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The Token Binding Protocol Version 1.0
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Abstract

This document specifies Version 1.0 of the Token Binding protocol. The Token Binding protocol allows client/server applications to create long-lived, uniquely identifiable TLS [[RFC5246](#)] bindings spanning multiple TLS sessions and connections. Applications are then enabled to cryptographically bind security tokens to the TLS layer, preventing token export and replay attacks. To protect privacy, the TLS Token Binding identifiers are only transmitted encrypted and can be reset by the user at any time.

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[1.](#) Introduction

Servers generate various security tokens (e.g. HTTP cookies, OAuth tokens) for applications to access protected resources. Any party in possession of such token gains access to the protected resource. Attackers export bearer tokens from the user's machine, present them to the servers, and impersonate authenticated users. The idea of Token Binding is to prevent such attacks by cryptographically binding security tokens to the TLS layer.

A TLS Token Binding is established by the user agent generating a private-public key pair (possibly within a secure hardware module, such as TPM) per target server, and proving possession of the private key on every TLS connection to the target server. The proof of possession involves signing the exported keying material [[RFC5705](#)] for the TLS connection with the private key. The corresponding public key is included in the TLS Token Binding identifier structure (described in the "TLS Token Binding ID Format" section of this document). TLS Token Bindings are long-lived, i.e. they encompass multiple TLS connections and TLS sessions between a given client and server. To protect privacy, TLS Token Binding IDs are never transmitted in clear text and can be reset by the user at any time, e.g. when clearing browser cookies.

When issuing a security token to a client that supports TLS Token Binding, a server includes the client's TLS Token Binding ID in the token. Later on, when a client presents a security token containing a TLS Token Binding ID, the server makes sure the ID in the token matches the ID of the TLS Token Binding established with the client. In the case of a mismatch, the server discards the token.

In order to successfully export and replay a bound security token, the attacker needs to also be able to export the client's private key, which is hard to do in the case of the key generated in a secure hardware module.

[1.1.](#) Requirements Language

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](#)].

[2.](#) Token Binding Protocol Overview

The client and server use the Token Binding Negotiation TLS Extension [[I-D.ietf-tokbind-negotiation](#)] to negotiate the Token Binding protocol version and the parameters (signature algorithm, length) of the Token Binding key. This negotiation does not require additional round-trips.

The Token Binding protocol consists of one message sent by the client to the server, proving possession of one or more client-generated asymmetric keys. This message is only sent if the client and server agree on the use of the Token Binding protocol and the key parameters. The Token Binding message is sent with the application protocol data in TLS application_data records.

A server receiving the Token Binding message verifies that the key parameters in the message match the Token Binding parameters negotiated via [[I-D.ietf-tokbind-negotiation](#)], and then validates the signatures contained in the Token Binding message. If either of these checks fails, the server terminates the connection, otherwise the TLS Token Binding is successfully established with the ID contained in the Token Binding message.

When a server supporting the Token Binding protocol receives a bound token, the server compares the TLS Token Binding ID in the security token with the TLS Token Binding ID established with the client. If the bound token came from a TLS connection without a Token Binding, or if the IDs don't match, the token is discarded.

This document defines the format of the Token Binding protocol message, the process of establishing a TLS Token Binding, the format of the Token Binding ID, and the process of validating a security token. Token Binding Negotiation TLS Extension [[I-D.ietf-tokbind-negotiation](#)] describes the negotiation of the Token Binding protocol and key parameters. Token Binding over HTTP [[I-D.ietf-tokbind-https](#)] explains how the Token Binding message is encapsulated within HTTP/1.1 [[RFC7230](#)] or HTTP/2 [[RFC7540](#)] messages. [[I-D.ietf-tokbind-https](#)] also describes Token Binding between multiple communicating parties: User Agent, Identity Provider and Relying Party.

3. Token Binding Protocol Message

The Token Binding message is sent by the client to prove possession of one or more private keys held by the client. This message **MUST** be sent if the client and server successfully negotiated the use of the Token Binding protocol via [[I-D.ietf-tokbind-negotiation](#)], and **MUST NOT** be sent otherwise. This message **MUST** be sent in the client's first application protocol message. This message **MAY** also be sent in subsequent application protocol messages, proving possession of additional private keys held by the same client, which can be used to facilitate token binding between more than two communicating parties. For example, Token Binding over HTTP [[I-D.ietf-tokbind-https](#)] specifies an encapsulation of the Token Binding message in HTTP application protocol messages, as well as scenarios involving more than two communicating parties.

The Token Binding message format is defined using TLS Presentation Language (see [Section 4 of \[RFC5246\]](#)):


```
enum {
    rsa2048_pkcs1.5(0), rsa2048_pss(1), ecdsap256(2), (255)
} TokenBindingKeyParameters;

struct {
    opaque modulus<1..2^16-1>;
    opaque publicexponent<1..2^8-1>;
} RSAPublicKey;

struct {
    opaque point <1..2^8-1>;
} ECPoint;

enum {
    provided_token_binding(0), referred_token_binding(1), (255)
} TokenBindingType;

struct {
    TokenBindingKeyParameters key_parameters;
    select (key_parameters) {
        case rsa2048_pkcs1.5:
        case rsa2048_pss:
            RSAPublicKey rsapubkey;
        case ecdsap256:
            ECPoint point;
    }
} TokenBindingID;

enum {
    (255) // No initial ExtensionType registrations
} ExtensionType;

struct {
    ExtensionType extension_type;
    opaque extension_data<0..2^16-1>;
} Extension;

struct {
    TokenBindingType tokenbinding_type;
    TokenBindingID tokenbindingid;
    opaque signature<0..2^16-1>; // Signature over the exported keying material
    value
    Extension extensions<0..2^16-1>;
} TokenBinding;

struct {
    TokenBinding tokenbindings<0..2^16-1>;
} TokenBindingMessage;
```


The Token Binding message consists of a series of TokenBinding structures, each containing the type of the token binding, the TokenBindingID, a signature over an exported keying material (EKM) value, optionally followed by Extension structures.

This document defines two Token Binding types:

- o provided_token_binding - used to establish a Token Binding when connecting to a server.
- o referred_token_binding - used when requesting tokens to be presented to a different server.

Token Binding over HTTP [[I-D.ietf-tokbind-https](#)] describes a use case for referred_token_binding where Token Bindings are established between multiple communicating parties: User Agent, Identity Provider and Relying Party. User Agent sends referred_token_binding to the Identity Provider in order to prove possession of the Token Binding key it uses with the Relying Party. The Identity Provider can then bind the token it is supplying (for presentation to the Relying Party) to the Token Binding ID contained in the referred_token_binding. Such bound token enjoys the protections discussed below in [Section 8](#) "Security Considerations".

This document establishes an IANA registry for Token Binding extensions in [Section 7.2](#) "Token Binding Types Registry". An implementation MUST ignore any unknown Token Binding types.

When an rsa2048_pkcs1.5 or rsa2048_pss key is used, TokenBinding.signature contains the signature generated using, respectively, the RSASSA-PKCS1-v1_5 or RSASSA-PSS signature scheme defined in [[RFC3447](#)]. RSAPublicKey.modulus and RSAPublicKey.publicexponent contain the length-prefixed modulus and exponent of the RSA public key represented in big-endian format.

When an ecdsap256 key is used, TokenBinding.signature contains a pair of 32-byte integers, R followed by S, generated using Curve P-256 as defined in [[ANSI.X9-62.2005](#)] and [[FIPS.186-4.2013](#)]. R and S are encoded in big-endian format, preserving any leading zero bytes. ECPoint.point contains the X coordinate followed by the Y coordinate. The X and Y coordinates are unsigned 32-byte integers encoded in big-endian format, preserving any leading zero bytes. Future specifications may define Token Binding keys using other elliptic curves with their corresponding signature and point formats.

The EKM is obtained using the Keying Material Exporters for TLS defined in [[RFC5705](#)], by supplying the following input values:

- o Label: The ASCII string "EXPORTER-Token-Binding" with no terminating NUL.
- o Context value: NULL (no application context supplied).
- o Length: 32 bytes.

4. Establishing a TLS Token Binding

4.1. Client Processing Rules

The client **MUST** include at least one TokenBinding structure in the Token Binding message. The key parameters used in the provided_token_binding **MUST** match those negotiated with the server via [[I-D.ietf-tokbind-negotiation](#)].

The client **SHOULD** generate and store Token Binding keys in a secure manner that prevents key export. In order to prevent cooperating servers from linking user identities, different keys **SHOULD** be used by the client for connections to different servers, according to the token scoping rules of the application protocol.

When the client needs to send a referred_token_binding to the Identity Provider, the client **SHALL** construct the referred TokenBinding structure in the following manner:

- o Set TokenBinding.tokenbinding_type to referred_token_binding.
- o Set TokenBinding.tokenbindingid to the Token Binding ID used with the Relying Party.
- o Set TokenBinding.signature to the result of signing the EKM value of the TLS connection to the Identity Provider, using the Token Binding key established with the Relying Party and the signature algorithm indicated by the associated key parameters. Note that these key parameters may differ from the key parameters negotiated with the Identity Provider.

Conveying referred Token Bindings in this fashion allows the Identity Provider to verify that the client controls the Token Binding key used with the Relying Party.

4.2. Server Processing Rules

The triple handshake vulnerability in TLS 1.2 and older TLS versions affects the security of the Token Binding protocol, as described in [Section 8](#) "Security Considerations". Therefore, the server **MUST NOT** negotiate the use of the Token Binding protocol with these TLS

versions, unless the server also negotiates Extended Master Secret [[RFC7627](#)] and Renegotiation Indication [[RFC5746](#)] TLS extensions.

The server MUST terminate the connection if the use of the Token Binding protocol was not negotiated, but the client sends the Token Binding message. If the Token Binding type is "provided_token_binding", the server MUST verify that the signature algorithm (including elliptic curve in the case of ECDSA) and key length in the Token Binding message match those negotiated via [[I-D.ietf-tokbind-negotiation](#)]. In the case of a mismatch, the server MUST terminate the connection. Token Bindings of type "referred_token_binding" may use different key parameters than those negotiated with this client.

If the Token Binding message does not contain at least one TokenBinding structure, or if a signature contained in any TokenBinding structure is invalid, the server MUST terminate the connection.

Servers MUST ignore any unknown extensions. Initially, no extension types are defined (see [Section 7.3](#) "Token Binding Extensions Registry"). One of the possible uses of extensions envisioned at the time of this writing is attestation: cryptographic proof that allows the server to verify that the Token Binding key is hardware-bound. The definitions of such Token Binding protocol extensions are outside the scope of this specification.

If all checks defined above have passed successfully, the TLS Token Binding between this client and server is established. The Token Binding ID(s) conveyed in the Token Binding Message can be provided to the server-side application. The application may then use the Token Binding IDs for bound security token creation and validation.

[5.](#) TLS Token Binding ID Format

The ID of the TLS Token Binding established as a result of Token Binding message processing is a binary representation of the following structure:

```
struct {  
    TokenBindingKeyParameters key_parameters;  
    select (key_parameters) {  
        case rsa2048_pkcs1.5:  
            case rsa2048_pss:  
                RSAPublicKey rsapubkey;  
            case ecdsap256:  
                ECPoint point;  
    }  
} TokenBindingID;
```

TokenBindingID contains the key parameters negotiated via [\[I-D.ietf-tokbind-negotiation\]](#). TLS Token Binding ID can be obtained from the TokenBinding structure described in the "Token Binding Protocol Message" section of this document by discarding the Token Binding type, signature and extensions. Token Binding protocol implementations SHOULD make Token Binding IDs available to the application as opaque byte sequences. E.g. server applications will use Token Binding IDs when generating and verifying bound tokens.

6. Security Token Validation

Security tokens can be bound to the TLS layer either by embedding the Token Binding ID in the token, or by maintaining a database mapping tokens to Token Binding IDs. The specific method of generating bound security tokens is application-defined and beyond the scope of this document.

Upon receipt of a security token, the server attempts to retrieve TLS Token Binding ID information from the token and from the TLS connection with the client. Application-provided policy determines whether to honor non-bound (bearer) tokens. If the token is bound and a TLS Token Binding has not been established for the client connection, the server MUST discard the token. If the TLS Token Binding ID for the token does not match the TLS Token Binding ID established for the client connection, the server MUST discard the token.

7. IANA Considerations

This section establishes three IANA registries: "Token Binding Key Parameters", "Token Binding Types" and "Token Binding Extensions". It also registers a new TLS exporter label in the TLS Exporter Label Registry.

7.1. Token Binding Key Parameters Registry

This document establishes a registry for identifiers of Token Binding key parameters entitled "Token Binding Key Parameters" under the "Token Binding Protocol" heading.

Entries in this registry require the following fields:

- o Value: The octet value that identifies a set of Token Binding key parameters (0-255).
- o Description: The description of the Token Binding key parameters.
- o Specification: A reference to a specification that defines the Token Binding key parameters.

This registry operates under the "Expert Review" policy as defined in [\[RFC5226\]](#). The designated expert is advised to encourage the inclusion of a reference to a permanent and readily available specification that enables the creation of interoperable implementations using the identified set of Token Binding key parameters.

An initial set of registrations for this registry follows:

Value: 0

Description: rsa2048_pkcs1.5

Specification: this document

Value: 1

Description: rsa2048_pss

Specification: this document

Value: 2

Description: ecdsap256

Specification: this document

7.2. Token Binding Types Registry

This document establishes a registry for Token Binding type identifiers entitled "Token Binding Types" under the "Token Binding Protocol" heading.

Entries in this registry require the following fields:

- o Value: The octet value that identifies the Token Binding type (0-255).
- o Description: The description of the Token Binding type.
- o Specification: A reference to a specification that defines the Token Binding type.

This registry operates under the "Expert Review" policy as defined in [\[RFC5226\]](#). The designated expert is advised to encourage the inclusion of a reference to a permanent and readily available specification that enables the creation of interoperable implementations using the identified Token Binding type.

An initial set of registrations for this registry follows:

Value: 0

Description: provided_token_binding

Specification: this document

Value: 1

Description: referred_token_binding

Specification: this document

7.3. Token Binding Extensions Registry

This document establishes a registry for Token Binding extensions entitled "Token Binding Extensions" under the "Token Binding Protocol" heading.

Entries in this registry require the following fields:

- o Value: The octet value that identifies the Token Binding extension (0-255).

- o Description: The description of the Token Binding extension.
- o Specification: A reference to a specification that defines the Token Binding extension.

This registry operates under the "Expert Review" policy as defined in [\[RFC5226\]](#). The designated expert is advised to encourage the inclusion of a reference to a permanent and readily available specification that enables the creation of interoperable implementations using the identified Token Binding extension. This document creates no initial registrations in the "Token Binding Extensions" registry.

7.4. Registration of Token Binding TLS Exporter Label

This document adds a registration for the "EXPORTER-Token-Binding" value in the TLS Exporter Label Registry to correspond to this specification.

8. Security Considerations

8.1. Security Token Replay

The goal of the Token Binding protocol is to prevent attackers from exporting and replaying security tokens, thereby impersonating legitimate users and gaining access to protected resources. Bound tokens can still be replayed by the malware present in the User Agent. In order to export the token to another machine and successfully replay it, the attacker also needs to export the corresponding private key. Token Binding private keys are therefore high-value assets and SHOULD be strongly protected, ideally by generating them in a hardware security module that prevents key export.

The manner in which a token is bound to the TLS layer is application-defined and beyond the scope of this document. However, the resulting bound token needs to be integrity-protected, so that an attacker cannot remove the binding or substitute a Token Binding ID of their choice without detection.

8.2. Downgrade Attacks

The Token Binding protocol is only used when negotiated via [\[I-D.ietf-tokbind-negotiation\]](#) within the TLS handshake. TLS prevents active attackers from modifying the messages of the TLS handshake, therefore it is not possible for the attacker to remove or modify the Token Binding Negotiation TLS Extension used to negotiate the Token Binding protocol and key parameters. The signature

algorithm and key length used in the TokenBinding of type "provided_token_binding" MUST match the parameters negotiated via [[I-D.ietf-tokbind-negotiation](#)].

8.3. Privacy Considerations

The Token Binding protocol uses persistent, long-lived TLS Token Binding IDs. To protect privacy, TLS Token Binding IDs are never transmitted in clear text and can be reset by the user at any time, e.g. when clearing browser cookies. Some applications offer a special privacy mode where they don't store or use tokens supplied by the server, e.g. "in private" browsing. When operating in this special privacy mode, applications SHOULD use newly generated Token Binding keys and delete them when exiting this mode, or else SHOULD NOT negotiate Token Binding at all.

In order to prevent cooperating servers from linking user identities, different keys SHOULD be used by the client for connections to different servers, according to the token scoping rules of the application protocol.

A server can use tokens and Token Binding IDs to track clients. Client applications that automatically limit the lifetime of tokens to maintain user privacy SHOULD apply the same validity time limits to Token Binding keys.

8.4. Token Binding Key Sharing Between Applications

Existing systems provide a variety of platform-specific mechanisms for certain applications to share tokens, e.g. to enable single sign-on scenarios. For these scenarios to keep working with bound tokens, the applications that are allowed to share tokens will need to also share Token Binding keys. Care must be taken to restrict the sharing of Token Binding keys to the same group(s) of applications that share the same tokens.

8.5. Triple Handshake Vulnerability in TLS 1.2 and Older TLS Versions

The Token Binding protocol relies on the exported keying material (EKM) to associate a TLS connection with a Token Binding. The triple handshake attack [[TRIPLE-HS](#)] is a known vulnerability in TLS 1.2 and older TLS versions, allowing the attacker to synchronize keying material between TLS connections. The attacker can then successfully replay bound tokens. For this reason, the Token Binding protocol MUST NOT be negotiated with these TLS versions, unless the Extended Master Secret [[RFC7627](#)] and Renegotiation Indication [[RFC5746](#)] TLS extensions have also been negotiated.

9. Acknowledgements

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