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Authors: M. Thomson
Mozilla

Secure Negotiation of Incompatible Protocols in TLS

Abstract

An extension is defined for TLS that allows a client and server to detect an attempt to force the use of less-preferred application protocol even where protocol options are incompatible. This supplements application-layer protocol negotiation, which allows choices between compatible protocols to be authenticated.

Discussion Venues

This note is to be removed before publishing as an RFC.

Discussion of this document takes place on the TLS Working Group mailing list (tls@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/tls/.

Source for this draft and an issue tracker can be found at https://github.com/martinthomson/snip.

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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1. Introduction

With increased diversity in protocol choice, some applications are able to use one of several semantically-equivalent protocols to achieve their goals. This is particularly notable in HTTP where there are currently three distinct protocols: HTTP/1.1 [HTTP11], HTTP/2 [HTTP2], and HTTP/3 [HTTP3]. This is also true for protocols that support variants based on both TLS [TLS] and DTLS [DTLS].

For protocols that are mutually compatible, Application-Layer Protocol Negotiation (ALPN; [ALPN]) provides a secure way to negotiate protocol selection.

In ALPN, the client offers a list of options in a TLS ClientHello and the server chooses the option that it most prefers. A downgrade attack occurs where both client and server support a protocol that the server prefers more than than the selected protocol. ALPN protects against this attack by ensuring that the server is aware of all options the client supports and including those options and the

server choice under the integrity protection provided by the TLS handshake.

This downgrade protection functions because protocol negotiation is part of the TLS handshake. The introduction of semantically-equivalent protocols that use incompatible handshakes introduces new opportunities for downgrade attack. For instance, it is not possible to negotiate the use of HTTP/2 based on an attempt to connect using HTTP/3. The former relies on TCP, whereas the latter uses UDP. These protocols are therefore mutually incompatible.

This document defines an extension to TLS that allows clients to discover when servers support alternative protocols that are incompatible with the currently-selected TLS version. This might be used to avoid downgrade attack caused by interference in protocol discovery mechanisms.

This extension is motivated by the addition of new mechanisms, such as [SVCB]. SVCB enables the discovery of servers that support multiple different protocols, some of which are incompatible. The extension can also be used to authenticate protocol choices that are discovered by other means.

2. Terminology

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

Two protocols are consider "compatible" if it is possible to negotiate either using the same connection attempt. In comparison, protocols are "incompatible" if they require separate attempts to establish a connection.

3. Incompatible Protocols and SVCB

The SVCB record [SVCB] allows a client to learn about services associated with a domain name. This includes how to locate a server, along with supplementary information about the server, including protocols that the server supports. This allows a client to start using a protocol of their choice without added latency, as the lookup can be performed concurrently with other name resolution. The added cost of the additional DNS queries is minimal.

However, SVCB provides no protection against a downgrade attack between incompatible protocols. An attacker could remove DNS records for client-preferred protocols, leaving the client to believe that only less-prefered, mutually-incompatible options are available. The

client only offers compatible options to a server in its TLS handshake. Even if a client were to inform the server that it supports a more preferred protocol, the server would not be able to act upon it.

Authenticating all of the information presented in SVCB records might provide clients with complete information about server support, but this is impractical for several reasons:

- it is not possible to ensure that all server instances in a deployment have the same protocol configuration, as deployments for a single name routinely include multiple providers that cannot coordinate closely;

- the ability to provide a subset of valid DNS records is integral to many strategies for managing servers; and

- it is difficult to ensure that cached DNS records are synchronized with server state.

Overall, an authenticated TLS handshake is a better source of authoritative information about the protocols that are supported.

4. Authenticating Incompatible Protocols

The incompatible_protocols(TBD) TLS extension provides clients with information about the incompatible protocols that are supported by servers.

```
enum {
    incompatible_protocols(TBD), (65535)
} ExtensionType;
```

A client that supports the extension advertises an empty extension. In response, a server that supports this extension includes a list of application protocol identifiers. The "extension_data" field of the value server extension uses the ProtocolNameList format defined in [ALPN]. This syntax is shown in Figure 1.

```
struct {
  select (Handshake.msg_type) {
    case client_hello:
      Empty;
    case encrypted_extensions:
      ProtocolNameList incompatible_protocols;
  };
} IncompatibleProtocols;
```

Figure 1: TLS Syntax for incompatible_protocols Extension

This extension only applies to the ClientHello and EncryptedExtensions messages. An implementation that receives this extension in any other handshake message MUST send a fatal illegal_parameter alert.

A server deployment that supports multiple incompatible protocols MAY advertise all protocols that are supported. A server MAY limit this to protocols that it considers to have similar semantics to protocols that the client lists in its application_layer_protocol_negotiation extension.

The definition of what a server includes is intentionally loose. It is better that a server offer more information than less as the needs of a client are not necessarily well reflected in its ALPN extension. However, it is not reasonable to require that a server advertise all potential protocols as that is unlikely to be practical.

A server MUST omit any compatible protocols from this extension on the understanding that the client will include compatible protocols in the application_layer_protocol_negotiation extension.

A server needs to ensure that protocols advertised in this fashion are available to the client within the same protocol authentication scope.

5. Protocol Authentication Scope

The protocol authentication scope is the set of protocol endpoints at a server that share a protocol configuration. A client learns of this scope as part of the process it follows to discover the server.

By default, the protocol authentication scope is a single protocol endpoint. The default protocol authentication scope offers no means to authenticate incompatible protocols as it is not possible for a client to access any endpoint that supports those protocols. A client cannot use information from the incompatible_protocols extension unless a wider scope is used.

[[TODO: This likely needs some discussion.]]

5.1. SVCB Discovery Scope

For SVCB records, the protocol authentication scope is defined by the set of ServiceForm SVCB records with the same SvcDomainName.

This ensures that the final choice a client makes between ServiceForm SVCB records is protected by this extension. If the client does not receive a SVCB record for a protocol that the server

includes in its incompatible_protocols extension, then it can assume that this omission was caused by an error or attack.

Thus, for SVCB, a choice between AliasForm records (or CNAME or DNAME records) is not authenticated, but choices between ServiceForm records is. This allows for server deployments for the same name to have different administrative control and protocol configurations.

5.2. QUIC Version Negotiation

TODO: define how this can be used to authenticate protocol choices where there are incompatible QUIC versions.

5.3. Alternative Services

It is possible to negotiate protocols based on an established connection without exposure to downgrade. The Alternative Services [ALTSVC] bootstrapping in HTTP/3 does just that. Assuming that HTTP/2 or HTTP/1.1 are not vulnerable to attacks that would compromise integrity, a server can advertise the presence of an endpoint that supports HTTP/3.

Under these assumptions Alternative Services is secure, but it has performance trade-offs. A client could attempt the protocol it prefers most, but that comes at a risk that this protocol is not supported by a server. A client could implement a fallback, which might even be performed concurrently (see [HAPPY-EYEBALLS]), but this costs time and resources. A client avoids these costs by attempting the protocol it believes to be most widely supported, though this comes with a performance penalty in cases where the most-preferred protocol is supported.

A server that is discovered using Alternative Services uses the default protocol authentication scope. As use of Alternative Services is discretionary for both client and server, a client cannot expect to receive information about incompatible protocols. To avoid downgrade, a client only has to avoid using an Alternative Service that offers a less-preferred protocol.

5.4. Scope for Other Discovery Methods

For other discovery methods, a definition for protocol authentication scope is needed before a client can act on what is learned using the incompatible_protocols extension. That definition needs to define how to discover server instances that support all incompatible protocols in the scope.

In particular, a server that is discovered using forms of DNS-based name resolution other than SVCB uses the default protocol

authentication scope. This discovery method does not provide enough information to locate other incompatible protocols.

For instance, an HTTPS server that is discovered using purely A or AAAA records (and CNAME or DNAME records) might advertise support for incompatible protocols, but as there is no way to determine where those protocols are supported, a client cannot act on the information. Note that Alternative Services do not change the protocol authentication scope.

Deployments of discovery methods that define a protocol authentication scope larger than the default need to ensure that every server provides information that is consistent with every protocol authentication scope that includes that server. A server that fails to indicate support for a protocol that is within a protocol authentication scope does not offer any protection against attack; a server that advertises a protocol that the client cannot discover risks this misconfiguration being identified as an attack by clients.

6. Incompatible Protocol Selection

This represents a different model for protocol selection than the one used by ALPN. In ALPN, the client presents a set of (compatible) options and the server chooses its most preferred.

In comparison, as the client makes a selection between incompatible protocols before making a connection attempt, this design only provides the client with information about other incompatible protocols that the server might support. Any choice to attempt a connection using those protocols is left to the client.

In summary:

- For compatible protocols, the server chooses

- For incompatible protocols, the client chooses

Detecting a potential downgrade between incompatible protocols does not automatically imply that a client abandon a connection attempt. This is left to client policy.

For a protocol like HTTP/3, this might not result in the client choosing to use HTTP/3, even if the server prefers that protocol. Blocking of UDP or QUIC is known to be widespread. As a result, clients might adopt a policy of tolerating a downgrade to a TCP-based protocol, even if HTTP/3 were preferred. However, as blocking of UDP is highly correlated by access network, clients that are able to establish HTTP/3 connections to some servers might choose to

apply a stricter response when a server that indicates HTTP/3 support is unreachable.

7. Security Considerations

This design depends on the integrity of the TLS handshake across all forms, including TLS [RFC8446], DTLS [DTLS], and QUIC [QUIC-TLS]. An attacker that can modify a TLS handshake in any one of these protocols can cause a client to believe that other options do not exist.

A server deployment that uses AliasForm SVCB records and does not uniformly support a client-preferred protocol is vulnerable to downgrade attacks that steer clients toward instances that lack support for that protocol. This attack is ineffective for protocols that are consistently supported by all server instances.

8. IANA Considerations

TODO: register the extension

9. References

9.1. Normative References

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Appendix A. Acknowledgments

Author's Address

Martin Thomson
Mozilla

Email: mt@lowentropy.net