course free to offer stronger cipher suites, e.g., using AES-256; when they do, the server SHOULD prefer the stronger cipher suite unless there are compelling reasons (e.g., seriously degraded performance) to choose otherwise.

This document does not change the mandatory-to-implement TLS cipher suite(s) prescribed by TLS. To maximize interoperability, RFC 5246 mandates implementation of the TLS_RSA_WITH_AES_128_CBC_SHA cipher suite, which is significantly weaker than the cipher suites recommended here (the GCM mode does not suffer from the same weakness, caused by the order of MAC-then-Encrypt in TLS [Krawczyk2001], since it uses an Authenticated Encryption with Associated Data (AEAD) mode of operation). Implementers should consider the interoperability gain against the loss in security when deploying the TLS_RSA_WITH_AES_128_CBC_SHA cipher suite. Other application protocols specify other cipher suites as mandatory to implement (MTI).

Note that some profiles of TLS 1.2 use different cipher suites. For example, [RFC6460] defines a profile that uses the TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256 and TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384 cipher suites.

[RFC4492] allows clients and servers to negotiate ECDH parameters (curves). Both clients and servers SHOULD include the "Supported Elliptic Curves" extension [RFC4492]. For interoperability, clients and servers SHOULD support the NIST P-256 (secp256r1) curve [RFC4492]. In addition, clients SHOULD send an ec_point_formats extension with a single element, "uncompressed".

4.3. Public Key Length

When using the cipher suites recommended in this document, two public keys are normally used in the TLS handshake: one for the Diffie-Hellman key agreement and one for server authentication. Where a client certificate is used, a third public key is added.

With a key exchange based on modular exponential (modp) Diffie-Hellman groups ("DHE" cipher suites), DH key lengths of at least 2048 bits are RECOMMENDED.

Rationale: For various reasons, in practice DH keys are typically generated in lengths that are powers of two (e.g., 2^10 = 1024 bits, 2^11 = 2048 bits, 2^12 = 4096 bits). Because a DH key of 1228 bits would be roughly equivalent to only an 80-bit symmetric key [RFC3766], it is better to use keys longer than that for the "DHE" family of cipher suites. A DH key of 1926 bits would be roughly equivalent to a 100-bit symmetric key [RFC3766] and a DH key of 2048 bits might be sufficient for at least the next 10 years [NIST.SP.800-56A]. See Section 4.4 for additional information on the use of modp Diffie-Hellman in TLS.

As noted in [RFC3766], correcting for the emergence of a TWIRL machine would imply that 1024-bit DH keys yield about 65 bits of equivalent strength and that a 2048-bit DH key would yield about 92 bits of equivalent strength.

With regard to ECDH keys, the IANA named curve registry contains 160-bit elliptic curves which are considered to be roughly equivalent to only an 80-bit symmetric key [ECRYPT-II]. Curves of less than 192-bits SHOULD NOT be used.

When using RSA servers SHOULD authenticate using certificates with at least a 2048-bit modulus for the public key. In addition, the use of the SHA-256 hash algorithm is RECOMMENDED (see [CAB-Baseline] for more details). Clients SHOULD indicate to servers that they request SHA-256, by using the "Signature Algorithms" extension defined in TLS 1.2.

4.4. Modular Exponential vs. Elliptic Curve DH Cipher Suites

Not all TLS implementations support both modular exponential (modp) and elliptic curve (EC) Diffie-Hellman groups, as required by Section 4.2. Some implementations are severely limited in the length of DH values. When such implementations need to be accommodated, the following are RECOMMENDED (in priority order):

1. Elliptic Curve DHE with appropriately negotiated parameters (e.g., the curve to be used) and a MAC algorithm stronger than HMAC-SHA1 [RFC5289]

2. TLS_DHE_RSA_WITH_AES_128_GCM_SHA256 [RFC5288], with 2048-bit Diffie-Hellman parameters

3. TLS_DHE_RSA_WITH_AES_128_GCM_SHA256, with 1024-bit parameters.

Rationale: Although Elliptic Curve Cryptography is widely deployed there are some communities where its uptake has been limited for several reasons, including its complexity compared to modular arithmetic and longstanding perceptions of IPR concerns (which, for the most part, have now been resolved [RFC6090]). Note that ECDHE cipher suites exist for both RSA and ECDSA certificates so moving to ECDHE cipher suites does not require moving away from RSA based certificates. On the other hand, there are two related issues hindering effective use of modp Diffie-Hellman cipher suites in TLS:

- There are no standardized, widely implemented protocol mechanisms to negotiate the DH groups or parameter lengths supported by client and server.

- Many servers choose DH parameters of 1024 bits or fewer.

- There are widely deployed client implementations that reject received DH parameters if they are longer than 1024 bits. In addition, several implementations do not perform appropriate validation of group parameters and are vulnerable to attacks referenced in Section 2.9 of [RFC7457]

Note that with DHE and ECDHE cipher suites, the TLS master key only depends on the Diffie-Hellman parameters and not on the strength of the RSA certificate; moreover, 1024 bit modp DH parameters are generally considered insufficient at this time.

With modp ephemeral DH, deployers ought to carefully evaluate interoperability vs. security considerations when configuring their TLS endpoints.

4.5. Truncated HMAC

Implementations MUST NOT use the Truncated HMAC extension, defined in Section 7 of [RFC6066].

Rationale: the extension does not apply to the AEAD cipher suites recommended above. However it does apply to most other TLS cipher suites. Its use has been shown to be insecure in [PatersonRS11].

5. Applicability Statement

The recommendations of this document primarily apply to the implementation and deployment of application protocols that are most commonly used with TLS and DTLS on the Internet today. Examples include, but are not limited to:

- Web software and services that wish to protect HTTP traffic with TLS.

- Email software and services that wish to protect IMAP, POP3, or SMTP traffic with TLS.

- Instant-messaging software and services that wish to protect XMPP or IRC traffic with TLS.

- Realtime media software and services that wish to protect SRTP traffic with DTLS.

This document does not modify the implementation and deployment recommendations (e.g., mandatory-to-implement cipher suites) prescribed by existing application protocols that employ TLS or DTLS. If the community that uses such an application protocol wishes to modernize its usage of TLS or DTLS to be consistent with the best practices recommended here, it needs to explicitly update the existing application protocol definition (one example is [I-D.ietf-uta-xmpp], which updates [RFC6120]).

Designers of new application protocols developed through the Internet Standards Process are expected to conform to the best practices recommended here, unless they provide documentation of compelling reasons that would prevent such conformance (e.g., widespread deployment on constrained devices that lack support for the necessary algorithms).

5.1. Security Services

This document provides recommendations for an audience that wishes to secure their communication with TLS to achieve the following:

- Confidentiality: all application-layer communication is encrypted with the goal that no party should be able to decrypt it except the intended receiver.

- Data integrity: any changes made to the communication in transit are detectable by the receiver.

- Authentication: an end-point of the TLS communication is authenticated as the intended entity to communicate with.

With regard to authentication, TLS enables authentication of one or both end-points in the communication. In the context of opportunistic security [RFC7435], TLS is sometimes used without authentication. As discussed in Section 5.2, considerations for opportunistic security are not in scope for this document.

If deployers deviate from the recommendations given in this document, they need to be aware that they might lose access to one of the foregoing security services.

This document applies only to environments where confidentiality is required. It recommends algorithms and configuration options that enforce secrecy of the data-in-transit.

This document also assumes that data integrity protection is always one of the goals of a deployment. In cases where integrity is not required, it does not make sense to employ TLS in the first place. There are attacks against confidentiality-only protection that utilize the lack of integrity to also break confidentiality (see for instance [DegabrieleP07] in the context of IPsec).

This document addresses itself to application protocols that are most commonly used on the Internet with TLS and DTLS. Typically, all communication between TLS clients and TLS servers requires all three of the above security services. This is particularly true where TLS clients are user agents like Web browsers or email software.

This document does not address the rarer deployment scenarios where one of the above three properties is not desired, such as the use case described under Section 5.2 below. As another scenario where confidentiality is not needed, consider a monitored network where the authorities in charge of the respective traffic domain require full access to unencrypted (plaintext) traffic, and where users collaborate and send their traffic in the clear.

5.2. Opportunistic Security

There are several important scenarios in which the use of TLS is optional, i.e., the client decides dynamically ("opportunistically") whether to use TLS with a particular server or to connect in the clear. This practice, often called "opportunistic security", is described at length in [RFC7435] and is often motivated by a desire for backward compatibility with legacy deployments.

In these scenarios, some of the recommendations in this document might be too strict, since adhering to them could cause fallback to cleartext, a worse outcome than using TLS with an outdated protocol version or cipher suite.

This document specifies best practices for TLS in general. A separate document containing recommendations for the use of TLS with opportunistic security is to be completed in the future.

6. IANA Considerations

This document requests no actions of IANA. [Note to RFC Editor: please remove this whole section before publication.]

7. Security Considerations

This entire document discusses the security practices directly affecting applications using the TLS protocol. This section contains broader security considerations related to technologies used in conjunction with or by TLS.

7.1. Host Name Validation

Application authors should take note that TLS implementations frequently do not validate host names and must therefore determine if the TLS implementation they are using does and, if not, write their own validation code or consider changing the TLS implementation.

It is noted that the requirements regarding host name validation (and in general, binding between the TLS layer and the protocol that runs above it) vary between different protocols. For HTTPS, these requirements are defined by Section 3 of [RFC2818].

Readers are referred to [RFC6125] for further details regarding generic host name validation in the TLS context. In addition, the RFC contains a long list of example protocols, some of which implement a policy very different from HTTPS.

If the host name is discovered indirectly and in an insecure manner (e.g., by an insecure DNS query for an MX or SRV record), it SHOULD NOT be used as a reference identifier [RFC6125] even when it matches the presented certificate. This proviso does not apply if the host name is discovered securely (for further discussion, see for example [I-D.ietf-dane-srv] and [I-D.ietf-dane-smtp-with-dane]).

Host name validation typically applies only to the leaf "end entity" certificate. Naturally, in order to ensure proper authentication in the context of the PKI, application clients need to verify the entire certification path in accordance with [RFC5280] (see also [RFC6125]).

7.2. AES-GCM

Section 4.2 above recommends the use of the AES-GCM authenticated encryption algorithm. Please refer to [RFC5246], Section 11 for general security considerations when using TLS 1.2, and to [RFC5288], Section 6 for security considerations that apply specifically to AES-GCM when used with TLS.

7.3. Forward Secrecy

Forward secrecy (also often called Perfect Forward Secrecy or "PFS" and defined in [RFC4949]) is a defense against an attacker who records encrypted conversations where the session keys are only encrypted with the communicating parties' long-term keys. Should the attacker be able to obtain these long-term keys at some point later in time, he will be able to decrypt the session keys and thus the entire conversation. In the context of TLS and DTLS, such compromise of long-term keys is not entirely implausible. It can happen, for example, due to:

- A client or server being attacked by some other attack vector, and the private key retrieved.
- A long-term key retrieved from a device that has been sold or otherwise decommissioned without prior wiping.
- A long-term key used on a device as a default key [Heninger2012].
- A key generated by a Trusted Third Party like a CA, and later retrieved from it either by extortion or compromise [Soghoian2011].
- A cryptographic break-through, or the use of asymmetric keys with insufficient length [Kleinjung2010].
- Social engineering attacks against system administrators.
- Collection of private keys from inadequately protected backups.

Forward secrecy ensures in such cases that the session keys cannot be determined even by an attacker who obtains the long-term keys some time after the conversation. It also protects against an attacker who is in possession of the long-term keys, but remains passive during the conversation.

Forward secrecy is generally achieved by using the Diffie-Hellman scheme to derive session keys. The Diffie-Hellman scheme has both parties maintain private secrets and send parameters over the network as modular powers over certain cyclic groups. The properties of the so-called Discrete Logarithm Problem (DLP) allow the parties to derive the session keys without an eavesdropper being able to do so. There is currently no known attack against DLP if sufficiently large parameters are chosen. A variant of the Diffie-Hellman scheme uses Elliptic Curves instead of the originally proposed modular arithmetics.

Unfortunately, many TLS/DTLS cipher suites were defined that do not feature forward secrecy, e.g., TLS_RSA_WITH_AES_256_CBC_SHA256. This document therefore advocates strict use of forward-secrecy-only ciphers.

7.4. Diffie-Hellman Exponent Reuse

For performance reasons, many TLS implementations reuse Diffie-Hellman and Elliptic Curve Diffie-Hellman exponents across multiple connections. Such reuse can result in major security issues:

- If exponents are reused for a long time (e.g., more than a few hours), an attacker who gains access to the host can decrypt previous connections. In other words, exponent reuse negates the effects of forward secrecy.

- TLS implementations that reuse exponents should test the DH public key they receive for group membership, in order to avoid some known attacks. These tests are not standardized in TLS at the time of writing. See [RFC6989] for recipient tests required of IKEv2 implementations that reuse DH exponents.

7.5. Certificate Revocation

The following considerations and recommendations represent the current state of the art regarding certificate revocation, even though no complete and efficient solution exists for the problem of checking the revocation status of common public key certificates [RFC5280]:

- Although Certificate Revocation Lists (CRLs) are the most widely supported mechanism for distributing revocation information, they have known scaling challenges that limit their usefulness (despite workarounds such as partitioned CRLS and delta CRLs).

- Proprietary mechanisms that embed revocation lists in the Web browser's configuration database cannot scale beyond a small number of the most heavily used Web servers.

- The On-Line Certification Status Protocol (OCSP) [RFC6960] presents both scaling and privacy issues. In addition, clients typically "soft-fail", meaning that they do not abort the TLS connection if the OCSP server does not respond (however, this might be a workaround to avoid denial of service attacks if an OSCP responder is taken offline).

- OCSP stapling (Section 8 of [RFC6066]) resolves the operational issues with OCSP, but is still ineffective in the presence of a

MITM attacker because the attacker can simply ignore the client's request for a stapled OCSP response.

- OCSP stapling as defined in [RFC6066] does not extend to intermediate certificates used in a certificate chain. Although [RFC6961] addresses this shortcoming, it is a recent addition without much deployment.

- Both CRLs and OSCP depend on relatively reliable connectivity to the Internet, which might not be available to certain kinds of nodes (such as newly provisioned devices that need to establish a secure connection in order to boot up for the first time).

With regard to common public key certificates, servers SHOULD support the following as a best practice given the current state of the art and as a foundation for a possible future solution:

1. OCSP [RFC6960]

2. Both the status_request extension defined in [RFC6066] and the status_request_v2 extension defined in [RFC6961] (this might enable interoperability with the widest range of clients)

3. The OCSP stapling extension defined in [RFC6961]

The considerations in this section do not apply to scenarios where the DANE-TLSA resource record [RFC6698] is used to signal to a client which certificate a server considers valid and good to use for TLS connections.

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9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2818] Rescorla, E., "HTTP Over TLS", RFC 2818, May 2000.

[RFC3766] Orman, H. and P. Hoffman, "Determining Strengths For Public Keys Used For Exchanging Symmetric Keys", BCP 86, RFC 3766, April 2004.

[RFC4492] Blake-Wilson, S., Bolyard, N., Gupta, V., Hawk, C., and B. Moeller, "Elliptic Curve Cryptography (ECC) Cipher Suites for Transport Layer Security (TLS)", RFC 4492, May 2006.

[RFC4949] Shirey, R., "Internet Security Glossary, Version 2", RFC 4949, August 2007.

[RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, August 2008.

[RFC5288] Salowey, J., Choudhury, A., and D. McGrew, "AES Galois Counter Mode (GCM) Cipher Suites for TLS", RFC 5288, August 2008.

[RFC5289] Rescorla, E., "TLS Elliptic Curve Cipher Suites with SHA-256/384 and AES Galois Counter Mode (GCM)", RFC 5289, August 2008.

[RFC5746] Rescorla, E., Ray, M., Dispensa, S., and N. Oskov, "Transport Layer Security (TLS) Renegotiation Indication Extension", RFC 5746, February 2010.

[RFC6066] Eastlake, D., "Transport Layer Security (TLS) Extensions: Extension Definitions", RFC 6066, January 2011.

[RFC6125] Saint-Andre, P. and J. Hodges, "Representation and Verification of Domain-Based Application Service Identity within Internet Public Key Infrastructure Using X.509 (PKIX) Certificates in the Context of Transport Layer Security (TLS)", RFC 6125, March 2011.

[RFC6176] Turner, S. and T. Polk, "Prohibiting Secure Sockets Layer (SSL) Version 2.0", RFC 6176, March 2011.

[RFC6347] Rescorla, E. and N. Modadugu, "Datagram Transport Layer Security Version 1.2", RFC 6347, January 2012.

[RFC7465] Popov, A., "Prohibiting RC4 Cipher Suites", RFC 7465, February 2015.

9.2. Informative References

[BETTERCRYPTO]
bettercrypto.org, , "Applied Crypto Hardening", 2015, <https://bettercrypto.org/static/applied-crypto-hardening.pdf>.

[CAB-Baseline]
CA/Browser Forum, , "Baseline Requirements for the Issuance and Management of Publicly-Trusted Certificates Version 1.1.6", 2013, <https://www.cabforum.org/documents.html>.

[DegabrieleP07]
Degabriele, J. and K. Paterson, "Attacking the IPsec standards in encryption-only configurations", 2007, <http://dx.doi.org/10.1109/SP.2007.8>.

[ECRYPT-II]
Smart, N., "ECRYPT II Yearly Report on Algorithms and Keysizes (2011-2012)", 2012, <http://www.ecrypt.eu.org/documents/D.SPA.20.pdf>.

[Heninger2012]
Heninger, N., Durumeric, Z., Wustrow, E., and J. Halderman, "Mining Your Ps and Qs: Detection of Widespread Weak Keys in Network Devices", Usenix Security Symposium 2012, 2012.

[I-D.ietf-dane-smtp-with-dane]
Dukhovni, V. and W. Hardaker, "SMTP security via opportunistic DANE TLS", draft-ietf-dane-smtp-with-dane-10 (work in progress), May 2014.

[I-D.ietf-dane-srv]
Finch, T., Miller, M., and P. Saint-Andre, "Using DNS-Based Authentication of Named Entities (DANE) TLSA Records with SRV Records", draft-ietf-dane-srv-06 (work in progress), June 2014.

[I-D.ietf-tls-downgrade-scsv]
Moeller, B. and A. Langley, "TLS Fallback Signaling Cipher Suite Value (SCSV) for Preventing Protocol Downgrade Attacks", draft-ietf-tls-downgrade-scsv-02 (work in progress), November 2014.

[I-D.ietf-tls-session-hash]
Bhargavan, K., Delignat-Lavaud, A., Pironti, A., Langley, A., and M. Ray, "Transport Layer Security (TLS) Session Hash and Extended Master Secret Extension", draft-ietf-tls-session-hash-03 (work in progress), November 2014.

[I-D.ietf-tls-sslv3-diediedie]
Barnes, R., Thomson, M., Pironti, A., and A. Langley, "Deprecating Secure Sockets Layer Version 3.0", draft-ietf-tls-sslv3-diediedie-00 (work in progress), December 2014.

[I-D.ietf-uta-xmpp]
Saint-Andre, P. and a. alkemade, "Use of Transport Layer Security (TLS) in the Extensible Messaging and Presence Protocol (XMPP)", draft-ietf-uta-xmpp-05 (work in progress), January 2015.

[Kleinjung2010]
Kleinjung, T., "Factorization of a 768-Bit RSA Modulus", CRYPTO 10, 2010, <https://eprint.iacr.org/2010/006.pdf>.

[Krawczyk2001]
Krawczyk, H., "The order of encryption and authentication for protecting communications (Or: how secure is SSL?)", CRYPTO 01, 2001, <https://eprint.iacr.org/2001/045.pdf>.

[Multiple-Encryption]
Merkle, R. and M. Hellman, "On the security of multiple encryption", Communications of the ACM 24, 1981, <http://dl.acm.org/citation.cfm?id=358718>.

[NIST.SP.800-56A]
Barker, E., Chen, L., Roginsky, A., and M. Smid, "Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography", NIST Special Publication 800-56A, 2013, <http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-56Ar2.pdf>.

[POODLE] Moeller, B., Duong, T., and K. Kotowicz, "This POODLE Bites: Exploiting the SSL 3.0 Fallback", 2014, <https://www.openssl.org/~bodo/ssl-poodle.pdf>.

[PatersonRS11]
Paterson, K., Ristenpart, T., and T. Shrimpton, "Tag size does matter: attacks and proofs for the TLS record protocol", 2011, <http://dx.doi.org/10.1007/978-3-642-25385-0_20>.

[RFC2246] Dierks, T. and C. Allen, "The TLS Protocol Version 1.0", RFC 2246, January 1999.

[RFC3602] Frankel, S., Glenn, R., and S. Kelly, "The AES-CBC Cipher Algorithm and Its Use with IPsec", RFC 3602, September 2003.

[RFC4346] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.1", RFC 4346, April 2006.

[RFC4347] Rescorla, E. and N. Modadugu, "Datagram Transport Layer Security", RFC 4347, April 2006.

[RFC5077] Salowey, J., Zhou, H., Eronen, P., and H. Tschofenig, "Transport Layer Security (TLS) Session Resumption without Server-Side State", RFC 5077, January 2008.

[RFC5116] McGrew, D., "An Interface and Algorithms for Authenticated Encryption", RFC 5116, January 2008.

[RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 5280, May 2008.

[RFC6090] McGrew, D., Igoe, K., and M. Salter, "Fundamental Elliptic Curve Cryptography Algorithms", RFC 6090, February 2011.

[RFC6101] Freier, A., Karlton, P., and P. Kocher, "The Secure Sockets Layer (SSL) Protocol Version 3.0", RFC 6101, August 2011.

[RFC6120] Saint-Andre, P., "Extensible Messaging and Presence Protocol (XMPP): Core", RFC 6120, March 2011.

[RFC6460] Salter, M. and R. Housley, "Suite B Profile for Transport Layer Security (TLS)", RFC 6460, January 2012.

[RFC6698] Hoffman, P. and J. Schlyter, "The DNS-Based Authentication of Named Entities (DANE) Transport Layer Security (TLS) Protocol: TLSA", RFC 6698, August 2012.

[RFC6797] Hodges, J., Jackson, C., and A. Barth, "HTTP Strict Transport Security (HSTS)", RFC 6797, November 2012.

[RFC6960] Santesson, S., Myers, M., Ankney, R., Malpani, A., Galperin, S., and C. Adams, "X.509 Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP", RFC 6960, June 2013.

[RFC6961] Pettersen, Y., "The Transport Layer Security (TLS) Multiple Certificate Status Request Extension", RFC 6961, June 2013.

[RFC6989] Sheffer, Y. and S. Fluhrer, "Additional Diffie-Hellman Tests for the Internet Key Exchange Protocol Version 2 (IKEv2)", RFC 6989, July 2013.

[RFC7435] Dukhovni, V., "Opportunistic Security: Some Protection Most of the Time", RFC 7435, December 2014.

[RFC7457] Sheffer, Y., Holz, R., and P. Saint-Andre, "Summarizing Known Attacks on Transport Layer Security (TLS) and Datagram TLS (DTLS)", RFC 7457, February 2015.

[Smith2013] Smith, B., "Proposal to Change the Default TLS Ciphersuites Offered by Browsers.", 2013, <https://briansmith.org/browser-ciphersuites-01.html>.

[Soghoian2011] Soghoian, C. and S. Stamm, "Certified lies: Detecting and defeating government interception attacks against SSL.", Proc. 15th Int. Conf. Financial Cryptography and Data Security , 2011.

[triple-handshake]
Delignat-Lavaud, A., Bhargavan, K., and A. Pironti, "Triple Handshakes Considered Harmful: Breaking and Fixing Authentication over TLS", 2014, <https://secure-resumption.com/>.

Appendix A. Change Log

Note to RFC Editor: please remove this section before publication.

A.1. draft-ietf-uta-tls-bcp-08

- More WGLC feedback.
- TLS 1.1 is now SHOULD NOT, just like TLS 1.0.
- SHOULD NOT use curves of less than 192 bits for ECDH.
- Clarification regarding OCSP and OSCP stapling.

A.2. draft-ietf-uta-tls-bcp-07

- WGLC feedback.

A.3. draft-ietf-uta-tls-bcp-06

- Undo unauthenticated TLS, following another long thread on the list.

A.4. draft-ietf-uta-tls-bcp-05

- Lots of comments by Sean Turner.
- Unauthenticated TLS, following a long thread on the list.

A.5. draft-ietf-uta-tls-bcp-04

- Some cleanup, and input from TLS WG discussion on applicability.

A.6. draft-ietf-uta-tls-bcp-03

- Disallow truncated HMAC.
- Applicability to DTLS.
- Some more text restructuring.
- Host name validation is sometimes irrelevant.

- HSTS: MUST implement, SHOULD deploy.
- Session identities are not protected, only tickets are.
- Clarified the target audience.

A.7. draft-ietf-uta-tls-bcp-02

- Rearranged some sections for clarity and re-styled the text so that normative text is followed by rationale where possible.
- Removed the recommendation to use Brainpool curves.
- Triple Handshake mitigation.
- MUST NOT negotiate algorithms lower than 112 bits of security.
- MUST implement SNI, but use per local policy.
- Changed SHOULD NOT negotiate or fall back to SSLv3 to MUST NOT.
- Added hostname validation.
- Non-normative discussion of DH exponent reuse.

A.8. draft-ietf-tls-bcp-01

- Clarified that specific TLS-using protocols may have stricter requirements.
- Changed TLS 1.0 from MAY to SHOULD NOT.
- Added discussion of "optional TLS" and HSTS.
- Recommended use of the Signature Algorithm and Renegotiation Info extensions.
- Use of a strong cipher for a resumption ticket: changed SHOULD to MUST.
- Added an informational discussion of certificate revocation, but no recommendations.

A.9. draft-ietf-tls-bcp-00

- Initial WG version, with only updated references.

A.10. draft-sheffer-tls-bcp-02

- Reorganized the content to focus on recommendations.
- Moved description of attacks to a separate document (draft-sheffer-uta-tls-attacks).
- Strengthened recommendations regarding session resumption.

A.11. draft-sheffer-tls-bcp-01

- Clarified our motivation in the introduction.
- Added a section justifying the need for forward secrecy.
- Added recommendations for RSA and DH parameter lengths. Moved from DHE to ECDHE, with a discussion on whether/when DHE is appropriate.
- Recommendation to avoid fallback to SSLv3.
- Initial information about browser support - more still needed!
- More clarity on compression.
- Client can offer stronger cipher suites.
- Discussion of the regular TLS mandatory cipher suite.

A.12. draft-sheffer-tls-bcp-00

- Initial version.

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