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Privacy Pass Issuance Protocol

Abstract

This document specifies two variants of the the two-message issuance protocol for Privacy Pass tokens: one that produces tokens that are privately verifiable, and another that produces tokens that are publicly verifiable. The privately verifiable issuance protocol optionally supports public metadata during the issuance flow.

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

The Privacy Pass protocol provides a privacy-preserving authorization mechanism. In essence, the protocol allows clients to provide cryptographic tokens that prove nothing other than that they have been created by a given server in the past [I-D.ietf-privacypass-architecture].

This document describes the issuance protocol for Privacy Pass. It specifies two variants: one that is privately verifiable based on the oblivious pseudorandom function from [OPRF], and one that is publicly verifiable based on the blind RSA signature scheme [BLINDRSA].

This document DOES NOT cover the architectural framework required for running and maintaining the Privacy Pass protocol in the Internet setting. In addition, it DOES NOT cover the choices that are necessary for ensuring that client privacy leaks do not occur. Both of these considerations are covered in [I-D.ietf-privacypass-architecture].

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.

The following terms are used throughout this document.

- *Client: An entity that provides authorization tokens to services across the Internet, in return for authorization.

- *Issuer: A service produces Privacy Pass tokens to clients.

- *Private Key: The secret key used by the Issuer for issuing tokens.

- *Public Key: The public key used by the Issuer for issuing and verifying tokens.

We assume that all protocol messages are encoded into raw byte format before being sent across the wire.

3. Configuration

Issuers MUST provide two parameters for configuration:

1. Issuer Request URI: a token request URL for generating access tokens. For example, an Issuer URL might be https://issuer.example.net/example-token-request. This parameter uses resource media type "text/plain".

2. Issuer Public Key values: an Issuer Public Key for an issuance protocol.

The Issuer parameters can be obtained from an Issuer via a directory object, which is a JSON object whose values are other JSON objects and URLs for the parameters.

Field Name	Value
issuer-request-uri	Issuer Request URI resource URL as a JSON string

Field Name	Value
token-keys	List of Issuer Public Key values, each as JSON objects

Table 1

Each "token-keys" JSON object contains the following fields and corresponding raw values.

Field Name	Value
token-type	Integer value of the Token Type, as defined in Section 8.1, as a JSON number
token-key	The base64url encoding of the public key for use with the issuance protocol, including padding, as a JSON string

Table 2

Issuers MAY advertise multiple token-keys for the same token-type to support key rotation. In this case, Issuers indicate preference for which token key to use based on the order of keys in the list, with preference given to keys earlier in the list.

Altogether, the Issuer's JSON directory could look like:

```
{
   "issuer-request-uri": "https://issuer.example.net/example-token-requ
   "token-keys": [
     {
       "token-type": 2,
       "token-key": "MI...AB",
     },
     {
       "token-type": 2,
       "token-key": "MI...AQ",
     }
   ]
}
```

Issuer directory resources have the media type "application/json" and are located at the well-known location /.well-known/token-issuer-directory.

4. Token Challenge Requirements

Clients receive challenges for tokens, as described in [AUTHSCHEME]. The basic token issuance protocols described in this document can be interactive or non-interactive, and per-origin or cross-origin.

5. Issuance Protocol for Privately Verifiable Tokens

The Privacy Pass issuance protocol is a two message protocol that takes as input a challenge from the redemption protocol and produces a token, as shown in the figure below.

Issuers provide a Private and Public Key, denoted skI and pkI, respectively, used to produce tokens as input to the protocol. See Section 5.5 for how this key pair is generated.

Clients provide the following as input to the issuance protocol:

- Issuer name, identifying the Issuer. This is typically a host name that can be used to construct HTTP requests to the Issuer.
- Issuer Public Key pkI, with a key identifier key_id computed as described in Section 5.5.
- Challenge value challenge, an opaque byte string. For example, this might be provided by the redemption protocol in [HTTP-Authentication].

Given this configuration and these inputs, the two messages exchanged in this protocol are described below. This section uses notation described in [OPRF], Section 4, including SerializeElement and DeserializeElement, SerializeScalar and DeserializeScalar, and DeriveKeyPair.

5.1. Client-to-Issuer Request

The Client first creates a context as follows:

```
client_context = SetupVOPRFClient(0x0004, pkI)
```

Here, 0x0004 is the two-octet identifier corresponding to the OPRF(P-384, SHA-384) ciphersuite in [OPRF]. SetupVOPRFClient is defined in [OPRF], Section 3.2.

The Client then creates an issuance request message for a random value nonce using the input challenge and Issuer key identifier as follows:

```
nonce = random(32)
context = SHA256(challenge)
token_input = concat(0x0001, nonce, context, key_id)
blind, blinded_element = client_context.Blind(token_input)
```

The Blind function is defined in [OPRF], Section 3.3.2. If the Blind function fails, the Client aborts the protocol. Otherwise, the Client then creates a TokenRequest structured as follows:

```
struct {
   uint16_t token_type = 0x0001;
   uint8_t token_key_id;
   uint8_t blinded_msg[Ne];
} TokenRequest;
```

The structure fields are defined as follows:

- "token_type" is a 2-octet integer, which matches the type in the challenge.

- "token_key_id" is the least significant byte of the key_id in network byte order (in other words, the last 8 bits of key_id).

- "blinded_msg" is the Ne-octet blinded message defined above, computed as SerializeElement(blinded_element). Ne is as defined in [OPRF], Section 4.

The values token_input and blinded_element are stored locally and used later as described in Section 5.3. The Client then generates an HTTP POST request to send to the Issuer, with the TokenRequest as the body. The media type for this request is "message/token-request". An example request is shown below.

```
:method = POST
:scheme = https
:authority = issuer.example.net
:path = /example-token-request
accept = message/token-response
cache-control = no-cache, no-store
content-type = message/token-request
content-length = <Length of TokenRequest>

<Bytes containing the TokenRequest>
```

Upon receipt of the request, the Issuer validates the following conditions:

- The TokenRequest contains a supported token_type.

*The TokenRequest.token_key_id corresponds to a key ID of a Public Key owned by the issuer.

*The TokenRequest.blinded_request is of the correct size.

If any of these conditions is not met, the Issuer MUST return an HTTP 400 error to the client.

5.2. Issuer-to-Client Response

Upon receipt of a TokenRequest, the Issuer tries to deseralize TokenRequest.blinded_msg using DeserializeElement from Section 2.1 of [OPRF], yielding blinded_element. If this fails, the Issuer MUST return an HTTP 400 error to the client. Otherwise, if the Issuer is willing to produce a token token to the Client, the Issuer completes the issuance flow by computing a blinded response as follows:

```
server_context = SetupVOPRFServer(0x0004, skI, pkI)
evaluate_element, proof = server_context.Evaluate(skI, blinded_element)
```

SetupVOPRFServer is in [OPRF], Section 3.2 and Evaluate is defined in [OPRF], Section 3.3.2. The Issuer then creates a TokenResponse structured as follows:

```
struct {
   uint8_t evaluate_msg[Nk];
   uint8_t evaluate_proof[Ns+Ns];
} TokenResponse;
```

The structure fields are defined as follows:

*"evaluate_msg" is the Ne-octet evaluated messaged, computed as SerializeElement(evaluate_element).

*"evaluate_proof" is the (Ns+Ns)-octet serialized proof, which is a pair of Scalar values, computed as concat(SerializeScalar(proof[0]), SerializeScalar(proof[1])), where Ns is as defined in [OPRF], Section 4.

The Issuer generates an HTTP response with status code 200 whose body consists of TokenResponse, with the content type set as "message/token-response".

```
:status = 200
content-type = message/token-response
content-length = <Length of TokenResponse>

<Bytes containing the TokenResponse>
```

5.3. Finalization

Upon receipt, the Client handles the response and, if successful, deserializes the body values TokenResponse.evaluate_response and TokenResponse.evaluate_proof, yielding evaluated_element and proof. If deserialization of either value fails, the Client aborts the protocol. Otherwise, the Client processes the response as follows:

```
authenticator = client_context.Finalize(token_input, blind, evaluated_el
```

The Finalize function is defined in [OPRF], Section 3.3.2. If this succeeds, the Client then constructs a Token as follows:

```
struct {
    uint16_t token_type = 0x0001
    uint8_t nonce[32];
    uint8_t challenge_digest[32];
    uint8_t token_key_id[32];
    uint8_t authenticator[Nk];
} Token;
```

Otherwise, the Client aborts the protocol.

5.4. Token Verification

To verify a token, a verifier creates a VOPRF context, evaluates the token contents, and compares the result against the token authenticator value, as follows:

```
server_context = SetupVOPRFServer(0x0004, skI, pkI)
token_authenticator_input =
  concat(Token.token_type,
         Token.nonce,
         Token.challenge_digest,
         Token.token_key_id)
token_authenticator = server_context.Evaluate(token_authenticator_input)
valid = (token_authenticator == Token.authenticator)
```

5.5. Issuer Configuration

Issuers are configured with Private and Public Key pairs, each denoted skI and pkI, respectively, used to produce tokens. Each key pair MUST be generated as follows:

```
seed = random(Ns)
(skI, pkI) = DeriveKeyPair(seed, "PrivacyPass")
```

The key identifier for this specific key pair, denoted key_id, is computed as follows:

```
key_id = SHA256(concat(0x0001, SerializeElement(pkI)))
```

6. Issuance Protocol for Publicly Verifiable Tokens

This section describes a variant of the issuance protocol in Section 5 for producing publicly verifiable tokens. It differs from the previous variant in two important ways:

1. The output tokens are publicly verifiable by anyone with the Issuer public key.

2. The issuance protocol does not admit public or private metadata to bind additional context to tokens.

The first property means that any Origin can select a given Issuer to produce tokens, as long as the Origin has the Issuer public key, without explicit coordination or permission from the Issuer. This is because the Issuer does not learn the Origin that requested the token during the issuance protocol.

Beyond these differences, the publicly verifiable issuance protocol variant is nearly identical to the privately verifiable issuance protocol variant. In particular, Issuers provide a Private and Public Key, denoted skI and pkI, respectively, used to produce tokens as input to the protocol. See Section 6.5 for how this key pair is generated.

Clients provide the following as input to the issuance protocol:

- Issuer name, identifying the Issuer. This is typically a host name that can be used to construct HTTP requests to the Issuer.

- Issuer Public Key pkI, with a key identifier key_id computed as described in Section 6.5.

- Challenge value challenge, an opaque byte string. For example, this might be provided by the redemption protocol in [HTTP-Authentication].

Given this configuration and these inputs, the two messages exchanged in this protocol are described below.

6.1. Client-to-Issuer Request

The Client first creates an issuance request message for a random value nonce using the input challenge and Issuer key identifier as follows:

```
nonce = random(32)
context = SHA256(challenge)
token_input = concat(0x0002, nonce, context, key_id)
blinded_msg, blind_inv = rsabssa_blind(pkI, token_input)
```

The rsabssa_blind function is defined in [BLINDRSA], Section 5.1.1.. The Client then creates a TokenRequest structured as follows:

```
struct {
   uint16_t token_type = 0x0002
   uint8_t token_key_id;
   uint8_t blinded_msg[Nk];
} TokenRequest;
```

The structure fields are defined as follows:

- "token_type" is a 2-octet integer, which matches the type in the challenge.

- "token_key_id" is the least significant byte of the key_id in network byte order (in other words, the last 8 bits of key_id).

- "blinded_msg" is the Nk-octet request defined above.

The Client then generates an HTTP POST request to send to the Issuer, with the TokenRequest as the body. The media type for this request is "message/token-request". An example request is shown below, where Nk = 512.

```
:method = POST
:scheme = https
:authority = issuer.example.net
:path = /example-token-request
accept = message/token-response
cache-control = no-cache, no-store
content-type = message/token-request
content-length = <Length of TokenRequest>

<Bytes containing the TokenRequest>
```

Upon receipt of the request, the Issuer validates the following conditions:

- The TokenRequest contains a supported token_type.

- The TokenRequest.token_key_id corresponds to a key ID of a Public Key owned by the issuer.

- The TokenRequest.blinded_msg is of the correct size.

If any of these conditions is not met, the Issuer MUST return an HTTP 400 error to the Client, which will forward the error to the client.

6.2. Issuer-to-Client Response

If the Issuer is willing to produce a token token to the Client, the Issuer completes the issuance flow by computing a blinded response as follows:

```
blind_sig = rsabssa_blind_sign(skI, TokenRequest.blinded_rmsg)
```

This is encoded and transmitted to the client in the following TokenResponse structure:

```
struct {
   uint8_t blind_sig[Nk];
} TokenResponse;
```

The rsabssa_blind_sign function is defined in [BLINDRSA], Section 5.1.2.. The Issuer generates an HTTP response with status code 200 whose body consists of TokenResponse, with the content type set as "message/token-response".

```
:status = 200
content-type = message/token-response
content-length = <Length of TokenResponse>

<Bytes containing the TokenResponse>
```

6.3. Finalization

Upon receipt, the Client handles the response and, if successful, processes the body as follows:

```
authenticator = rsabssa_finalize(pkI, nonce, blind_sig, blind_inv)
```

The rsabssa_finalize function is defined in [BLINDRSA], Section 5.1.3.. If this succeeds, the Client then constructs a Token as described in [HTTP-Authentication] as follows:

```
struct {
    uint16_t token_type = 0x0002
    uint8_t nonce[32];
    uint8_t challenge_digest[32];
    uint8_t token_key_id[32];
    uint8_t authenticator[Nk];
} Token;
```

Otherwise, the Client aborts the protocol.

6.4. Token Verification

To verify a token, a verifier checks that Token.authenticator is a valid signature over the remainder of the token input as described below. The function RSA-Verify(msg, pk, sig) is a procedure to verify a signature sig over message msg using the public key pk. Its implementation is not specified in this document.

```
token_authenticator_input =
  concat(Token.token_type,
         Token.nonce,
         Token.challenge_digest,
         Token.token_key_id)
valid = RSA-Verify(token_authenticator_input, pkI, Token.authenticator)
```

6.5. Issuer Configuration

Issuers are configured with Private and Public Key pairs, each denoted skI and pkI, respectively, used to produce tokens. Each key pair SHALL be generated as as specified in FIPS 186-4 [DSS].

The key identifier for a keypair (skI, pkI), denoted key_id, is computed as SHA256(encoded_key), where encoded_key is a DER-encoded SubjectPublicKeyInfo (SPKI) object carrying pkI. The SPKI object MUST use the RSASSA-PSS OID [RFC5756], which specifies the hash algorithm and salt size. The salt size MUST match the output size of the hash function associated with the public key and token type.

7. Security considerations

This document outlines how to instantiate the Issuance protocol based on the VOPRF defined in [OPRF] and blind RSA protocol defnied in [BLINDRSA]. All security considerations described in the VOPRF document also apply in the Privacy Pass use-case. Considerations related to broader privacy and security concerns in a multi-Client and multi-Issuer setting are deferred to the Architecture document [I-D.ietf-privacypass-architecture].

8. IANA considerations

8.1. Token Type

This document updates the "Token Type" Registry with the following values.

Value	Name	Publicly Verifiable	Public Metadata	Private Metadata	Nk	Reference
0x0001		N	N	N	48	Section 5

Value	Name	Publicly Verifiable	Public Metadata	Private Metadata	Nk	Reference
	VOPRF (P-384, SHA-384)					
0x0002	Blind RSA (SHA-384, 2048-bit)	Y	N	N	256	Section 6

Table 3: Token Types

8.2. Media Types

This specification defines the following protocol messages, along with their corresponding media types:

*TokenRequest: "message/token-request"

*TokenResponse: "message/token-response"

The definition for each media type is in the following subsections.

8.2.1. "message/token-request" media type

Type name: message

Subtype name: token-request

Required parameters: N/A

Optional parameters: None

Encoding considerations: only "8bit" or "binary" is permitted

Security considerations: see Section 7

Interoperability considerations: N/A

Published specification: this specification

Applications that use this media type: N/A

Fragment identifier considerations: N/A

Additional information:

Magic number(s): N/A

Deprecated alias names for this type: N/A

File extension(s): N/A

Macintosh file type code(s):
N/A

Person and email address to contact for further information: see Authors' Addresses section

Intended usage: COMMON

Restrictions on usage: N/A

Author: see Authors' Addresses section

Change controller: IESG

8.2.2. "message/token-response" media type

Type name: message

Subtype name: access-token-response

Required parameters: N/A

Optional parameters: None

Encoding considerations: only "8bit" or "binary" is permitted

Security considerations: see Section 7

Interoperability considerations: N/A

Published specification: this specification

Applications that use this media type: N/A

Fragment identifier considerations: N/A

Additional information:

Magic number(s): N/A

Deprecated alias names for this type: N/A

File extension(s): N/A

Macintosh file type code(s): N/A

Person and email address to contact for further information: see Authors' Addresses section

Intended usage: COMMON

Restrictions on usage:

N/A

Author: see Authors' Addresses section

Change controller: IESG

9. References

9.1. Normative References

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[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/rfc/rfc8174>.

9.2. Informative References

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Appendix A. Acknowledgements

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Appendix B. Test Vectors

This section includes test vectors for the two basic issuance protocols specified in this document. Appendix B.1 contains test vectors for token issuance protocol 1 (0x0001), and Appendix B.2 contains test vectors for token issuance protocol 2 (0x0002).

B.1. Issuance Protocol 1 - VOPRF(P-384, SHA-384)

The test vector below lists the following values:

- skS: The encoded OPRF private key, serialized using SerializeScalar from Section 2.1 of [OPRF] and represented as a hexadecimal string.
- pkS: The encoded OPRF public key, serialized using SerializeElement from Section 2.1 of [OPRF] and represented as a hexadecimal string.
- challenge: A random challenge digest, represented as a hexadecimal string.
- nonce: The 32-byte client nonce generated according to Section 5.1, represented as a hexadecimal string.
- blind: The blind used when computing the OPRF blinded message, serialized using SerializeScalar from Section 2.1 of [OPRF] and represented as a hexadecimal string.
- token_request: The TokenRequest message constructed according to Section 5.1, represented as a hexadecimal string.

- *token_request: The TokenResponse message constructed according to Section 5.2, represented as a hexadecimal string.

- *token: The output Token from the protocol, represented as a hexadecimal string.

```
skS: 0177781aeced893dccdf80713d318a801e2a0498240fdcf650304bbbfd0f8d3b5c0
cf6cfee457aaa983ec02ff283b7a9
pkS: 022c63f79ac59c0ba3d204245f676a2133bd6120c90d67afa05cd6f8614294b7366
c252c6458300551b79a4911c2590a36
challenge:
a5d46383359ef34e3c4a7b8d1b3165778bffc9b70c9e6a60dd14143e4c9c9fbd
nonce: 5d4799f8338ddc50a6685f83b8ecd264b2f157015229d12b3384c0f199efe7b8
blind: 0322fec505230992256296063d989b59cc03e83184eb6187076d264137622d202
48e4e525bdc007b80d1560e0a6f49d9
token_request: 00011a02861fd50d14be873611cff0131d2c872c79d0260c6763498a2
a3f14ca926009c0f247653406e1d52b68d61b7ed2bac9ea
token_response: 038e3625b6a769668a99680e46cf9479f5dc1e86d57164ab3b4a569d
dfc486bf1485d4916a5194fdc0518d3e8444968421ba36e8144aa7902705ff0f3cf40586
3d69451a2a7ba210cc45760c2f1a6045134d877b39e8bcbbf920e5de4a3372557debf211
765cd969976860bc039f9082d6a3e03f8e891246240173d2cf3d69a4613b0f8415979029
22e74c7a1f2e4639e4
token: 00015d4799f8338ddc50a6685f83b8ecd264b2f157015229d12b3384c0f199efe
7b8742cdfb0ed756ea680868ef109a280a393e001d2fa56b1be46ecb31fa25e76731a5b1
d698ea7ab843b8e8a71ed9b2fffa70457a43a8fc687939424b29a7554b40fde130ab7a82
2715909cb73f99a45b640ca1c85180ba9ca1a40bab8b664406a34bcbc63b5e2e5c455cea
00001a968f7
```

B.2. Issuance Protocol 2 - Blind RSA, 4096

The test vector below lists the following values:

- *skS: The PEM-encoded PKCS#8 RSA private key used for signing tokens, represented as a hexadecimal string.

- *pkS: The DER-encoded SubjectPublicKeyInfo object carrying the public key corresponding to skS, as described in Section 6.5, represented as a hexadecimal string.

- *challenge: A random challenge digest, represented as a hexadecimal string.

- *nonce: The 32-byte client nonce generated according to Section 6.1, represented as a hexadecimal string.

- *blind: The blind used when computing the blind RSA blinded message, represented as a hexadecimal string.

*salt: The randomly generated 48-byte salt used when encoding the blinded token request message, represented as a hexadecimal string.

*token_request: The TokenRequest message constructed according to Section 6.1, represented as a hexadecimal string.

*token_request: The TokenResponse message constructed according to Section 6.2, represented as a hexadecimal string.

*token: The output Token from the protocol, represented as a hexadecimal string.

skS: 2d2d2d2d2d424547494e2050524956415445204b45592d2d2d2d2d0a4d494945765
149424144414e42676b71686b6947397730424151454641415343424b63776767536a416
74541416f49424151444c4775317261705831736334420a4f6b7a387179573553793 56b6
f6a41303543554b66717444774e38366a424b5a4f76457245526b49314c527876734d645
3327961326333616b4745714c756b440a556a35743561496b3172417643655844644e445
0344232505570785143 6e6969396e6b492b6d6772576974444449487138613979313758 6
e6c5079596f784f530a646f6558563835464f314a752b62397336356d586d34516a75513
9455961497138337172445056 7a50335758712b524e4d6363793232696867636 24c766d4
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