

Workgroup: OAuth Working Group
Internet-Draft: draft-ietf-oauth-v2-1-04
Published: 5 October 2021
Intended Status: Standards Track
Expires: 8 April 2022
Authors: D. Hardt A. Parecki T. Lodderstedt
 Hellö Okta yes.com

The OAuth 2.1 Authorization Framework

Abstract

The OAuth 2.1 authorization framework enables a third-party application to obtain limited access to an HTTP service, either on behalf of a resource owner by orchestrating an approval interaction between the resource owner and an authorization service, or by allowing the third-party application to obtain access on its own behalf. This specification replaces and obsoletes the OAuth 2.0 Authorization Framework described in RFC 6749.

Status of This Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 8 April 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in

Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. [Introduction](#)
 - 1.1. [Roles](#)
 - 1.2. [Protocol Flow](#)
 - 1.3. [Authorization Grant](#)
 - 1.3.1. [Authorization Code](#)
 - 1.3.2. [Refresh Token](#)
 - 1.3.3. [Client Credentials](#)
 - 1.4. [Access Token](#)
 - 1.5. [TLS Version](#)
 - 1.6. [HTTP Redirections](#)
 - 1.7. [Interoperability](#)
 - 1.8. [Compatibility with OAuth 2.0](#)
 - 1.9. [Notational Conventions](#)
2. [Client Registration](#)
 - 2.1. [Client Types](#)
 - 2.2. [Client Identifier](#)
 - 2.3. [Client Redirection Endpoint](#)
 - 2.3.1. [Endpoint Request Confidentiality](#)
 - 2.3.2. [Registration Requirements](#)
 - 2.3.3. [Multiple Redirect URIs](#)
 - 2.3.4. [Invalid Endpoint](#)
 - 2.3.5. [Endpoint Content](#)
 - 2.4. [Client Authentication](#)
 - 2.4.1. [Client Secret](#)
 - 2.4.2. [Other Authentication Methods](#)
 - 2.5. [Unregistered Clients](#)
3. [Protocol Endpoints](#)
 - 3.1. [Authorization Endpoint](#)
 - 3.2. [Token Endpoint](#)
 - 3.2.1. [Client Authentication](#)
 - 3.2.2. [Token Request](#)
 - 3.2.3. [Token Response](#)
4. [Grant Types](#)
 - 4.1. [Authorization Code Grant](#)
 - 4.1.1. [Authorization Request](#)
 - 4.1.2. [Authorization Response](#)
 - 4.1.3. [Token Endpoint Extension](#)
 - 4.2. [Client Credentials Grant](#)
 - 4.2.1. [Token Endpoint Extension](#)
 - 4.3. [Refresh Token Grant](#)
 - 4.3.1. [Token Endpoint Extension](#)
 - 4.3.2. [Refresh Token Response](#)
 - 4.4. [Extension Grants](#)

- 5. [Accessing Protected Resources](#)
 - 5.1. [Access Token Types](#)
 - 5.2. [Bearer Tokens](#)
 - 5.2.1. [Authenticated Requests](#)
 - 5.2.2. [The WWW-Authenticate Response Header Field](#)
 - 5.2.3. [Error Codes](#)
 - 5.3. [Error Response](#)
 - 5.3.1. [Extension Token Types](#)
- 6. [Extensibility](#)
 - 6.1. [Defining Access Token Types](#)
 - 6.2. [Defining New Endpoint Parameters](#)
 - 6.3. [Defining New Authorization Grant Types](#)
 - 6.4. [Defining New Authorization Endpoint Response Types](#)
 - 6.5. [Defining Additional Error Codes](#)
- 7. [Security Considerations](#)
 - 7.1. [Access Token Security Considerations](#)
 - 7.1.1. [Security Threats](#)
 - 7.1.2. [Threat Mitigation](#)
 - 7.1.3. [Summary of Recommendations](#)
 - 7.1.4. [Token Replay Prevention](#)
 - 7.1.5. [Access Token Privilege Restriction](#)
 - 7.2. [Client Authentication](#)
 - 7.2.1. [Client Authentication of Native Apps](#)
 - 7.3. [Registration of Native App Clients](#)
 - 7.4. [Client Impersonation](#)
 - 7.4.1. [Impersonation of Native Apps](#)
 - 7.4.2. [Access Token Privilege Restriction](#)
 - 7.4.3. [Access Token Replay Prevention](#)
 - 7.5. [Refresh Tokens](#)
 - 7.6. [Client Impersonating Resource Owner](#)
 - 7.7. [Protecting the Authorization Code Flow](#)
 - 7.7.1. [Loopback Redirect Considerations in Native Apps](#)
 - 7.7.2. [HTTP 307 Redirect](#)
 - 7.8. [Authorization Codes](#)
 - 7.9. [Request Confidentiality](#)
 - 7.10. [Ensuring Endpoint Authenticity](#)
 - 7.11. [Credentials-Guessing Attacks](#)
 - 7.12. [Phishing Attacks](#)
 - 7.13. [Fake External User-Agents in Native Apps](#)
 - 7.14. [Malicious External User-Agents in Native Apps](#)
 - 7.15. [Cross-Site Request Forgery](#)
 - 7.16. [Clickjacking](#)
 - 7.17. [Code Injection and Input Validation](#)
 - 7.18. [Open Redirectors](#)
 - 7.18.1. [Client as Open Redirector](#)
 - 7.18.2. [Authorization Server as Open Redirector](#)
 - 7.19. [Authorization Server Mix-Up Mitigation in Native Apps](#)
 - 7.20. [Embedded User Agents in Native Apps](#)
 - 7.21. [Other Recommendations](#)

- [8. Native Applications](#)
 - [8.1. Using Inter-App URI Communication for OAuth in Native Apps](#)
 - [8.2. Initiating the Authorization Request from a Native App](#)
 - [8.3. Receiving the Authorization Response in a Native App](#)
 - [8.3.1. Private-Use URI Scheme Redirection](#)
 - [8.3.2. Claimed "https" Scheme URI Redirection](#)
 - [8.3.3. Loopback Interface Redirection](#)
- [9. Browser-Based Apps](#)
- [10. Differences from OAuth 2.0](#)
- [11. IANA Considerations](#)
- [12. References](#)
 - [12.1. Normative References](#)
 - [12.2. Informative References](#)
- [Appendix A. Augmented Backus-Naur Form \(ABNF\) Syntax](#)
 - [A.1. "client_id" Syntax](#)
 - [A.2. "client_secret" Syntax](#)
 - [A.3. "response_type" Syntax](#)
 - [A.4. "scope" Syntax](#)
 - [A.5. "state" Syntax](#)
 - [A.6. "redirect_uri" Syntax](#)
 - [A.7. "error" Syntax](#)
 - [A.8. "error_description" Syntax](#)
 - [A.9. "error_uri" Syntax](#)
 - [A.10. "grant_type" Syntax](#)
 - [A.11. "code" Syntax](#)
 - [A.12. "access_token" Syntax](#)
 - [A.13. "token_type" Syntax](#)
 - [A.14. "expires_in" Syntax](#)
 - [A.15. "refresh_token" Syntax](#)
 - [A.16. Endpoint Parameter Syntax](#)
 - [A.17. "code_verifier" Syntax](#)
 - [A.18. "code_challenge" Syntax](#)
- [Appendix B. Use of application/x-www-form-urlencoded Media Type](#)
- [Appendix C. Extensions](#)
- [Appendix D. Acknowledgements](#)
- [Appendix E. Document History](#)
- [Authors' Addresses](#)

1. Introduction

In the traditional client-server authentication model, the client requests an access-restricted resource (protected resource) on the server by authenticating with the server using the resource owner's credentials. In order to provide third-party applications access to

restricted resources, the resource owner shares its credentials with the third party. This creates several problems and limitations:

- *Third-party applications are required to store the resource owner's credentials for future use, typically a password in clear-text.

- *Servers are required to support password authentication, despite the security weaknesses inherent in passwords.

- *Third-party applications gain overly broad access to the resource owner's protected resources, leaving resource owners without any ability to restrict duration or access to a limited subset of resources.

- *Resource owners often reuse passwords with other unrelated services, despite best security practices. This password reuse means a vulnerability or exposure in one service may have security implications in completely unrelated services.

- *Resource owners cannot revoke access to an individual third party without revoking access to all third parties, and must do so by changing their password.

- *Compromise of any third-party application results in compromise of the end-user's password and all of the data protected by that password.

OAuth addresses these issues by introducing an authorization layer and separating the role of the client from that of the resource owner. In OAuth, the client requests access to resources controlled by the resource owner and hosted by the resource server. Instead of using the resource owner's credentials to access protected resources, the client obtains an access token - a credential representing a specific set of access attributes such as scope and lifetime. Access tokens are issued to clients by an authorization server with the approval of the resource owner. The client uses the access token to access the protected resources hosted by the resource server.

For example, an end-user (resource owner) can grant a printing service (client) access to their protected photos stored at a photo-sharing service (resource server), without sharing their username and password with the printing service. Instead, they authenticate directly with a server trusted by the photo-sharing service (authorization server), which issues the printing service delegation-specific credentials (access token).

This specification is designed for use with HTTP ([\[RFC7231\]](#)). The use of OAuth over any protocol other than HTTP is out of scope.

Since the publication of the OAuth 2.0 Authorization Framework ([RFC6749]) in October 2012, it has been updated by OAuth 2.0 for Native Apps ([RFC8252]), OAuth Security Best Current Practice ([I-D.ietf-oauth-security-topics]), and OAuth 2.0 for Browser-Based Apps ([I-D.ietf-oauth-browser-based-apps]). The OAuth 2.0 Authorization Framework: Bearer Token Usage ([RFC6750]) has also been updated with ([I-D.ietf-oauth-security-topics]). This Standards Track specification consolidates the information in all of these documents and removes features that have been found to be insecure in [I-D.ietf-oauth-security-topics].

1.1. Roles

OAuth defines four roles:

"resource owner": An entity capable of granting access to a protected resource. When the resource owner is a person, it is referred to as an end-user. This is sometimes abbreviated as "RO".

"resource server": The server hosting the protected resources, capable of accepting and responding to protected resource requests using access tokens. The resource server is often accessible via an API. This is sometimes abbreviated as "RS".

"client": An application making protected resource requests on behalf of the resource owner and with its authorization. The term "client" does not imply any particular implementation characteristics (e.g., whether the application executes on a server, a desktop, or other devices).

"authorization server": The server issuing access tokens to the client after successfully authenticating the resource owner and obtaining authorization. This is sometimes abbreviated as "AS".

The interaction between the authorization server and resource server is beyond the scope of this specification, however several extensions have been defined to provide an option for interoperability between resource servers and authorization servers. The authorization server may be the same server as the resource server or a separate entity. A single authorization server may issue access tokens accepted by multiple resource servers.

1.2. Protocol Flow



Figure 1: Abstract Protocol Flow

The abstract OAuth 2.1 flow illustrated in [Figure 1](#) describes the interaction between the four roles and includes the following steps:

1. The client requests authorization from the resource owner. The authorization request can be made directly to the resource owner (as shown), or preferably indirectly via the authorization server as an intermediary.
2. The client receives an authorization grant, which is a credential representing the resource owner's authorization, expressed using one of the authorization grant types defined in this specification or using an extension grant type. The authorization grant type depends on the method used by the client to request authorization and the types supported by the authorization server.
3. The client requests an access token by authenticating with the authorization server and presenting the authorization grant.
4. The authorization server authenticates the client and validates the authorization grant, and if valid, issues an access token.
5. The client requests the protected resource from the resource server and authenticates by presenting the access token.
6. The resource server validates the access token, and if valid, serves the request.

The preferred method for the client to obtain an authorization grant from the resource owner (depicted in steps (1) and (2)) is to use

the authorization server as an intermediary, which is illustrated in [Figure 3](#) in [Section 4.1](#).

1.3. Authorization Grant

An authorization grant is a credential representing the resource owner's authorization (to access its protected resources) used by the client to obtain an access token. This specification defines three grant types - authorization code, refresh token, and client credentials - as well as an extensibility mechanism for defining additional types.

1.3.1. Authorization Code

An authorization code is a temporary credential used to obtain an access token. Instead of the client requesting authorization directly from the resource owner, the client directs the resource owner to an authorization server (via its user agent, which in turn directs the resource owner back to the client with the authorization code). The client can then exchange the authorization code for an access token.

Before directing the resource owner back to the client with the authorization code, the authorization server authenticates the resource owner, and may request the resource owner's consent or otherwise inform them of the client's request. Because the resource owner only authenticates with the authorization server, the resource owner's credentials are never shared with the client, and the client does not need to have knowledge of any additional authentication steps such as multi-factor authentication or delegated accounts.

The authorization code provides a few important security benefits, such as the ability to authenticate the client, as well as the transmission of the access token directly to the client without passing it through the resource owner's user agent and potentially exposing it to others, including the resource owner.

1.3.2. Refresh Token

Refresh tokens are credentials used to obtain access tokens. Refresh tokens are issued to the client by the authorization server and are used to obtain a new access token when the current access token becomes invalid or expires, or to obtain additional access tokens with identical or narrower scope (access tokens may have a shorter lifetime and fewer permissions than authorized by the resource owner). Issuing a refresh token is optional at the discretion of the authorization server, and may be issued based on properties of the client, properties of the request, policies within the authorization server, or any other criteria. If the authorization server issues a

refresh token, it is included when issuing an access token (i.e., step (2) in [Figure 2](#)).

A refresh token is a string representing the authorization granted to the client by the resource owner. The string is considered opaque to the client. The refresh token may be an identifier used to retrieve the authorization information or may encode this information into the string itself. Unlike access tokens, refresh tokens are intended for use only with authorization servers and are never sent to resource servers.

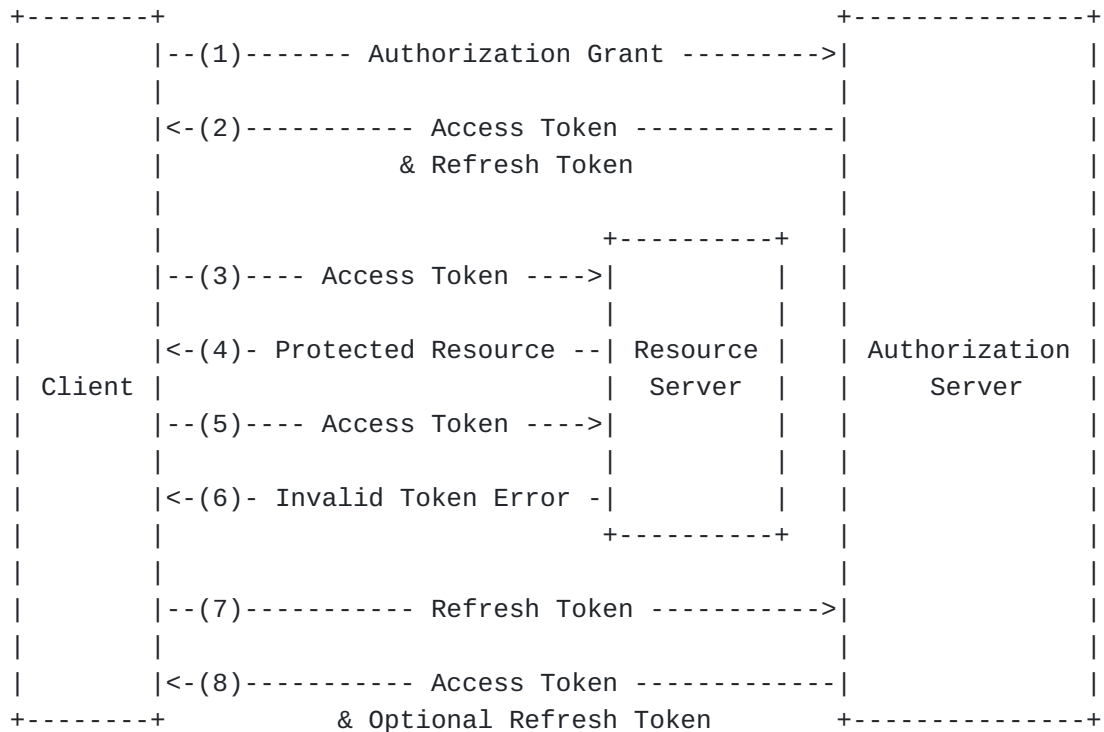


Figure 2: Refreshing an Expired Access Token

The flow illustrated in [Figure 2](#) includes the following steps:

1. The client requests an access token by authenticating with the authorization server and presenting an authorization grant.
2. The authorization server authenticates the client and validates the authorization grant, and if valid, issues an access token and optionally a refresh token.
3. The client makes a protected resource request to the resource server by presenting the access token.
4. The resource server validates the access token, and if valid, serves the request.

5. Steps (3) and (4) repeat until the access token expires. If the client knows the access token expired, it skips to step (7); otherwise, it makes another protected resource request.
6. Since the access token is invalid, the resource server returns an invalid token error.
7. The client requests a new access token by presenting the refresh token and providing client authentication if it has been issued credentials. The client authentication requirements are based on the client type and on the authorization server policies.
8. The authorization server authenticates the client and validates the refresh token, and if valid, issues a new access token (and, optionally, a new refresh token).

1.3.3. Client Credentials

The client credentials or other forms of client authentication (e.g. a `client_secret` or a private key used to sign a JWT) can be used as an authorization grant when the authorization scope is limited to the protected resources under the control of the client, or to protected resources previously arranged with the authorization server. Client credentials are used as an authorization grant typically when the client is acting on its own behalf (the client is also the resource owner) or is requesting access to protected resources based on an authorization previously arranged with the authorization server.

1.4. Access Token

Access tokens are credentials used to access protected resources. An access token is a string representing an authorization issued to the client. The string is considered opaque to the client, even if it has a structure. Depending on the authorization server, the access token string may be parseable by the resource server, such as when using the JSON Web Token Profile for Access Tokens ([[I-D.ietf-oauth-access-token-jwt](#)]).

Access tokens represent specific scopes and durations of access, granted by the resource owner, and enforced by the resource server and authorization server.

The token may be used by the RS to retrieve the authorization information, or the token may self-contain the authorization information in a verifiable manner (i.e., a token string consisting of a signed data payload). One example of a token retrieval mechanism is Token Introspection [[RFC7662](#)], in which the RS calls an endpoint on the AS to validate the token presented by the client.

One example of a structured token format is [[I-D.ietf-oauth-access-token-jwt](#)], a method of encoding access token data as a JSON Web Token [[RFC7519](#)].

Additional authentication credentials, which are beyond the scope of this specification, may be required in order for the client to use an access token. This is typically referred to as a sender-constrained access token, such as Mutual TLS Access Tokens [[RFC8705](#)].

The access token provides an abstraction layer, replacing different authorization constructs (e.g., username and password) with a single token understood by the resource server. This abstraction enables issuing access tokens more restrictive than the authorization grant used to obtain them, as well as removing the resource server's need to understand a wide range of authentication methods.

Access tokens can have different formats, structures, and methods of utilization (e.g., cryptographic properties) based on the resource server security requirements. Access token attributes and the methods used to access protected resources may be extended beyond what is described in this specification.

Access tokens (as well as any confidential access token attributes) MUST be kept confidential in transit and storage, and only shared among the authorization server, the resource servers the access token is valid for, and the client to whom the access token is issued. Access token credentials MUST only be transmitted using TLS as described in [Section 1.5](#) with server authentication as defined by [[RFC2818](#)].

The authorization server MUST ensure that access tokens cannot be generated, modified, or guessed to produce valid access tokens by unauthorized parties.

1.5. TLS Version

Whenever Transport Layer Security (TLS) is used by this specification, the appropriate version (or versions) of TLS will vary over time, based on the widespread deployment and known security vulnerabilities. Refer to [[BCP195](#)] for up to date recommendations on transport layer security.

Implementations MAY also support additional transport-layer security mechanisms that meet their security requirements.

1.6. HTTP Redirections

This specification makes extensive use of HTTP redirections, in which the client or the authorization server directs the resource

owner's user agent to another destination. While the examples in this specification show the use of the HTTP 302 status code, any other method available via the user agent to accomplish this redirection, with the exception of HTTP 307, is allowed and is considered to be an implementation detail. See [Section 7.7.2](#) for details.

1.7. Interoperability

OAuth 2.1 provides a rich authorization framework with well-defined security properties.

This specification leaves a few required components partially or fully undefined (e.g., client registration, authorization server capabilities, endpoint discovery). Some of these behaviors are defined in optional extensions which implementations can choose to use, such as:

- *[\[RFC8414\]](#): Authorization Server Metadata, defining an endpoint clients can use to look up the information needed to interact with a particular OAuth server
- *[\[RFC7591\]](#): Dynamic Client Registration, providing a mechanism for programmatically registering clients with an authorization server
- *[\[RFC7592\]](#): Dynamic Client Management, providing a mechanism for updating dynamically registered client information
- *[\[RFC7662\]](#): Token Introspection, defining a mechanism for resource servers to obtain information about access tokens

Please refer to [Appendix C](#) for a list of current known extensions at the time of this publication.

1.8. Compatibility with OAuth 2.0

OAuth 2.1 is compatible with OAuth 2.0 with the extensions and restrictions from known best current practices applied. Specifically, features not specified in OAuth 2.0 core, such as PKCE, are required in OAuth 2.1. Additionally, some features available in OAuth 2.0, such as the Implicit or Resource Owner Credentials grant types, are not specified in OAuth 2.1. Furthermore, some behaviors allowed in OAuth 2.0 are restricted in OAuth 2.1, such as the strict string matching of redirect URIs required by OAuth 2.1.

See [Section 10](#) for more details on the differences from OAuth 2.0.

1.9. Notational Conventions

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.

This specification uses the Augmented Backus-Naur Form (ABNF) notation of [[RFC5234](#)]. Additionally, the rule URI-reference is included from "Uniform Resource Identifier (URI): Generic Syntax" [[RFC3986](#)].

Certain security-related terms are to be understood in the sense defined in [[RFC4949](#)]. These terms include, but are not limited to, "attack", "authentication", "authorization", "certificate", "confidentiality", "credential", "encryption", "identity", "sign", "signature", "trust", "validate", and "verify".

The term "payload" is to be interpreted as described in Section 3.3 of [[RFC7231](#)].

The term "user agent" is to be interpreted as described in [[RFC7230](#)].

Unless otherwise noted, all the protocol parameter names and values are case sensitive.

2. Client Registration

Before initiating the protocol, the client must establish its registration with the authorization server. The means through which the client registers with the authorization server are beyond the scope of this specification but typically involve the client developer manually registering the client at the authorization server's website after creating an account and agreeing to the service's Terms of Service, or by using Dynamic Client Registration ([[RFC7591](#)]).

Client registration does not require a direct interaction between the client and the authorization server. When supported by the authorization server, registration can rely on other means for establishing trust and obtaining the required client properties (e.g., redirect URI, client type). For example, registration can be accomplished using a self-issued or third-party-issued assertion, or by the authorization server performing client discovery using a trusted channel.

When registering a client, the client developer SHALL:

- *specify the client type as described in [Section 2.1](#),
- *provide client details needed by the grant type in use, such as redirect URIs as described in [Section 2.3](#), and
- *include any other information required by the authorization server (e.g., application name, website, description, logo image, the acceptance of legal terms).

Dynamic Client Registration ([\[RFC7591\]](#)) defines a common general data model for clients that may be used even with manual client registration.

2.1. Client Types

OAuth 2.1 defines three client types based on their ability to authenticate securely with the authorization server as well as the authorization server's assurance of the client's identity.

"confidential": Clients that have credentials and have a prior relationship with the AS are designated as "confidential clients"

"credentialed": Clients that have credentials but no prior relationship with the AS are designated as "credentialed clients"

"public": Clients without credentials are called "public clients"

Any clients with credentials MUST take precautions to prevent leakage and abuse of their credentials.

Authorization servers SHOULD consider the level of confidence in a client's identity when deciding whether they allow such a client access to more critical functions, such as the Client Credentials grant type.

A single `client_id` MUST NOT be treated as more than one type of client.

For example, a client that has been registered at the authorization server by a registered application developer, where the client is expected to be run as server-side code, would be considered a confidential client. A client that runs on an end-user's device, and uses Dynamic Client Registration ([\[RFC7591\]](#)) to establish credentials the first time the app runs, would be considered a credentialed client. An application deployed as a single-page app on a static web host would be considered a public client.

This specification has been designed around the following client profiles:

"web application": A web application is a confidential client running on a web server. Resource owners access the client via an HTML user interface rendered in a user agent on the device used by the resource owner. The client credentials as well as any access tokens issued to the client are stored on the web server and are not exposed to or accessible by the resource owner.

"browser-based application": A browser-based application is a public client in which the client code is downloaded from a web server and executes within a user agent (e.g., web browser) on the device used by the resource owner. Protocol data and credentials are easily accessible (and often visible) to the resource owner. Since such applications reside within the user agent, they can make seamless use of the user agent capabilities when requesting authorization.

"native application": A native application is a public client installed and executed on the device used by the resource owner. Protocol data and credentials are accessible to the resource owner. It is assumed that any client authentication credentials included in the application can be extracted. On the other hand, dynamically issued credentials such as access tokens or refresh tokens can receive an acceptable level of protection. At a minimum, these credentials are protected from hostile servers with which the application may interact. On some platforms, these credentials might be protected from other applications residing on the same device.

2.2. Client Identifier

The authorization server issues the registered client a client identifier - a unique string representing the registration information provided by the client. The client identifier is not a secret; it is exposed to the resource owner and **MUST NOT** be used alone for client authentication. The client identifier is unique to the authorization server.

The client identifier string size is left undefined by this specification. The client should avoid making assumptions about the identifier size. The authorization server **SHOULD** document the size of any identifier it issues.

Authorization servers **SHOULD NOT** allow clients to choose or influence their `client_id` value. See [Section 7.6](#) for details.

2.3. Client Redirection Endpoint

The client redirection endpoint (also referred to as "redirect endpoint") is the URI of the client that the authorization server redirects the user agent back to after completing its interaction with the resource owner.

The authorization server redirects the user agent to one of the client's redirection endpoints previously established with the authorization server during the client registration process.

The redirect URI MUST be an absolute URI as defined by [\[RFC3986\]](#) Section 4.3. The endpoint URI MAY include an "application/x-www-form-urlencoded" formatted (per Appendix B) query component ([\[RFC3986\]](#) Section 3.4), which MUST be retained when adding additional query parameters. The endpoint URI MUST NOT include a fragment component.

2.3.1. Endpoint Request Confidentiality

The redirection endpoint SHOULD require the use of TLS as described in [Section 1.5](#) when the requested response type is code, or when the redirection request will result in the transmission of sensitive credentials over an open network. If TLS is not available, the authorization server SHOULD warn the resource owner about the insecure endpoint prior to redirection (e.g., display a message during the authorization request).

2.3.2. Registration Requirements

Authorization servers MUST require clients to register their complete redirect URI (including the path component) and reject authorization requests that specify a redirect URI that doesn't exactly match one that was registered; the exception is loopback redirects, where an exact match is required except for the port URI component.

For private-use URI scheme-based redirect URIs, authorization servers SHOULD enforce the requirement in [Section 8.3.1](#) that clients use schemes that are reverse domain name based. At a minimum, any private-use URI scheme that doesn't contain a period character (.) SHOULD be rejected.

The client MAY use the state request parameter to achieve per-request customization if needed rather than varying the redirect URI per request.

The authorization server MAY allow the client to register multiple redirect URIs.

Without requiring registration of redirect URIs, attackers can use the authorization endpoint as an open redirector as described in [Section 7.18](#).

2.3.3. Multiple Redirect URIs

If multiple redirect URIs have been registered, the client MUST include a redirect URI with the authorization request using the `redirect_uri` request parameter.

2.3.4. Invalid Endpoint

If an authorization request fails validation due to a missing, invalid, or mismatching redirect URI, the authorization server SHOULD inform the resource owner of the error and MUST NOT automatically redirect the user agent to the invalid redirect URI.

2.3.5. Endpoint Content

The redirection request to the client's endpoint typically results in an HTML document response, processed by the user agent. If the HTML response is served directly as the result of the redirection request, any script included in the HTML document will execute with full access to the redirect URI and the credentials (e.g. authorization code) it contains. Additionally, the request URL containing the authorization code may be sent in the HTTP Referer header to any embedded images, stylesheets and other elements loaded in the page.

The client SHOULD NOT include any third-party scripts (e.g., third-party analytics, social plug-ins, ad networks) in the redirection endpoint response. Instead, it SHOULD extract the credentials from the URI and redirect the user agent again to another endpoint without exposing the credentials (in the URI or elsewhere). If third-party scripts are included, the client MUST ensure that its own scripts (used to extract and remove the credentials from the URI) will execute first.

2.4. Client Authentication

If the client is confidential or credentialed, the authorization server MAY accept any form of client authentication meeting its security requirements (e.g., password, public/private key pair).

The authorization server MUST authenticate the client whenever possible. If the authorization server cannot authenticate the client due to the client's nature, the authorization server SHOULD utilize other means to protect resource owners from such potentially malicious clients. For example, the authorization server can engage

the resource owner to assist in identifying the client and its origin.

It is RECOMMENDED to use asymmetric (public-key based) methods for client authentication such as mTLS [[RFC8705](#)] or "private_key_jwt" [[OpenID](#)]. When asymmetric methods for client authentication are used, authorization servers do not need to store sensitive symmetric keys, making these methods more robust against a number of attacks.

The authorization server MAY establish a client authentication method with public clients, which converts them to credentialed clients. However, the authorization server MUST NOT rely on credentialed client authentication for the purpose of identifying the client.

The client MUST NOT use more than one authentication method in each request to prevent a conflict of which authentication mechanism is authoritative for the request.

2.4.1. Client Secret

Clients in possession of a client secret, sometimes known as a client password, MAY use the HTTP Basic authentication scheme as defined in [[RFC7235](#)] to authenticate with the authorization server. The client identifier is encoded using the application/x-www-form-urlencoded encoding algorithm per Appendix B, and the encoded value is used as the username; the client secret is encoded using the same algorithm and used as the password. The authorization server MUST support the HTTP Basic authentication scheme for authenticating clients that were issued a client secret.

For example (with extra line breaks for display purposes only):

```
Authorization: Basic czZCaGRSa3F0Mzo3RmpmcDBaQnIxS3REUmJuZlZkbU13
```

In addition to that, the authorization server MAY support including the client credentials in the request-body using the following parameters:

"client_id": REQUIRED. The client identifier issued to the client during the registration process described by [Section 2.2](#).

"client_secret": REQUIRED. The client secret.

Including the client credentials in the request-body using the two parameters is NOT RECOMMENDED and SHOULD be limited to clients unable to directly utilize the HTTP Basic authentication scheme (or other password-based HTTP authentication schemes). The parameters can only be transmitted in the request-body and MUST NOT be included in the request URI.

For example, a request to refresh an access token ([Section 4.3](#)) using the body parameters (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Content-Type: application/x-www-form-urlencoded

grant_type=refresh_token&refresh_token=tGzv3J0kF0XG5Qx2TlKWIA
&client_id=s6BhdRkqt3&client_secret=7Fjfp0ZBr1KtDRbnfVdmIw
```

The authorization server MUST require the use of TLS as described in [Section 1.5](#) when sending requests using password authentication.

Since this client authentication method involves a password, the authorization server MUST protect any endpoint utilizing it against brute force attacks.

2.4.2. Other Authentication Methods

The authorization server MAY support any suitable authentication scheme matching its security requirements. When using other authentication methods, the authorization server MUST define a mapping between the client identifier (registration record) and authentication scheme.

Some additional authentication methods such as mTLS [[RFC8705](#)] and "private_key_jwt" [[OpenID](#)] are defined in the "[OAuth Token Endpoint Authentication Methods](#)" registry, and may be useful as generic client authentication methods beyond the specific use of protecting the token endpoint.

2.5. Unregistered Clients

This specification does not exclude the use of unregistered clients. However, the use of such clients is beyond the scope of this specification and requires additional security analysis and review of its interoperability impact.

3. Protocol Endpoints

The authorization process utilizes two authorization server endpoints (HTTP resources):

- *Authorization endpoint - used by the client to obtain authorization from the resource owner via user agent redirection.

- *Token endpoint - used by the client to exchange an authorization grant for an access token, typically with client authentication.

As well as one client endpoint:

*Redirection endpoint - used by the authorization server to return responses containing authorization credentials to the client via the resource owner user agent.

Not every authorization grant type utilizes both endpoints. Extension grant types MAY define additional endpoints as needed.

3.1. Authorization Endpoint

The authorization endpoint is used to interact with the resource owner and obtain an authorization grant. The authorization server MUST first verify the identity of the resource owner. The way in which the authorization server authenticates the resource owner (e.g., username and password login, session cookies) is beyond the scope of this specification.

The means through which the client obtains the location of the authorization endpoint are beyond the scope of this specification, but the location is typically provided in the service documentation, or in the authorization server's metadata document ([[RFC8414](#)]).

The endpoint URI MAY include an "application/x-www-form-urlencoded" formatted (per Appendix B) query component ([[RFC3986](#)] Section 3.4), which MUST be retained when adding additional query parameters. The endpoint URI MUST NOT include a fragment component.

Since requests to the authorization endpoint result in user authentication and the transmission of clear-text credentials (in the HTTP response), the authorization server MUST require the use of TLS as described in [Section 1.5](#) when sending requests to the authorization endpoint.

The authorization server MUST support the use of the HTTP GET method [[RFC7231](#)] for the authorization endpoint and MAY support the use of the POST method as well.

The authorization server MUST ignore unrecognized request parameters.

Request and response parameters defined by this specification MUST NOT be included more than once. Parameters sent without a value MUST be treated as if they were omitted from the request.

3.2. Token Endpoint

The token endpoint is used by the client to obtain an access token using a grant such as those described in [Section 4](#) and [Section 4.3](#).

The means through which the client obtains the location of the token endpoint are beyond the scope of this specification, but the location is typically provided in the service documentation and configured during development of the client, or provided in the authorization server's metadata document ([\[RFC8414\]](#)) and fetched programmatically at runtime.

The endpoint URI MAY include an application/x-www-form-urlencoded formatted (per Appendix B) query component ([\[RFC3986\]](#) Section 3.4) and MUST NOT include a fragment component.

Since requests to the token endpoint result in the transmission of clear-text credentials (in the HTTP request and response), the authorization server MUST require the use of TLS as described in [Section 1.5](#) when sending requests to the token endpoint.

The client MUST use the HTTP POST method when making access token requests.

The authorization server MUST ignore unrecognized request parameters.

Parameters sent without a value MUST be treated as if they were omitted from the request. Request and response parameters defined by this specification MUST NOT be included more than once.

3.2.1. Client Authentication

Confidential or credentialed clients MUST authenticate with the authorization server as described in [Section 2.4](#) when making requests to the token endpoint.

Client authentication is used for:

- *Enforcing the binding of refresh tokens and authorization codes to the client they were issued to. Client authentication adds an additional layer of security when an authorization code is transmitted to the redirection endpoint over an insecure channel.
- *Recovering from a compromised client by disabling the client or changing its credentials, thus preventing an attacker from abusing stolen refresh tokens. Changing a single set of client credentials is significantly faster than revoking an entire set of refresh tokens.
- *Implementing authentication management best practices, which require periodic credential rotation. Rotation of an entire set of refresh tokens can be challenging, while rotation of a single set of client credentials is significantly easier.

3.2.2. Token Request

The client makes a request to the token endpoint by sending the following parameters using the application/x-www-form-urlencoded format per Appendix B with a character encoding of UTF-8 in the HTTP request payload:

"client_id": REQUIRED, if the client is not authenticating with the authorization server as described in [Section 3.2.1](#).

"scope": OPTIONAL. The scope of the access request as described by [Section 3.2.2.1](#).

"grant_type": REQUIRED. Identifier of the grant type the client uses with the particular token request. This specification defines the values `authorization_code`, `refresh_token`, and `client_credentials`. The grant type determines the further parameters required or supported by the token request. The details of those grant types are defined below.

Confidential or credentialed clients MUST authenticate with the authorization server as described in [Section 3.2.1](#).

For example, the client makes the following HTTP request using TLS (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Authorization: Basic czZCaGRSa3F0MzpnWDFmQmF0M2JW
Content-Type: application/x-www-form-urlencoded

grant_type=authorization_code&code=Splxl0BeZQQYbYS6WxSbIA
&redirect_uri=https%3A%2F%2Fclient%2Eexample%2Ecom%2Fcb
&code_verifier=3641a2d12d66101249cdf7a79c000c1f8c05d2aafc14bf146497bed
```

The authorization server MUST:

- *require client authentication for confidential and credentialed clients (or clients with other authentication requirements),

- *authenticate the client if client authentication is included

Further grant type specific processing rules apply and are specified with the respective grant type.

3.2.2.1. Access Token Scope

The authorization and token endpoints allow the client to specify the scope of the access request using the `scope` request parameter.

In turn, the authorization server uses the scope response parameter to inform the client of the scope of the access token issued.

The value of the scope parameter is expressed as a list of space-delimited, case-sensitive strings. The strings are defined by the authorization server. If the value contains multiple space-delimited strings, their order does not matter, and each string adds an additional access range to the requested scope.

```
scope          = scope-token *( SP scope-token )
scope-token    = 1*( %x21 / %x23-5B / %x5D-7E )
```

The authorization server MAY fully or partially ignore the scope requested by the client, based on the authorization server policy or the resource owner's instructions. If the issued access token scope is different from the one requested by the client, the authorization server MUST include the scope response parameter to inform the client of the actual scope granted.

If the client omits the scope parameter when requesting authorization, the authorization server MUST either process the request using a pre-defined default value or fail the request indicating an invalid scope. The authorization server SHOULD document its scope requirements and default value (if defined).

3.2.3. Token Response

If the access token request is valid and authorized, the authorization server issues an access token and optional refresh token.

If the request client authentication failed or is invalid, the authorization server returns an error response as described in [Section 3.2.3.1](#).

The authorization server issues an access token and optional refresh token by creating an HTTP response body using the application/json media type as defined by [[RFC8259](#)] with the following parameters and an HTTP 200 (OK) status code:

"access_token": REQUIRED. The access token issued by the authorization server.

"token_type": REQUIRED. The type of the access token issued as described in [Section 5.1](#). Value is case insensitive.

"expires_in": RECOMMENDED. The lifetime in seconds of the access token. For example, the value 3600 denotes that the access token will expire in one hour from the time the response was generated.

If omitted, the authorization server SHOULD provide the expiration time via other means or document the default value.

"scope": RECOMMENDED, if identical to the scope requested by the client; otherwise, REQUIRED. The scope of the access token as described by [Section 3.2.2.1](#).

"refresh_token": OPTIONAL. The refresh token, which can be used to obtain new access tokens based on the grant passed in the corresponding token request.

Authorization servers SHOULD determine, based on a risk assessment and their own policies, whether to issue refresh tokens to a certain client. If the authorization server decides not to issue refresh tokens, the client MAY obtain new access tokens by starting the OAuth flow over, for example initiating a new authorization code request. In such a case, the authorization server may utilize cookies and persistent grants to optimize the user experience.

If refresh tokens are issued, those refresh tokens MUST be bound to the scope and resource servers as consented by the resource owner. This is to prevent privilege escalation by the legitimate client and reduce the impact of refresh token leakage.

The parameters are serialized into a JavaScript Object Notation (JSON) structure by adding each parameter at the highest structure level. Parameter names and string values are included as JSON strings. Numerical values are included as JSON numbers. The order of parameters does not matter and can vary.

The authorization server MUST include the HTTP Cache-Control response header field [[RFC7234](#)] with a value of no-store in any response containing tokens, credentials, or other sensitive information.

For example:

```
HTTP/1.1 200 OK
Content-Type: application/json
Cache-Control: no-store

{
  "access_token": "2YotnFZFEjr1zCsicMWpAA",
  "token_type": "Bearer",
  "expires_in": 3600,
  "refresh_token": "tGzv3J0kF0XG5Qx2TlKWIA",
  "example_parameter": "example_value"
}
```


The client MUST ignore unrecognized value names in the response. The sizes of tokens and other values received from the authorization server are left undefined. The client should avoid making assumptions about value sizes. The authorization server SHOULD document the size of any value it issues.

3.2.3.1. Error Response

The authorization server responds with an HTTP 400 (Bad Request) status code (unless specified otherwise) and includes the following parameters with the response:

"error": REQUIRED. A single ASCII [[USASCII](#)] error code from the following:

"invalid_request": The request is missing a required parameter, includes an unsupported parameter value (other than grant type), repeats a parameter, includes multiple credentials, utilizes more than one mechanism for authenticating the client, contains a code_verifier although no code_challenge was sent in the authorization request, or is otherwise malformed.

"invalid_client": Client authentication failed (e.g., unknown client, no client authentication included, or unsupported authentication method). The authorization server MAY return an HTTP 401 (Unauthorized) status code to indicate which HTTP authentication schemes are supported. If the client attempted to authenticate via the Authorization request header field, the authorization server MUST respond with an HTTP 401 (Unauthorized) status code and include the WWW-Authenticate response header field matching the authentication scheme used by the client.

"invalid_grant": The provided authorization grant (e.g., authorization code, resource owner credentials) or refresh token is invalid, expired, revoked, does not match the redirect URI used in the authorization request, or was issued to another client.

"unauthorized_client": The authenticated client is not authorized to use this authorization grant type.

"unsupported_grant_type": The authorization grant type is not supported by the authorization server.

"invalid_scope": The requested scope is invalid, unknown, malformed, or exceeds the scope granted by the resource owner.

Values for the error parameter MUST NOT include characters outside the set %x20-21 / %x23-5B / %x5D-7E.

"error_description": OPTIONAL. Human-readable ASCII [[USASCII](#)] text providing additional information, used to assist the client developer in understanding the error that occurred. Values for the error_description parameter MUST NOT include characters outside the set %x20-21 / %x23-5B / %x5D-7E.

"error_uri": OPTIONAL. A URI identifying a human-readable web page with information about the error, used to provide the client developer with additional information about the error. Values for the error_uri parameter MUST conform to the URI-reference syntax and thus MUST NOT include characters outside the set %x21 / %x23-5B / %x5D-7E.

The parameters are included in the payload of the HTTP response using the application/json media type as defined by [[RFC7159](#)]. The parameters are serialized into a JSON structure by adding each parameter at the highest structure level. Parameter names and string values are included as JSON strings. Numerical values are included as JSON numbers. The order of parameters does not matter and can vary.

For example:

```
HTTP/1.1 400 Bad Request
Content-Type: application/json
Cache-Control: no-store
```

```
{
  "error": "invalid_request"
}
```

4. Grant Types

To request an access token, the client obtains authorization from the resource owner. This specification defines the following authorization grant types:

- *authorization code
- *client credentials, and
- *refresh token

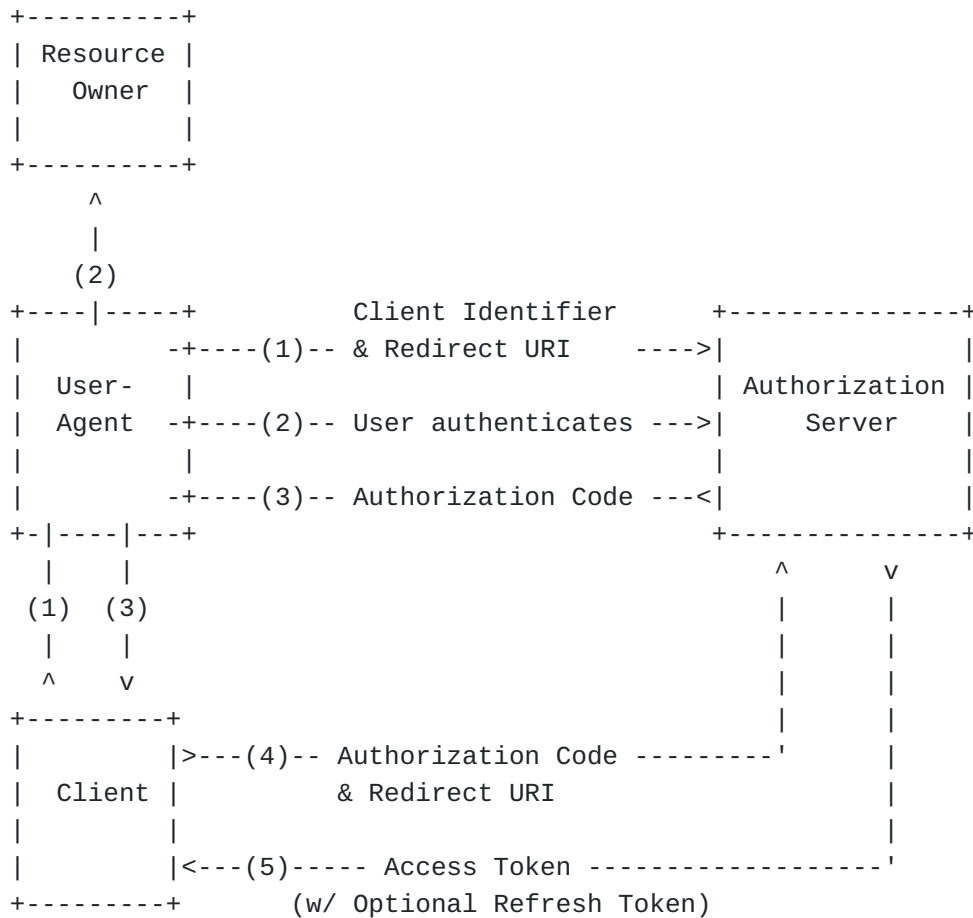
It also provides an extension mechanism for defining additional grant types.

4.1. Authorization Code Grant

The authorization code grant type is used to obtain both access tokens and refresh tokens.

The grant type uses the additional authorization endpoint to let the authorization server interact with the resource owner in order to get consent for resource access.

Since this is a redirect-based flow, the client must be capable of initiating the flow with the resource owner's user agent (typically a web browser) and capable of being redirected back to from the authorization server.



Note: The lines illustrating steps (1), (2), and (3) are broken into two parts as they pass through the user agent.

Figure 3: Authorization Code Flow

The flow illustrated in [Figure 3](#) includes the following steps:

(1) The client initiates the flow by directing the resource owner's user agent to the authorization endpoint. The client includes its

client identifier, code challenge (derived from a generated code verifier), optional requested scope, optional local state, and a redirect URI to which the authorization server will send the user agent back once access is granted (or denied).

(2) The authorization server authenticates the resource owner (via the user agent) and establishes whether the resource owner grants or denies the client's access request.

(3) Assuming the resource owner grants access, the authorization server redirects the user agent back to the client using the redirect URI provided earlier (in the request or during client registration). The redirect URI includes an authorization code and any local state provided by the client earlier.

(4) The client requests an access token from the authorization server's token endpoint by including the authorization code received in the previous step, and including its code verifier. When making the request, the client authenticates with the authorization server if it can. The client includes the redirect URI used to obtain the authorization code for verification.

(5) The authorization server authenticates the client when possible, validates the authorization code, validates the code verifier, and ensures that the redirect URI received matches the URI used to redirect the client in step (3). If valid, the authorization server responds back with an access token and, optionally, a refresh token.

4.1.1. Authorization Request

To begin the authorization request, the client builds the authorization request URI by adding parameters to the authorization server's authorization endpoint URI. The client will eventually redirect the user agent to this URI to initiate the request.

Clients use a unique secret per authorization request to protect against authorization code injection and CSRF attacks. The client first generates this secret, which it can use at the time of redeeming the authorization code to prove that the client using the authorization code is the same client that requested it.

The client constructs the request URI by adding the following parameters to the query component of the authorization endpoint URI using the application/x-www-form-urlencoded format, per Appendix B:

"response_type": REQUIRED. The authorization endpoint supports different sets of request and response parameters. The client determines the type of flow by using a certain response_type value. This specification defines the value code, which must be

used to signal that the client wants to use the authorization code flow.

Extension response types MAY contain a space-delimited (%x20) list of values, where the order of values does not matter (e.g., response type a b is the same as b a). The meaning of such composite response types is defined by their respective specifications.

Some extension response types are defined by ([\[OpenID\]](#)).

If an authorization request is missing the response_type parameter, or if the response type is not understood, the authorization server MUST return an error response as described in [Section 4.1.2.1](#).

"client_id": REQUIRED. The client identifier as described in [Section 2.2](#).

"code_challenge": REQUIRED or RECOMMENDED (see [Section 7.8](#)). Code challenge.

"code_challenge_method": OPTIONAL, defaults to plain if not present in the request. Code verifier transformation method is S256 or plain.

"redirect_uri": OPTIONAL. As described in [Section 2.3](#).

"scope": OPTIONAL. The scope of the access request as described by [Section 3.2.2.1](#).

"state": OPTIONAL. An opaque value used by the client to maintain state between the request and callback. The authorization server includes this value when redirecting the user agent back to the client.

The code_verifier is a unique high-entropy cryptographically random string generated for each authorization request, using the unreserved characters [A-Z] / [a-z] / [0-9] / "-" / "." / "_" / "~", with a minimum length of 43 characters and a maximum length of 128 characters.

The client stores the code_verifier temporarily, and calculates the code_challenge which it uses in the authorization request.

ABNF for code_verifier is as follows.

```
code-verifier = 43*128unreserved
unreserved = ALPHA / DIGIT / "-" / "." / "_" / "~"
ALPHA = %x41-5A / %x61-7A
DIGIT = %x30-39
```

NOTE: The code verifier SHOULD have enough entropy to make it impractical to guess the value. It is RECOMMENDED that the output of a suitable random number generator be used to create a 32-octet sequence. The octet sequence is then base64url-encoded to produce a 43-octet URL-safe string to use as the code verifier.

The client then creates a code_challenge derived from the code verifier by using one of the following transformations on the code verifier:

S256

```
code_challenge = BASE64URL-ENCODE(SHA256(ASCII(code_verifier)))
```

plain

```
code_challenge = code_verifier
```

If the client is capable of using S256, it MUST use S256, as S256 is Mandatory To Implement (MTI) on the server. Clients are permitted to use plain only if they cannot support S256 for some technical reason, for example constrained environments that do not have a hashing function available, and know via out-of-band configuration or via Authorization Server Metadata ([\[RFC8414\]](#)) that the server supports plain.

ABNF for code_challenge is as follows.

```
code-challenge = 43*128unreserved
unreserved = ALPHA / DIGIT / "-" / "." / "_" / "~"
ALPHA = %x41-5A / %x61-7A
DIGIT = %x30-39
```

The properties code_challenge and code_verifier are adopted from the OAuth 2.0 extension known as "Proof-Key for Code Exchange", or PKCE ([\[RFC7636\]](#)) where this technique was originally developed.

Clients MUST use code_challenge and code_verifier and authorization servers MUST enforce their use except under the conditions described in [Section 7.8](#). In this case, using and enforcing code_challenge and code_verifier as described in the following is still RECOMMENDED.

The client directs the resource owner to the constructed URI using an HTTP redirection, or by other means available to it via the user agent.

For example, the client directs the user agent to make the following HTTP request using TLS (with extra line breaks for display purposes only):

```
GET /authorize?response_type=code&client_id=s6BhdRkqt3&state=xyz
&redirect_uri=https%3A%2F%2Fclient%2Eexample%2Ecom%2Fcb
&code_challenge=6fdkQaPm51l13DSukcAH3Mdx7_ntechYd1vi3n0hMZY
&code_challenge_method=S256 HTTP/1.1
Host: server.example.com
```

The authorization server validates the request to ensure that all required parameters are present and valid.

In particular, the authorization server MUST validate the `redirect_uri` in the request if present, ensuring that it matches one of the registered redirect URIs previously established during client registration ([Section 2](#)). When comparing the two URIs the authorization server MUST use simple character-by-character string comparison as defined in [[RFC3986](#)], Section 6.2.1.

If the request is valid, the authorization server authenticates the resource owner and obtains an authorization decision (by asking the resource owner or by establishing approval via other means).

When a decision is established, the authorization server directs the user agent to the provided client redirect URI using an HTTP redirection response, or by other means available to it via the user agent.

4.1.2. Authorization Response

If the resource owner grants the access request, the authorization server issues an authorization code and delivers it to the client by adding the following parameters to the query component of the redirect URI using the `application/x-www-form-urlencoded` format, per Appendix B:

"code": REQUIRED. The authorization code generated by the authorization server and is opaque to the client. The authorization code MUST expire shortly after it is issued to mitigate the risk of leaks. A maximum authorization code lifetime of 10 minutes is RECOMMENDED. The client MUST NOT use the authorization code more than once. If an authorization code is used more than once, the authorization server MUST deny the request and SHOULD revoke (when possible) all access tokens and refresh tokens previously issued based on that authorization code. The authorization code is bound to the client identifier, code challenge and redirect URI.

"state": REQUIRED if the state parameter was present in the client authorization request. The exact value received from the client.

For example, the authorization server redirects the user agent by sending the following HTTP response:

HTTP/1.1 302 Found

Location: <https://client.example.com/cb?code=Sp1xl0BeZQQYbYS6WxSbIA&state=xyz>

The client MUST ignore unrecognized response parameters. The authorization code string size is left undefined by this specification. The client should avoid making assumptions about code value sizes. The authorization server SHOULD document the size of any value it issues.

The authorization server MUST associate the `code_challenge` and `code_challenge_method` values with the issued authorization code so the code challenge can be verified later.

The exact method that the server uses to associate the `code_challenge` with the issued code is out of scope for this specification. The code challenge could be stored on the server and associated with the code there. The `code_challenge` and `code_challenge_method` values may be stored in encrypted form in the code itself, but the server MUST NOT include the `code_challenge` value in a response parameter in a form that entities other than the AS can extract.

4.1.2.1. Error Response

If the request fails due to a missing, invalid, or mismatching redirect URI, or if the client identifier is missing or invalid, the authorization server SHOULD inform the resource owner of the error and MUST NOT automatically redirect the user agent to the invalid redirect URI.

An AS MUST reject requests without a `code_challenge` from public clients, and MUST reject such requests from other clients unless there is reasonable assurance that the client mitigates authorization code injection in other ways. See [Section 7.8](#) for details.

If the server does not support the requested `code_challenge_method` transformation, the authorization endpoint MUST return the authorization error response with error value set to `invalid_request`. The `error_description` or the response of `error_uri` SHOULD explain the nature of error, e.g., transform algorithm not supported.

If the resource owner denies the access request or if the request fails for reasons other than a missing or invalid redirect URI, the authorization server informs the client by adding the following parameters to the query component of the redirect URI using the application/x-www-form-urlencoded format, per Appendix B:

"error":

REQUIRED. A single ASCII [[USASCII](#)] error code from the following:

"invalid_request": The request is missing a required parameter, includes an invalid parameter value, includes a parameter more than once, or is otherwise malformed.

"unauthorized_client": The client is not authorized to request an authorization code using this method.

"access_denied": The resource owner or authorization server denied the request.

"unsupported_response_type": The authorization server does not support obtaining an authorization code using this method.

"invalid_scope": The requested scope is invalid, unknown, or malformed.

"server_error": The authorization server encountered an unexpected condition that prevented it from fulfilling the request. (This error code is needed because a 500 Internal Server Error HTTP status code cannot be returned to the client via an HTTP redirect.)

"temporarily_unavailable": The authorization server is currently unable to handle the request due to a temporary overloading or maintenance of the server. (This error code is needed because a 503 Service Unavailable HTTP status code cannot be returned to the client via an HTTP redirect.)

Values for the error parameter MUST NOT include characters outside the set %x20-21 / %x23-5B / %x5D-7E.

"error_description": OPTIONAL. Human-readable ASCII [[USASCII](#)] text providing additional information, used to assist the client developer in understanding the error that occurred. Values for the error_description parameter MUST NOT include characters outside the set %x20-21 / %x23-5B / %x5D-7E.

"error_uri": OPTIONAL. A URI identifying a human-readable web page with information about the error, used to provide the client developer with additional information about the error. Values for the error_uri parameter MUST conform to the URI-reference syntax and thus MUST NOT include characters outside the set %x21 / %x23-5B / %x5D-7E.

"state": REQUIRED if a state parameter was present in the client authorization request. The exact value received from the client.

For example, the authorization server redirects the user agent by sending the following HTTP response:

```
HTTP/1.1 302 Found
Location: https://client.example.com/cb?error=access_denied&state=xyz
```

4.1.3. Token Endpoint Extension

The authorization grant type is identified at the token endpoint with the `grant_type` value of `authorization_code`.

If this value is set, the following additional token request parameters beyond [Section 3.2.2](#) are required:

"code": REQUIRED. The authorization code received from the authorization server.

"redirect_uri": REQUIRED, if the `redirect_uri` parameter was included in the authorization request as described in [Section 4.1.1](#), and their values MUST be identical.

"code_verifier": REQUIRED, if the `code_challenge` parameter was included in the authorization request. MUST NOT be used otherwise. The original code verifier string.

For example, the client makes the following HTTP request using TLS (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Authorization: Basic czZCaGRSa3F0MzpnWDFmQmF0M2JW
Content-Type: application/x-www-form-urlencoded

grant_type=authorization_code&code=Splxl0BeZQQYbYS6WxSbIA
&redirect_uri=https%3A%2F%2Fclient%2Eexample%2Ecom%2Fcb
&code_verifier=3641a2d12d66101249cdf7a79c000c1f8c05d2aafc14bf146497bed
```

In addition to the processing rules in [Section 3.2.2](#), the authorization server MUST:

- *ensure that the authorization code was issued to the authenticated confidential or credentialed client, or if the client is public, ensure that the code was issued to `client_id` in the request,
- *verify that the authorization code is valid,
- *verify that the `code_verifier` parameter is present if and only if a `code_challenge` parameter was present in the authorization request,

*if a code_verifier is present, verify the code_verifier by calculating the code challenge from the received code_verifier and comparing it with the previously associated code_challenge, after first transforming it according to the code_challenge_method method specified by the client, and

*ensure that the redirect_uri parameter is present if the redirect_uri parameter was included in the initial authorization request as described in [Section 4.1.1](#), and if included ensure that their values are identical.

4.2. Client Credentials Grant

The client can request an access token using only its client credentials (or other supported means of authentication) when the client is requesting access to the protected resources under its control, or those of another resource owner that have been previously arranged with the authorization server (the method of which is beyond the scope of this specification).

The client credentials grant type MUST only be used by confidential or credentialed clients.

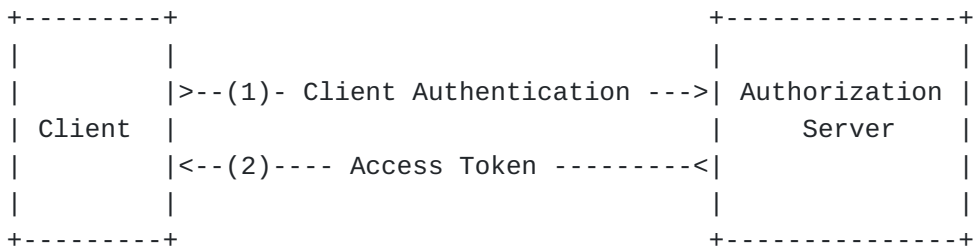


Figure 4: Client Credentials Grant

The use of the client credentials grant illustrated in [Figure 4](#) includes the following steps:

(1) The client authenticates with the authorization server and requests an access token from the token endpoint.

(2) The authorization server authenticates the client, and if valid, issues an access token.

4.2.1. Token Endpoint Extension

The authorization grant type is identified at the token endpoint with the grant_type value of client_credentials.

If this value is set, no additional parameters beyond [Section 3.2.2](#) are required/supported:

For example, the client makes the following HTTP request using transport-layer security (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Authorization: Basic czZCaGRSa3F0MzpnWDFmQmF0M2JW
Content-Type: application/x-www-form-urlencoded
```

```
grant_type=client_credentials
```

The authorization server MUST authenticate the client.

4.3. Refresh Token Grant

The refresh token is a credential issued by the authorization server to a client, which can be used to obtain new (fresh) access tokens based on an existing grant. The client uses this option either because the previous access token has expired or the client previously obtained an access token with a scope more narrow than approved by the respective grant and later requires an access token with a different scope under the same grant.

4.3.1. Token Endpoint Extension

The authorization grant type is identified at the token endpoint with the `grant_type` value of `refresh_token`.

If this value is set, the following additional parameters beyond [Section 3.2.2](#) are required/supported:

"refresh_token": REQUIRED. The refresh token issued to the client.

Because refresh tokens are typically long-lasting credentials used to request additional access tokens, the refresh token is bound to the client to which it was issued. Confidential or credentialed clients MUST authenticate with the authorization server as described in [Section 3.2.1](#).

For example, the client makes the following HTTP request using transport-layer security (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Authorization: Basic czZCaGRSa3F0MzpnWDFmQmF0M2JW
Content-Type: application/x-www-form-urlencoded
```

```
grant_type=refresh_token&refresh_token=tGzv3J0kF0XG5Qx2TlKWIA
```

In addition to the processing rules in [Section 3.2.2](#), the authorization server MUST:

- *validate the refresh token.

Authorization servers SHOULD utilize one of these methods to detect refresh token replay by malicious actors for public clients:

- **Sender-constrained refresh tokens*: the authorization server cryptographically binds the refresh token to a certain client instance by utilizing [[I-D.ietf-oauth-token-binding](#)], [[RFC8705](#)], [[I-D.ietf-oauth-dpop](#)], or another suitable method.

- **Refresh token rotation*: the authorization server issues a new refresh token with every access token refresh response. The previous refresh token is invalidated but information about the relationship is retained by the authorization server. If a refresh token is compromised and subsequently used by both the attacker and the legitimate client, one of them will present an invalidated refresh token, which will inform the authorization server of the breach. The authorization server cannot determine which party submitted the invalid refresh token, but it will revoke the active refresh token. This stops the attack at the cost of forcing the legitimate client to obtain a fresh authorization grant.

Implementation note: the grant to which a refresh token belongs may be encoded into the refresh token itself. This can enable an authorization server to efficiently determine the grant to which a refresh token belongs, and by extension, all refresh tokens that need to be revoked. Authorization servers MUST ensure the integrity of the refresh token value in this case, for example, using signatures.

4.3.2. Refresh Token Response

If valid and authorized, the authorization server issues an access token as described in [Section 3.2.3](#).

The authorization server MAY issue a new refresh token, in which case the client MUST discard the old refresh token and replace it with the new refresh token.

The authorization server MAY revoke the old refresh token after issuing a new refresh token to the client. If a new refresh token is issued, the refresh token scope MUST be identical to that of the refresh token included by the client in the request.

Authorization servers MAY revoke refresh tokens automatically in case of a security event, such as:

- *password change

- *logout at the authorization server

Refresh tokens SHOULD expire if the client has been inactive for some time, i.e., the refresh token has not been used to obtain new access tokens for some time. The expiration time is at the discretion of the authorization server. It might be a global value or determined based on the client policy or the grant associated with the refresh token (and its sensitivity).

4.4. Extension Grants

The client uses an extension grant type by specifying the grant type using an absolute URI (defined by the authorization server) as the value of the `grant_type` parameter of the token endpoint, and by adding any additional parameters necessary.

For example, to request an access token using the Device Authorization Grant as defined by [\[RFC8628\]](#) after the user has authorized the client on a separate device, the client makes the following HTTP request using TLS (with extra line breaks for display purposes only):

```
POST /token HTTP/1.1
Host: server.example.com
Content-Type: application/x-www-form-urlencoded
```

```
grant_type=urn%3Aietf%3Aparams%3Aoauth%3Agrant-type%3Adevice_code
&device_code=GmRhmhcXhwEzkoEqiMEg_DnyEysNkuNhszIySk9eS
&client_id=C409020731
```

If the access token request is valid and authorized, the authorization server issues an access token and optional refresh token as described in [Section 3.2.3](#). If the request failed client authentication or is invalid, the authorization server returns an error response as described in [Section 3.2.3.1](#).

5. Accessing Protected Resources

The client accesses protected resources by presenting the access token to the resource server. The resource server MUST validate the access token and ensure that it has not expired and that its scope covers the requested resource. The methods used by the resource server to validate the access token (as well as any error responses) are beyond the scope of this specification, but generally involve an interaction or coordination between the resource server and the

authorization server. For example, when the resource server and authorization server are colocated or are part of the same system, they may share a database or other storage; when the two components are operated independently, they may use Token Introspection [[RFC7662](#)] or a structured access token format such as a JWT [[I-D.ietf-oauth-access-token-jwt](#)].

The method in which the client utilizes the access token to access protected resources at the resource server depends on the type of access token issued by the authorization server. Typically, it involves using the HTTP Authorization request header field [[RFC7235](#)] with an authentication scheme defined by the specification of the access token type used, such as Bearer, defined below.

5.1. Access Token Types

The access token type provides the client with the information required to successfully utilize the access token to make a protected resource request (along with type-specific attributes). The client MUST NOT use an access token if it does not understand the token type.

For example, the Bearer token type defined in this specification is utilized by simply including the access token string in the request:

```
GET /resource/1 HTTP/1.1
Host: example.com
Authorization: Bearer mF_9.B5f-4.1JqM
```

The above example is provided for illustration purposes only.

Each access token type definition specifies the additional attributes (if any) sent to the client together with the `access_token` response parameter. It also defines the HTTP authentication method used to include the access token when making a protected resource request.

5.2. Bearer Tokens

A Bearer Token is a security token with the property that any party in possession of the token (a "bearer") can use the token in any way that any other party in possession of it can. Using a bearer token does not require a bearer to prove possession of cryptographic key material (proof-of-possession).

Bearer tokens may be enhanced with proof-of-possession specifications such as mTLS [[RFC8705](#)] to provide proof-of-possession characteristics.

5.2.1. Authenticated Requests

This section defines two methods of sending Bearer tokens in resource requests to resource servers. Clients MUST use one of the two methods defined below, and MUST NOT use more than one method to transmit the token in each request.

In particular, clients MUST NOT send the access token in a URI query parameter, and resource servers MUST ignore access tokens in a URI query parameter.

5.2.1.1. Authorization Request Header Field

When sending the access token in the Authorization request header field defined by HTTP/1.1 [RFC7235], the client uses the Bearer authentication scheme to transmit the access token.

For example:

```
GET /resource HTTP/1.1
Host: server.example.com
Authorization: Bearer mF_9.B5f-4.1JqM
```

The syntax of the Authorization header field for this scheme follows the usage of the Basic scheme defined in Section 2 of [RFC2617]. Note that, as with Basic, it does not conform to the generic syntax defined in Section 1.2 of [RFC2617] but is compatible with the general authentication framework in HTTP 1.1 Authentication [RFC7235], although it does not follow the preferred practice outlined therein in order to reflect existing deployments. The syntax for Bearer credentials is as follows:

```
b64token    = 1*( ALPHA / DIGIT /
                "-" / "." / "_" / "~" / "+" / "/" ) *"="
credentials = "Bearer" 1*SP b64token
```

Clients SHOULD make authenticated requests with a bearer token using the Authorization request header field with the Bearer HTTP authorization scheme. Resource servers MUST support this method.

5.2.1.2. Form-Encoded Body Parameter

When sending the access token in the HTTP request payload, the client adds the access token to the request-body using the access_token parameter. The client MUST NOT use this method unless all of the following conditions are met:

*The HTTP request entity-header includes the Content-Type header field set to application/x-www-form-urlencoded.

*The payload follows the encoding requirements of the application/x-www-form-urlencoded content-type as defined by HTML 4.01 [[W3C.REC-html401-19991224](#)].

*The HTTP request payload is single-part.

*The content to be encoded in the payload MUST consist entirely of ASCII [[USASCII](#)] characters.

*The HTTP request method is one for which the request-body has defined semantics. In particular, this means that the GET method MUST NOT be used.

The payload MAY include other request-specific parameters, in which case the access_token parameter MUST be properly separated from the request-specific parameters using & character(s) (ASCII code 38).

For example, the client makes the following HTTP request using transport-layer security:

```
POST /resource HTTP/1.1
Host: server.example.com
Content-Type: application/x-www-form-urlencoded

access_token=mF_9.B5f-4.1JqM
```

The application/x-www-form-urlencoded method SHOULD NOT be used except in application contexts where participating clients do not have access to the Authorization request header field. Resource servers MAY support this method.

5.2.2. The WWW-Authenticate Response Header Field

If the protected resource request does not include authentication credentials or does not contain an access token that enables access to the protected resource, the resource server MUST include the HTTP WWW-Authenticate response header field; it MAY include it in response to other conditions as well. The WWW-Authenticate header field uses the framework defined by HTTP/1.1 [[RFC7235](#)].

All challenges for this token type MUST use the auth-scheme value Bearer. This scheme MUST be followed by one or more auth-param values. The auth-param attributes used or defined by this specification for this token type are as follows. Other auth-param attributes MAY be used as well.

A realm attribute MAY be included to indicate the scope of protection in the manner described in HTTP/1.1 [[RFC7235](#)]. The realm attribute MUST NOT appear more than once.

The scope attribute is defined in [Section 3.2.2.1](#). The scope attribute is a space-delimited list of case-sensitive scope values indicating the required scope of the access token for accessing the requested resource. scope values are implementation defined; there is no centralized registry for them; allowed values are defined by the authorization server. The order of scope values is not significant. In some cases, the scope value will be used when requesting a new access token with sufficient scope of access to utilize the protected resource. Use of the scope attribute is OPTIONAL. The scope attribute MUST NOT appear more than once. The scope value is intended for programmatic use and is not meant to be displayed to end-users.

Two example scope values follow; these are taken from the OpenID Connect [[OpenID.Messages](#)] and the Open Authentication Technology Committee (OATC) Online Multimedia Authorization Protocol [[OMAP](#)] OAuth 2.0 use cases, respectively:

```
scope="openid profile email"  
scope="urn:example:channel=HB0&urn:example:rating=G,PG-13"
```

If the protected resource request included an access token and failed authentication, the resource server SHOULD include the error attribute to provide the client with the reason why the access request was declined. The parameter value is described in [Section 5.2.3](#). In addition, the resource server MAY include the error_description attribute to provide developers a human-readable explanation that is not meant to be displayed to end-users. It also MAY include the error_uri attribute with an absolute URI identifying a human-readable web page explaining the error. The error, error_description, and error_uri attributes MUST NOT appear more than once.

Values for the scope attribute (specified in Appendix A.4) MUST NOT include characters outside the set %x21 / %x23-5B / %x5D-7E for representing scope values and %x20 for delimiters between scope values. Values for the error and error_description attributes (specified in Appendixes A.7 and A.8) MUST NOT include characters outside the set %x20-21 / %x23-5B / %x5D-7E. Values for the error_uri attribute (specified in Appendix A.9 of) MUST conform to the URI-reference syntax and thus MUST NOT include characters outside the set %x21 / %x23-5B / %x5D-7E.

For example, in response to a protected resource request without authentication:

```
HTTP/1.1 401 Unauthorized  
WWW-Authenticate: Bearer realm="example"
```

And in response to a protected resource request with an authentication attempt using an expired access token:

```
HTTP/1.1 401 Unauthorized
WWW-Authenticate: Bearer realm="example",
                  error="invalid_token",
                  error_description="The access token expired"
```

5.2.3. Error Codes

When a request fails, the resource server responds using the appropriate HTTP status code (typically, 400, 401, 403, or 405) and includes one of the following error codes in the response:

"invalid_request": The request is missing a required parameter, includes an unsupported parameter or parameter value, repeats the same parameter, uses more than one method for including an access token, or is otherwise malformed. The resource server SHOULD respond with the HTTP 400 (Bad Request) status code.

"invalid_token": The access token provided is expired, revoked, malformed, or invalid for other reasons. The resource SHOULD respond with the HTTP 401 (Unauthorized) status code. The client MAY request a new access token and retry the protected resource request.

"insufficient_scope": The request requires higher privileges (scopes) than provided by the scopes granted to the client and represented by the access token.

The resource server SHOULD respond with the HTTP 403 (Forbidden) status code and MAY include the scope attribute with the scope necessary to access the protected resource.

If the request lacks any authentication information (e.g., the client was unaware that authentication is necessary or attempted using an unsupported authentication method), the resource server SHOULD NOT include an error code or other error information.

For example:

```
HTTP/1.1 401 Unauthorized
WWW-Authenticate: Bearer realm="example"
```

5.3. Error Response

If a resource access request fails, the resource server SHOULD inform the client of the error. The method by which the resource server does this is determined by the particular token type, such as the description of Bearer tokens in [Section 5.2.3](#).

5.3.1. Extension Token Types

[RFC6750] establishes a common registry in [Section 11.4](#) for error values to be shared among OAuth token authentication schemes.

New authentication schemes designed primarily for OAuth token authentication SHOULD define a mechanism for providing an error status code to the client, in which the error values allowed are registered in the error registry established by this specification.

Such schemes MAY limit the set of valid error codes to a subset of the registered values. If the error code is returned using a named parameter, the parameter name SHOULD be error.

Other schemes capable of being used for OAuth token authentication, but not primarily designed for that purpose, MAY bind their error values to the registry in the same manner.

New authentication schemes MAY choose to also specify the use of the error_description and error_uri parameters to return error information in a manner parallel to their usage in this specification.

6. Extensibility

6.1. Defining Access Token Types

Access token types can be defined in one of two ways: registered in the Access Token Types registry (following the procedures in Section 11.1 of [RFC6749]), or by using a unique absolute URI as its name.

Types utilizing a URI name SHOULD be limited to vendor-specific implementations that are not commonly applicable, and are specific to the implementation details of the resource server where they are used.

All other types MUST be registered. Type names MUST conform to the type-name ABNF. If the type definition includes a new HTTP authentication scheme, the type name SHOULD be identical to the HTTP authentication scheme name (as defined by [RFC2617]). The token type example is reserved for use in examples.

```
type-name = 1*name-char
name-char = "-" / "." / "_" / DIGIT / ALPHA
```

6.2. Defining New Endpoint Parameters

New request or response parameters for use with the authorization endpoint or the token endpoint are defined and registered in the

OAuth Parameters registry following the procedure in Section 11.2 of [\[RFC6749\]](#).

Parameter names MUST conform to the param-name ABNF, and parameter values syntax MUST be well-defined (e.g., using ABNF, or a reference to the syntax of an existing parameter).

```
param-name = 1*name-char
name-char  = "-" / "." / "_" / DIGIT / ALPHA
```

Unregistered vendor-specific parameter extensions that are not commonly applicable and that are specific to the implementation details of the authorization server where they are used SHOULD utilize a vendor-specific prefix that is not likely to conflict with other registered values (e.g., begin with 'companyname_').

6.3. Defining New Authorization Grant Types

New authorization grant types can be defined by assigning them a unique absolute URI for use with the grant_type parameter. If the extension grant type requires additional token endpoint parameters, they MUST be registered in the OAuth Parameters registry as described by Section 11.2 of [\[RFC6749\]](#).

6.4. Defining New Authorization Endpoint Response Types

New response types for use with the authorization endpoint are defined and registered in the Authorization Endpoint Response Types registry following the procedure in Section 11.3 of [\[RFC6749\]](#). Response type names MUST conform to the response-type ABNF.

```
response-type = response-name *( SP response-name )
response-name = 1*response-char
response-char = "_" / DIGIT / ALPHA
```

If a response type contains one or more space characters (%x20), it is compared as a space-delimited list of values in which the order of values does not matter. Only one order of values can be registered, which covers all other arrangements of the same set of values.

For example, an extension can define and register the code other_token response type. Once registered, the same combination cannot be registered as other_token code, but both values can be used to denote the same response type.

6.5. Defining Additional Error Codes

In cases where protocol extensions (i.e., access token types, extension parameters, or extension grant types) require additional

error codes to be used with the authorization code grant error response ([Section 4.1.2.1](#)), the token error response ([Section 3.2.3.1](#)), or the resource access error response ([Section 5.3](#)), such error codes MAY be defined.

Extension error codes MUST be registered (following the procedures in Section 11.4 of [[RFC6749](#)]) if the extension they are used in conjunction with is a registered access token type, a registered endpoint parameter, or an extension grant type. Error codes used with unregistered extensions MAY be registered.

Error codes MUST conform to the error ABNF and SHOULD be prefixed by an identifying name when possible. For example, an error identifying an invalid value set to the extension parameter example SHOULD be named `example_invalid`.

```
error      = 1*error-char
error-char = %x20-21 / %x23-5B / %x5D-7E
```

7. Security Considerations

As a flexible and extensible framework, OAuth's security considerations depend on many factors. The following sections provide implementers with security guidelines focused on the three client profiles described in [Section 2.1](#): web application, browser-based application, and native application.

A comprehensive OAuth security model and analysis, as well as background for the protocol design, is provided by [[RFC6819](#)] and [[I-D.ietf-oauth-security-topics](#)].

7.1. Access Token Security Considerations

7.1.1. Security Threats

The following list presents several common threats against protocols utilizing some form of tokens. This list of threats is based on NIST Special Publication 800-63 [[NIST800-63](#)].

7.1.1.1. Access token manufacture/modification

An attacker may generate a bogus access token or modify the token contents (such as the authentication or attribute statements) of an existing token, causing the resource server to grant inappropriate access to the client. For example, an attacker may modify the token to extend the validity period; a malicious client may modify the assertion to gain access to information that they should not be able to view.

7.1.1.2. Access token disclosure

Access tokens may contain authentication and attribute statements that include sensitive information.

7.1.1.3. Access token redirect

An attacker uses an access token generated for consumption by one resource server to gain access to a different resource server that mistakenly believes the token to be for it.

7.1.1.4. Access token replay

An attacker attempts to use an access token that has already been used with that resource server in the past.

7.1.2. Threat Mitigation

A large range of threats can be mitigated by protecting the contents of the access token by using a digital signature.

Alternatively, a bearer token can contain a reference to authorization information, rather than encoding the information directly. Such references MUST be infeasible for an attacker to guess; using a reference may require an extra interaction between a server and the access token issuer to resolve the reference to the authorization information. The mechanics of such an interaction are not defined by this specification.

This document does not specify the encoding or the contents of the access token; hence, detailed recommendations about the means of guaranteeing access token integrity protection are outside the scope of this specification. The access token integrity protection MUST be sufficient to prevent the token from being modified. One example of an encoding and signing mechanism for access tokens is described in [[I-D.ietf-oauth-access-token-jwt](#)].

To deal with access token redirects, it is important for the authorization server to include the identity of the intended recipients (the audience), typically a single resource server (or a list of resource servers), in the token. Restricting the use of the token to a specific scope is also RECOMMENDED.

The authorization server MUST implement TLS as described in which version(s) ought to be implemented will vary over time and will depend on the widespread deployment and known security vulnerabilities at the time of implementation. Refer to [Section 1.5](#). [[BCP195](#)] for up to date recommendations on transport layer security.

To protect against access token disclosure, confidentiality protection MUST be applied using TLS with a ciphersuite that provides confidentiality and integrity protection. This requires that the communication interaction between the client and the authorization server, as well as the interaction between the client and the resource server, utilize confidentiality and integrity protection. Since TLS is mandatory to implement and to use with this specification, it is the preferred approach for preventing token disclosure via the communication channel. For those cases where the client is prevented from observing the contents of the access token, token encryption MUST be applied in addition to the usage of TLS protection. As a further defense against token disclosure, the client MUST validate the TLS certificate chain when making requests to protected resources, including checking the Certificate Revocation List (CRL) [[RFC5280](#)].

If cookies are transmitted without TLS protection, any information contained in them is at risk of disclosure. Therefore, Bearer tokens MUST NOT be stored in cookies that can be sent in the clear, as any information in them is at risk of disclosure. See "HTTP State Management Mechanism" [[RFC6265](#)] for security considerations about cookies.

In some deployments, including those utilizing load balancers, the TLS connection to the resource server terminates prior to the actual server that provides the resource. This could leave the token unprotected between the front-end server where the TLS connection terminates and the back-end server that provides the resource. In such deployments, sufficient measures MUST be employed to ensure confidentiality of the access token between the front-end and back-end servers; encryption of the token is one such possible measure.

To deal with access token capture and replay, the following recommendations are made: First, the lifetime of the token MUST be limited; one means of achieving this is by putting a validity time field inside the protected part of the token. Note that using short-lived tokens reduces the impact of them being leaked. Second, confidentiality protection of the exchanges between the client and the authorization server and between the client and the resource server MUST be applied. As a consequence, no eavesdropper along the communication path is able to observe the token exchange. Consequently, such an on-path adversary cannot replay the token. Furthermore, when presenting the token to a resource server, the client MUST verify the identity of that resource server, as per [[BCP195](#)] and Section 3.1 of "HTTP Over TLS" [[RFC2818](#)]. Note that the client MUST validate the TLS certificate chain when making these requests to protected resources. Presenting the token to an unauthenticated and unauthorized resource server or failing to

validate the certificate chain will allow adversaries to steal the token and gain unauthorized access to protected resources.

7.1.3. Summary of Recommendations

7.1.3.1. Safeguard bearer tokens

Client implementations MUST ensure that bearer tokens are not leaked to unintended parties, as they will be able to use them to gain access to protected resources. This is the primary security consideration when using bearer tokens and underlies all the more specific recommendations that follow.

7.1.3.2. Validate TLS certificate chains

The client MUST validate the TLS certificate chain when making requests to protected resources. Failing to do so may enable DNS hijacking attacks to steal the token and gain unintended access.

7.1.3.3. Always use TLS (https)

Clients MUST always use TLS (https) or equivalent transport security when making requests with bearer tokens. Failing to do so exposes the token to numerous attacks that could give attackers unintended access.

7.1.3.4. Don't store bearer tokens in HTTP cookies

Implementations MUST NOT store bearer tokens within cookies that can be sent in the clear (which is the default transmission mode for cookies). Implementations that do store bearer tokens in cookies MUST take precautions against cross-site request forgery.

7.1.3.5. Issue short-lived bearer tokens

Authorization servers SHOULD issue short-lived bearer tokens, particularly when issuing tokens to clients that run within a web browser or other environments where information leakage may occur. Using short-lived bearer tokens can reduce the impact of them being leaked.

7.1.3.6. Issue scoped bearer tokens

Authorization servers SHOULD issue bearer tokens that contain an audience restriction, scoping their use to the intended relying party or set of relying parties.

7.1.3.7. Don't pass bearer tokens in page URLs

Bearer tokens MUST NOT be passed in page URLs (for example, as query string parameters). Instead, bearer tokens SHOULD be passed in HTTP message headers or message bodies for which confidentiality measures are taken. Browsers, web servers, and other software may not adequately secure URLs in the browser history, web server logs, and other data structures. If bearer tokens are passed in page URLs, attackers might be able to steal them from the history data, logs, or other unsecured locations.

7.1.4. Token Replay Prevention

A sender-constrained access token scopes the applicability of an access token to a certain sender. This sender is obliged to demonstrate knowledge of a certain secret as prerequisite for the acceptance of that access token at the recipient (e.g., a resource server).

Authorization and resource servers SHOULD use mechanisms for sender-constrained access tokens to prevent token replay as described in Section 4.8.1.1.2 of [[I-D.ietf-oauth-security-topics](#)]. The use of Mutual TLS for OAuth 2.0 [[RFC8705](#)] is RECOMMENDED.

It is RECOMMENDED to use end-to-end TLS. If TLS traffic needs to be terminated at an intermediary, refer to Section 4.11 of [[I-D.ietf-oauth-security-topics](#)] for further security advice.

7.1.5. Access Token Privilege Restriction

The privileges associated with an access token SHOULD be restricted to the minimum required for the particular application or use case. This prevents clients from exceeding the privileges authorized by the resource owner. It also prevents users from exceeding their privileges authorized by the respective security policy. Privilege restrictions also help to reduce the impact of access token leakage.

In particular, access tokens SHOULD be restricted to certain resource servers (audience restriction), preferably to a single resource server. To put this into effect, the authorization server associates the access token with certain resource servers and every resource server is obliged to verify, for every request, whether the access token sent with that request was meant to be used for that particular resource server. If not, the resource server MUST refuse to serve the respective request. Clients and authorization servers MAY utilize the parameters scope or resource as specified in this document and [[RFC8707](#)], respectively, to determine the resource server they want to access.

Additionally, access tokens SHOULD be restricted to certain resources and actions on resource servers or resources. To put this into effect, the authorization server associates the access token with the respective resource and actions and every resource server is obliged to verify, for every request, whether the access token sent with that request was meant to be used for that particular action on the particular resource. If not, the resource server must refuse to serve the respective request. Clients and authorization servers MAY utilize the parameter `scope` and `authorization_details` as specified in [[I-D.ietf-oauth-rar](#)] to determine those resources and/or actions.

7.2. Client Authentication

The authorization server MUST only rely on client authentication if the process of issuance/registration and distribution of the underlying credentials ensures their confidentiality.

When client authentication is not possible, the authorization server SHOULD employ other means to validate the client's identity - for example, by requiring the registration of the client redirect URI or enlisting the resource owner to confirm identity. A valid redirect URI is not sufficient to verify the client's identity when asking for resource owner authorization but can be used to prevent delivering credentials to a counterfeit client after obtaining resource owner authorization.

The authorization server must consider the security implications of interacting with unauthenticated clients and take measures to limit the potential exposure of other credentials (e.g., refresh tokens) issued to such clients.

The privileges an authorization server associates with a certain client identity MUST depend on the assessment of the overall process for client identification and client credential lifecycle management. For example, authentication of a dynamically registered client just ensures the authorization server it is talking to the same client again. In contrast, if there is a web application whose developer's identity was verified, who signed a contract and is issued a client secret that is only used in a secure backend service, the authorization server might allow this client to access more sensitive services or to use the client credentials grant type.

7.2.1. Client Authentication of Native Apps

Secrets that are statically included as part of an app distributed to multiple users should not be treated as confidential secrets, as one user may inspect their copy and learn the shared secret. For this reason, it is NOT RECOMMENDED for authorization servers to

require client authentication of public native apps clients using a shared secret, as this serves little value beyond client identification which is already provided by the `client_id` request parameter.

Authorization servers that still require a statically included shared secret for native app clients MUST treat the client as a public client (as defined in [Section 2.1](#)), and not accept the secret as proof of the client's identity. Without additional measures, such clients are subject to client impersonation (see [Section 7.4.1](#)).

7.3. Registration of Native App Clients

Except when using a mechanism like Dynamic Client Registration [[RFC7591](#)] to provision per-instance secrets, native apps are classified as public clients, as defined in [Section 2.1](#); they MUST be registered with the authorization server as such. Authorization servers MUST record the client type in the client registration details in order to identify and process requests accordingly.

Authorization servers MAY request the inclusion of other platform-specific information, such as the app package or bundle name, or other information that may be useful for verifying the calling app's identity on operating systems that support such functions.

For private-use URI scheme-based redirect URIs, authorization servers SHOULD require that the URI scheme be based on a domain name that is under the control of the app. In addition to the collision-resistant properties, this can help to prove ownership in the event of a dispute where two apps claim the same private-use URI scheme (where one app is acting maliciously). For example, if two apps claimed `com.example.app`, the owner of `example.com` could petition the app store operator to remove the counterfeit app. Such a petition is harder to prove if a generic URI scheme was used.

7.4. Client Impersonation

A malicious client can impersonate another client and obtain access to protected resources if the impersonated client fails to, or is unable to, keep its client credentials confidential.

The authorization server SHOULD enforce explicit resource owner authentication and provide the resource owner with information about the client and the requested authorization scope and lifetime. It is up to the resource owner to review the information in the context of the current client and to authorize or deny the request.

The authorization server SHOULD NOT process repeated authorization requests automatically (without active resource owner interaction) without authenticating the client or relying on other measures to

ensure that the repeated request comes from the original client and not an impersonator.

7.4.1. Impersonation of Native Apps

As stated above, the authorization server SHOULD NOT process authorization requests automatically without user consent or interaction, except when the identity of the client can be assured. This includes the case where the user has previously approved an authorization request for a given client ID - unless the identity of the client can be proven, the request SHOULD be processed as if no previous request had been approved.

Measures such as claimed https scheme redirects MAY be accepted by authorization servers as identity proof. Some operating systems may offer alternative platform-specific identity features that MAY be accepted, as appropriate.

7.4.2. Access Token Privilege Restriction

The client SHOULD request access tokens with the minimal scope necessary. The authorization server SHOULD take the client identity into account when choosing how to honor the requested scope and MAY issue an access token with less rights than requested.

The privileges associated with an access token SHOULD be restricted to the minimum required for the particular application or use case. This prevents clients from exceeding the privileges authorized by the resource owner. It also prevents users from exceeding their privileges authorized by the respective security policy. Privilege restrictions also help to reduce the impact of access token leakage.

In particular, access tokens SHOULD be restricted to certain resource servers (audience restriction), preferably to a single resource server. To put this into effect, the authorization server associates the access token with certain resource servers and every resource server is obliged to verify, for every request, whether the access token sent with that request was meant to be used for that particular resource server. If not, the resource server MUST refuse to serve the respective request. Clients and authorization servers MAY utilize the parameters `scope` or `resource` as specified in [\[RFC8707\]](#), respectively, to determine the resource server they want to access.

7.4.3. Access Token Replay Prevention

Additionally, access tokens SHOULD be restricted to certain resources and actions on resource servers or resources. To put this into effect, the authorization server associates the access token with the respective resource and actions and every resource server

is obliged to verify, for every request, whether the access token sent with that request was meant to be used for that particular action on the particular resource. If not, the resource server must refuse to serve the respective request. Clients and authorization servers MAY utilize the parameter `scope` and `authorization_details` as specified in [[I-D.ietf-oauth-rar](#)] to determine those resources and/or actions.

Authorization and resource servers SHOULD use mechanisms for sender-constrained access tokens to prevent token replay as described in (`#pop_tokens`). A sender-constrained access token scopes the applicability of an access token to a certain sender. This sender is obliged to demonstrate knowledge of a certain secret as prerequisite for the acceptance of that access token at the recipient (e.g., a resource server). The use of Mutual TLS for OAuth 2.0 [[RFC8705](#)] is RECOMMENDED.

7.5. Refresh Tokens

Authorization servers MAY issue refresh tokens to clients.

Refresh tokens MUST be kept confidential in transit and storage, and shared only among the authorization server and the client to whom the refresh tokens were issued. The authorization server MUST maintain the binding between a refresh token and the client to whom it was issued. Refresh tokens MUST only be transmitted using TLS as described in [Section 1.5](#) with server authentication as defined by [[RFC2818](#)].

The authorization server MUST verify the binding between the refresh token and client identity whenever the client identity can be authenticated. When client authentication is not possible, the authorization server SHOULD issue sender-constrained refresh tokens or use refresh token rotation as described in (`#refreshing-an-access-token`).

The authorization server MUST ensure that refresh tokens cannot be generated, modified, or guessed to produce valid refresh tokens by unauthorized parties.

7.6. Client Impersonating Resource Owner

Resource servers may make access control decisions based on the identity of the resource owner as communicated in the sub claim returned by the authorization server in a token introspection response [[RFC7662](#)] or other mechanisms. If a client is able to choose its own `client_id` during registration with the authorization server, then there is a risk that it can register with the same sub value as a privileged user. A subsequent access token obtained under the client credentials grant may be mistaken for an access token

authorized by the privileged user if the resource server does not perform additional checks.

Authorization servers SHOULD NOT allow clients to influence their `client_id` or `sub` value or any other claim if that can cause confusion with a genuine resource owner. Where this cannot be avoided, authorization servers MUST provide other means for the resource server to distinguish between access tokens authorized by a resource owner from access tokens authorized by the client itself.

7.7. Protecting the Authorization Code Flow

When comparing client redirect URIs against pre-registered URIs, authorization servers MUST utilize exact string matching. This measure contributes to the prevention of leakage of authorization codes and access tokens (see `(#insufficient_uri_validation)`). It can also help to detect mix-up attacks (see `(#mix_up)`).

Clients MUST NOT expose URLs that forward the user's browser to arbitrary URIs obtained from a query parameter ("open redirector"). Open redirectors can enable exfiltration of authorization codes and access tokens, see `(#open_redirector_on_client)`.

Clients MUST prevent Cross-Site Request Forgery (CSRF). In this context, CSRF refers to requests to the redirection endpoint that do not originate at the authorization server, but a malicious third party (see Section 4.4.1.8. of [[RFC6819](#)] for details). Clients that have ensured that the authorization server supports the `code_challenge` parameter MAY rely the CSRF protection provided by that mechanism. In OpenID Connect flows, the `nonce` parameter provides CSRF protection. Otherwise, one-time use CSRF tokens carried in the `state` parameter that are securely bound to the user agent MUST be used for CSRF protection (see `(#csrf_countermeasures)`).

In order to prevent mix-up attacks (see `(#mix_up)`), clients MUST only process redirect responses of the authorization server they sent the respective request to and from the same user agent this authorization request was initiated with. Clients MUST store the authorization server they sent an authorization request to and bind this information to the user agent and check that the authorization response was received from the correct authorization server. Clients MUST ensure that the subsequent access token request, if applicable, is sent to the same authorization server. Clients SHOULD use distinct redirect URIs for each authorization server as a means to identify the authorization server a particular response came from.

An AS that redirects a request potentially containing user credentials MUST avoid forwarding these user credentials accidentally (see [Section 7.7.2](#) for details).

7.7.1. Loopback Redirect Considerations in Native Apps

Loopback interface redirect URIs use the http scheme (i.e., without Transport Layer Security (TLS)). This is acceptable for loopback interface redirect URIs as the HTTP request never leaves the device.

Clients should open the network port only when starting the authorization request and close it once the response is returned.

Clients should listen on the loopback network interface only, in order to avoid interference by other network actors.

Clients should use loopback IP literals rather than the string localhost as described in [Section 8.3.3](#).

7.7.2. HTTP 307 Redirect

An AS which redirects a request that potentially contains user credentials MUST NOT use the HTTP 307 status code for redirection. If an HTTP redirection (and not, for example, JavaScript) is used for such a request, AS SHOULD use HTTP status code 303 "See Other".

At the authorization endpoint, a typical protocol flow is that the AS prompts the user to enter their credentials in a form that is then submitted (using the HTTP POST method) back to the authorization server. The AS checks the credentials and, if successful, redirects the user agent to the client's redirect URI.

If the status code 307 were used for redirection, the user agent would send the user credentials via HTTP POST to the client.

This discloses the sensitive credentials to the client. If the relying party is malicious, it can use the credentials to impersonate the user at the AS.

The behavior might be unexpected for developers, but is defined in [\[RFC7231\]](#), Section 6.4.7. This status code does not require the user agent to rewrite the POST request to a GET request and thereby drop the form data in the POST request body.

In the HTTP standard [\[RFC7231\]](#), only the status code 303 unambiguously enforces rewriting the HTTP POST request to an HTTP GET request. For all other status codes, including the popular 302, user agents can opt not to rewrite POST to GET requests and therefore to reveal the user credentials to the client. (In

practice, however, most user agents will only show this behaviour for 307 redirects.)

Therefore, the RECOMMENDED status code for HTTP redirects is 303.

7.8. Authorization Codes

Authorization codes MUST be short lived and single-use. If the authorization server observes multiple attempts to exchange an authorization code for an access token, the authorization server SHOULD attempt to revoke all refresh and access tokens already granted based on the compromised authorization code.

If the client can be authenticated, the authorization servers MUST authenticate the client and ensure that the authorization code was issued to the same client.

Clients MUST prevent injection (replay) of authorization codes into the authorization response by attackers. To this end, using `code_challenge` and `code_verifier` is REQUIRED for clients and authorization servers MUST enforce their use, unless both of the following criteria are met:

- *The client is a confidential client.

- *In the specific deployment and the specific request, there is reasonable assurance for authorization server that the client implements the OpenID Connect nonce mechanism properly.

In this case, using and enforcing `code_challenge` and `code_verifier` is still RECOMMENDED.

The `code_challenge` or OpenID Connect nonce value MUST be transaction-specific and securely bound to the client and the user agent in which the transaction was started. If a transaction leads to an error, fresh values for `code_challenge` or nonce MUST be chosen.

Historic note: Although PKCE [[RFC7636](#)] was originally designed as a mechanism to protect native apps, this advice applies to all kinds of OAuth clients, including web applications and other confidential clients.

Clients SHOULD use code challenge methods that do not expose the `code_verifier` in the authorization request. Otherwise, attackers that can read the authorization request (cf. Attacker A4 in (#secmodel)) can break the security provided by this mechanism. Currently, S256 is the only such method.

When an authorization code arrives at the token endpoint, the authorization server MUST do the following check:

1. If there was a code_challenge in the authorization request for which this code was issued, there must be a code_verifier in the token request, and it MUST be verified according to the steps in [Section 3.2.2](#). (This is no change from the current behavior in [[RFC7636](#)].)
2. If there was no code_challenge in the authorization request, any request to the token endpoint containing a code_verifier MUST be rejected.

Authorization servers MUST support the code_challenge and code_verifier parameters.

Authorization servers MUST provide a way to detect their support for the code_challenge mechanism. To this end, they MUST either (a) publish the element code_challenge_methods_supported in their AS metadata ([\[RFC8414\]](#)) containing the supported code_challenge_methods (which can be used by the client to detect support) or (b) provide a deployment-specific way to ensure or determine support by the AS.

7.9. Request Confidentiality

Access tokens, refresh tokens, authorization codes, and client credentials MUST NOT be transmitted in the clear.

The state and scope parameters SHOULD NOT include sensitive client or resource owner information in plain text, as they can be transmitted over insecure channels or stored insecurely.

7.10. Ensuring Endpoint Authenticity

In order to prevent man-in-the-middle attacks, the authorization server MUST require the use of TLS with server authentication as defined by [\[RFC2818\]](#) for any request sent to the authorization and token endpoints. The client MUST validate the authorization server's TLS certificate as defined by [\[RFC6125\]](#) and in accordance with its requirements for server identity authentication.

7.11. Credentials-Guessing Attacks

The authorization server MUST prevent attackers from guessing access tokens, authorization codes, refresh tokens, resource owner passwords, and client credentials.

The probability of an attacker guessing generated tokens (and other credentials not intended for handling by end-users) MUST be less

than or equal to $2^{(-128)}$ and SHOULD be less than or equal to $2^{(-160)}$.

The authorization server MUST utilize other means to protect credentials intended for end-user usage.

7.12. Phishing Attacks

Wide deployment of this and similar protocols may cause end-users to become inured to the practice of being redirected to websites where they are asked to enter their passwords. If end-users are not careful to verify the authenticity of these websites before entering their credentials, it will be possible for attackers to exploit this practice to steal resource owners' passwords.

Service providers should attempt to educate end-users about the risks phishing attacks pose and should provide mechanisms that make it easy for end-users to confirm the authenticity of their sites. Client developers should consider the security implications of how they interact with the user agent (e.g., external, embedded), and the ability of the end-user to verify the authenticity of the authorization server.

To reduce the risk of phishing attacks, the authorization servers MUST require the use of TLS on every endpoint used for end-user interaction.

7.13. Fake External User-Agents in Native Apps

The native app that is initiating the authorization request has a large degree of control over the user interface and can potentially present a fake external user agent, that is, an embedded user agent made to appear as an external user agent.

When all good actors are using external user agents, the advantage is that it is possible for security experts to detect bad actors, as anyone faking an external user agent is provably bad. On the other hand, if good and bad actors alike are using embedded user agents, bad actors don't need to fake anything, making them harder to detect. Once a malicious app is detected, it may be possible to use this knowledge to blacklist the app's signature in malware scanning software, take removal action (in the case of apps distributed by app stores) and other steps to reduce the impact and spread of the malicious app.

Authorization servers can also directly protect against fake external user agents by requiring an authentication factor only available to true external user agents.

Users who are particularly concerned about their security when using in-app browser tabs may also take the additional step of opening the request in the full browser from the in-app browser tab and complete the authorization there, as most implementations of the in-app browser tab pattern offer such functionality.

7.14. Malicious External User-Agents in Native Apps

If a malicious app is able to configure itself as the default handler for https scheme URIs in the operating system, it will be able to intercept authorization requests that use the default browser and abuse this position of trust for malicious ends such as phishing the user.

This attack is not confined to OAuth; a malicious app configured in this way would present a general and ongoing risk to the user beyond OAuth usage by native apps. Many operating systems mitigate this issue by requiring an explicit user action to change the default handler for http and https scheme URIs.

7.15. Cross-Site Request Forgery

An attacker might attempt to inject a request to the redirect URI of the legitimate client on the victim's device, e.g., to cause the client to access resources under the attacker's control. This is a variant of an attack known as Cross-Site Request Forgery (CSRF).

The traditional countermeasures are CSRF tokens that are bound to the user agent and passed in the state parameter to the authorization server as described in [[RFC6819](#)]. The same protection is provided by the code_verifier parameter or the OpenID Connect nonce value.

When using code_verifier instead of state or nonce for CSRF protection, it is important to note that:

- *Clients MUST ensure that the AS supports the code_challenge_method intended to be used by the client. If an authorization server does not support the requested method, state or nonce MUST be used for CSRF protection instead.

- *If state is used for carrying application state, and integrity of its contents is a concern, clients MUST protect state against tampering and swapping. This can be achieved by binding the contents of state to the browser session and/or signed/encrypted state values [[I-D.bradley-oauth-jwt-encoded-state](#)].

AS therefore MUST provide a way to detect their supported code challenge methods either via AS metadata according to [[RFC8414](#)] or provide a deployment-specific way to ensure or determine support.

7.16. Clickjacking

As described in Section 4.4.1.9 of [RFC6819], the authorization request is susceptible to clickjacking. An attacker can use this vector to obtain the user's authentication credentials, change the scope of access granted to the client, and potentially access the user's resources.

Authorization servers MUST prevent clickjacking attacks. Multiple countermeasures are described in [RFC6819], including the use of the X-Frame-Options HTTP response header field and frame-busting JavaScript. In addition to those, authorization servers SHOULD also use Content Security Policy (CSP) level 2 [CSP-2] or greater.

To be effective, CSP must be used on the authorization endpoint and, if applicable, other endpoints used to authenticate the user and authorize the client (e.g., the device authorization endpoint, login pages, error pages, etc.). This prevents framing by unauthorized origins in user agents that support CSP. The client MAY permit being framed by some other origin than the one used in its redirection endpoint. For this reason, authorization servers SHOULD allow administrators to configure allowed origins for particular clients and/or for clients to register these dynamically.

Using CSP allows authorization servers to specify multiple origins in a single response header field and to constrain these using flexible patterns (see [CSP-2] for details). Level 2 of this standard provides a robust mechanism for protecting against clickjacking by using policies that restrict the origin of frames (using frame-ancestors) together with those that restrict the sources of scripts allowed to execute on an HTML page (by using script-src). A non-normative example of such a policy is shown in the following listing:

```
HTTP/1.1 200 OK Content-Security-Policy: frame-ancestors https://  
ext.example.org:8000 Content-Security-Policy: script-src 'self' X-  
Frame-Options: ALLOW-FROM https://ext.example.org:8000 ...
```

Because some user agents do not support [CSP-2], this technique SHOULD be combined with others, including those described in [RFC6819], unless such legacy user agents are explicitly unsupported by the authorization server. Even in such cases, additional countermeasures SHOULD still be employed.

7.17. Code Injection and Input Validation

A code injection attack occurs when an input or otherwise external variable is used by an application unsanitized and causes modification to the application logic. This may allow an attacker to

gain access to the application device or its data, cause denial of service, or introduce a wide range of malicious side-effects.

The authorization server and client MUST sanitize (and validate when possible) any value received - in particular, the value of the state and redirect_uri parameters.

7.18. Open Redirectors

The following attacks can occur when an AS or client has an open redirector. An open redirector is an endpoint that forwards a user's browser to an arbitrary URI obtained from a query parameter.

7.18.1. Client as Open Redirector

Clients MUST NOT expose open redirectors. Attackers may use open redirectors to produce URLs pointing to the client and utilize them to exfiltrate authorization codes and access tokens, as described in (#redir_uri_open_redir). Another abuse case is to produce URLs that appear to point to the client. This might trick users into trusting the URL and follow it in their browser. This can be abused for phishing.

In order to prevent open redirection, clients should only redirect if the target URLs are whitelisted or if the origin and integrity of a request can be authenticated. Countermeasures against open redirection are described by OWASP [[owasp_redir](#)].

7.18.2. Authorization Server as Open Redirector

Just as with clients, attackers could try to utilize a user's trust in the authorization server (and its URL in particular) for performing phishing attacks. OAuth authorization servers regularly redirect users to other web sites (the clients), but must do so in a safe way.

[Section 4.1.2.1](#) already prevents open redirects by stating that the AS MUST NOT automatically redirect the user agent in case of an invalid combination of client_id and redirect_uri.

However, an attacker could also utilize a correctly registered redirect URI to perform phishing attacks. The attacker could, for example, register a client via dynamic client registration [[RFC7591](#)] and intentionally send an erroneous authorization request, e.g., by using an invalid scope value, thus instructing the AS to redirect the user agent to its phishing site.

The AS MUST take precautions to prevent this threat. Based on its risk assessment, the AS needs to decide whether it can trust the redirect URI and SHOULD only automatically redirect the user agent

if it trusts the redirect URI. If the URI is not trusted, the AS MAY inform the user and rely on the user to make the correct decision.

7.19. Authorization Server Mix-Up Mitigation in Native Apps

(TODO: merge this with the regular mix-up section when it is brought in)

To protect against a compromised or malicious authorization server attacking another authorization server used by the same app, it is REQUIRED that a unique redirect URI is used for each authorization server used by the app (for example, by varying the path component), and that authorization responses are rejected if the redirect URI they were received on doesn't match the redirect URI in an outgoing authorization request.

The native app MUST store the redirect URI used in the authorization request with the authorization session data (i.e., along with state and other related data) and MUST verify that the URI on which the authorization response was received exactly matches it.

The requirement of [Section 7.3](#), specifically that authorization servers reject requests with URIs that don't match what was registered, is also required to prevent such attacks.

7.20. Embedded User Agents in Native Apps

Embedded user agents are a technically possible method for authorizing native apps. These embedded user agents are unsafe for use by third parties to the authorization server by definition, as the app that hosts the embedded user agent can access the user's full authentication credential, not just the OAuth authorization grant that was intended for the app.

In typical web-view-based implementations of embedded user agents, the host application can record every keystroke entered in the login form to capture usernames and passwords, automatically submit forms to bypass user consent, and copy session cookies and use them to perform authenticated actions as the user.

Even when used by trusted apps belonging to the same party as the authorization server, embedded user agents violate the principle of least privilege by having access to more powerful credentials than they need, potentially increasing the attack surface.

Encouraging users to enter credentials in an embedded user agent without the usual address bar and visible certificate validation features that browsers have makes it impossible for the user to know if they are signing in to the legitimate site; even when they are,

it trains them that it's OK to enter credentials without validating the site first.

Aside from the security concerns, embedded user agents do not share the authentication state with other apps or the browser, requiring the user to log in for every authorization request, which is often considered an inferior user experience.

7.21. Other Recommendations

Authorization servers SHOULD NOT allow clients to influence their `client_id` or `sub` value or any other claim if that can cause confusion with a genuine resource owner (see `#client_impersonating`).

8. Native Applications

Native applications are clients installed and executed on the device used by the resource owner (i.e., desktop application, native mobile application). Native applications require special consideration related to security, platform capabilities, and overall end-user experience.

The authorization endpoint requires interaction between the client and the resource owner's user agent. The best current practice is to perform the OAuth authorization request in an external user agent (typically the browser) rather than an embedded user agent (such as one implemented with web-views).

The native application can capture the response from the authorization server using a redirect URI with a scheme registered with the operating system to invoke the client as the handler, manual copy-and-paste of the credentials, running a local web server, installing a user agent extension, or by providing a redirect URI identifying a server-hosted resource under the client's control, which in turn makes the response available to the native application.

Previously, it was common for native apps to use embedded user agents (commonly implemented with web-views) for OAuth authorization requests. That approach has many drawbacks, including the host app being able to copy user credentials and cookies as well as the user needing to authenticate from scratch in each app. See [Section 7.20](#) for a deeper analysis of the drawbacks of using embedded user agents for OAuth.

Native app authorization requests that use the browser are more secure and can take advantage of the user's authentication state. Being able to use the existing authentication session in the browser enables single sign-on, as users don't need to authenticate to the

authorization server each time they use a new app (unless required by the authorization server policy).

Supporting authorization flows between a native app and the browser is possible without changing the OAuth protocol itself, as the OAuth authorization request and response are already defined in terms of URIs. This encompasses URIs that can be used for inter-app communication. Some OAuth server implementations that assume all clients are confidential web clients will need to add an understanding of public native app clients and the types of redirect URIs they use to support this best practice.

8.1. Using Inter-App URI Communication for OAuth in Native Apps

Just as URIs are used for OAuth on the web to initiate the authorization request and return the authorization response to the requesting website, URIs can be used by native apps to initiate the authorization request in the device's browser and return the response to the requesting native app.

By adopting the same methods used on the web for OAuth, benefits seen in the web context like the usability of a single sign-on session and the security of a separate authentication context are likewise gained in the native app context. Reusing the same approach also reduces the implementation complexity and increases interoperability by relying on standards-based web flows that are not specific to a particular platform.

Native apps MUST use an external user agent to perform OAuth authorization requests. This is achieved by opening the authorization request in the browser (detailed in [Section 8.2](#)) and using a redirect URI that will return the authorization response back to the native app (defined in [Section 8.3](#)).

8.2. Initiating the Authorization Request from a Native App

Native apps needing user authorization create an authorization request URI with the authorization code grant type per [Section 4.1](#) using a redirect URI capable of being received by the native app.

The function of the redirect URI for a native app authorization request is similar to that of a web-based authorization request. Rather than returning the authorization response to the OAuth client's server, the redirect URI used by a native app returns the response to the app. Several options for a redirect URI that will return the authorization response to the native app in different platforms are documented in [Section 8.3](#). Any redirect URI that allows the app to receive the URI and inspect its parameters is viable.

After constructing the authorization request URI, the app uses platform-specific APIs to open the URI in an external user agent. Typically, the external user agent used is the default browser, that is, the application configured for handling http and https scheme URIs on the system; however, different browser selection criteria and other categories of external user agents MAY be used.

This best practice focuses on the browser as the RECOMMENDED external user agent for native apps. An external user agent designed specifically for user authorization and capable of processing authorization requests and responses like a browser MAY also be used. Other external user agents, such as a native app provided by the authorization server may meet the criteria set out in this best practice, including using the same redirect URI properties, but their use is out of scope for this specification.

Some platforms support a browser feature known as "in-app browser tabs", where an app can present a tab of the browser within the app context without switching apps, but still retain key benefits of the browser such as a shared authentication state and security context. On platforms where they are supported, it is RECOMMENDED, for usability reasons, that apps use in-app browser tabs for the authorization request.

8.3. Receiving the Authorization Response in a Native App

There are several redirect URI options available to native apps for receiving the authorization response from the browser, the availability and user experience of which varies by platform.

To fully support native apps, authorization servers MUST offer at least the three redirect URI options described in the following subsections to native apps. Native apps MAY use whichever redirect option suits their needs best, taking into account platform-specific implementation details.

8.3.1. Private-Use URI Scheme Redirection

Many mobile and desktop computing platforms support inter-app communication via URIs by allowing apps to register private-use URI schemes (sometimes colloquially referred to as "custom URL schemes") like com.example.app. When the browser or another app attempts to load a URI with a private-use URI scheme, the app that registered it is launched to handle the request.

To perform an authorization request with a private-use URI scheme redirect, the native app launches the browser with a standard authorization request, but one where the redirect URI utilizes a private-use URI scheme it registered with the operating system.

When choosing a URI scheme to associate with the app, apps MUST use a URI scheme based on a domain name under their control, expressed in reverse order, as recommended by Section 3.8 of [\[RFC7595\]](#) for private-use URI schemes.

For example, an app that controls the domain name `app.example.com` can use `com.example.app` as their scheme. Some authorization servers assign client identifiers based on domain names, for example, `client1234.usercontent.example.net`, which can also be used as the domain name for the scheme when reversed in the same manner. A scheme such as `myapp`, however, would not meet this requirement, as it is not based on a domain name.

When there are multiple apps by the same publisher, care must be taken so that each scheme is unique within that group. On platforms that use app identifiers based on reverse-order domain names, those identifiers can be reused as the private-use URI scheme for the OAuth redirect to help avoid this problem.

Following the requirements of Section 3.2 of [\[RFC3986\]](#), as there is no naming authority for private-use URI scheme redirects, only a single slash (/) appears after the scheme component. A complete example of a redirect URI utilizing a private-use URI scheme is:

```
com.example.app:/oauth2redirect/example-provider
```

When the authorization server completes the request, it redirects to the client's redirect URI as it would normally. As the redirect URI uses a private-use URI scheme, it results in the operating system launching the native app, passing in the URI as a launch parameter. Then, the native app uses normal processing for the authorization response.

8.3.2. Claimed "https" Scheme URI Redirection

Some operating systems allow apps to claim https scheme [\[RFC7230\]](#) URIs in the domains they control. When the browser encounters a claimed URI, instead of the page being loaded in the browser, the native app is launched with the URI supplied as a launch parameter.

Such URIs can be used as redirect URIs by native apps. They are indistinguishable to the authorization server from a regular web-based client redirect URI. An example is:

```
https://app.example.com/oauth2redirect/example-provider
```

As the redirect URI alone is not enough to distinguish public native app clients from confidential web clients, it is REQUIRED in [Section 7.3](#) that the client type be recorded during client registration to enable the server to determine the client type and act accordingly.

App-claimed https scheme redirect URIs have some advantages compared to other native app redirect options in that the identity of the destination app is guaranteed to the authorization server by the operating system. For this reason, native apps SHOULD use them over the other options where possible.

8.3.3. Loopback Interface Redirection

Native apps that are able to open a port on the loopback network interface without needing special permissions (typically, those on desktop operating systems) can use the loopback interface to receive the OAuth redirect.

Loopback redirect URIs use the http scheme and are constructed with the loopback IP literal and whatever port the client is listening on.

That is, `http://127.0.0.1:{port}/{path}` for IPv4, and `http://[::1]:{port}/{path}` for IPv6. An example redirect using the IPv4 loopback interface with a randomly assigned port:

```
http://127.0.0.1:51004/oauth2redirect/example-provider
```

An example redirect using the IPv6 loopback interface with a randomly assigned port:

```
http://[::1]:61023/oauth2redirect/example-provider
```

While redirect URIs using the name localhost (i.e., `http://localhost:{port}/{path}`) function similarly to loopback IP redirects, the use of localhost is NOT RECOMMENDED. Specifying a redirect URI with the loopback IP literal rather than localhost avoids inadvertently listening on network interfaces other than the loopback interface. It is also less susceptible to client-side firewalls and misconfigured host name resolution on the user's device.

The authorization server MUST allow any port to be specified at the time of the request for loopback IP redirect URIs, to accommodate clients that obtain an available ephemeral port from the operating system at the time of the request.

Clients SHOULD NOT assume that the device supports a particular version of the Internet Protocol. It is RECOMMENDED that clients attempt to bind to the loopback interface using both IPv4 and IPv6 and use whichever is available.

9. Browser-Based Apps

Browser-based apps are clients that run in a web browser, typically written in JavaScript, also known as "single-page apps". These types of apps have particular security considerations similar to native apps.

TODO: Bring in the normative text of the browser-based apps BCP when it is finalized.

10. Differences from OAuth 2.0

This draft consolidates the functionality in OAuth 2.0 [[RFC6749](#)], OAuth 2.0 for Native Apps ([\[RFC8252\]](#)), Proof Key for Code Exchange ([\[RFC7636\]](#)), OAuth 2.0 for Browser-Based Apps ([\[I-D.ietf-oauth-browser-based-apps\]](#)), OAuth Security Best Current Practice ([\[I-D.ietf-oauth-security-topics\]](#)), and Bearer Token Usage ([\[RFC6750\]](#)).

Where a later draft updates or obsoletes functionality found in the original [[RFC6749](#)], that functionality in this draft is updated with the normative changes described in a later draft, or removed entirely.

A non-normative list of changes from OAuth 2.0 is listed below:

- *The authorization code grant is extended with the functionality from PKCE ([\[RFC7636\]](#)) such that the default method of using the authorization code grant according to this specification requires the addition of the PKCE parameters
- *Redirect URIs must be compared using exact string matching as per Section 4.1.3 of [\[I-D.ietf-oauth-security-topics\]](#)
- *The Implicit grant (response_type=token) is omitted from this specification as per Section 2.1.2 of [\[I-D.ietf-oauth-security-topics\]](#)
- *The Resource Owner Password Credentials grant is omitted from this specification as per Section 2.4 of [\[I-D.ietf-oauth-security-topics\]](#)
- *Bearer token usage omits the use of bearer tokens in the query string of URIs as per Section 4.3.2 of [\[I-D.ietf-oauth-security-topics\]](#)
- *Refresh tokens should either be sender-constrained or one-time use as per Section 4.12.2 of [\[I-D.ietf-oauth-security-topics\]](#)

11. IANA Considerations

This document does not require any IANA actions.

All referenced registries are defined by [RFC6749] and related documents that this work is based upon. No changes to those registries are required by this specification.

12. References

12.1. Normative References

- [BCP195] Saint-Andre, P., "Recommendations for Secure Use of Transport Layer Security (TLS)", 2015.
- [I-D.ietf-oauth-security-topics] Lodderstedt, T., Bradley, J., Labunets, A., and D. Fett, "OAuth 2.0 Security Best Current Practice", Work in Progress, Internet-Draft, draft-ietf-oauth-security-topics-18, 13 April 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-security-topics-18.txt>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC2617] Franks, J., Hallam-Baker, P., Hostetler, J., Lawrence, S., Leach, P., Luotonen, A., and L. Stewart, "HTTP Authentication: Basic and Digest Access Authentication", RFC 2617, DOI 10.17487/RFC2617, June 1999, <<https://www.rfc-editor.org/info/rfc2617>>.
- [RFC2818] Rescorla, E., "HTTP Over TLS", RFC 2818, DOI 10.17487/RFC2818, May 2000, <<https://www.rfc-editor.org/info/rfc2818>>.
- [RFC3629] Yergeau, F., "UTF-8, a transformation format of ISO 10646", STD 63, RFC 3629, DOI 10.17487/RFC3629, November 2003, <<https://www.rfc-editor.org/info/rfc3629>>.
- [RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifier (URI): Generic Syntax", STD 66, RFC 3986, DOI 10.17487/RFC3986, January 2005, <<https://www.rfc-editor.org/info/rfc3986>>.
- [RFC4949] Shirey, R., "Internet Security Glossary, Version 2", FYI 36, RFC 4949, DOI 10.17487/RFC4949, August 2007, <<https://www.rfc-editor.org/info/rfc4949>>.

- [RFC5234] Crocker, D., Ed. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", STD 68, RFC 5234, DOI 10.17487/RFC5234, January 2008, <<https://www.rfc-editor.org/info/rfc5234>>.
- [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, DOI 10.17487/RFC5280, May 2008, <<https://www.rfc-editor.org/info/rfc5280>>.
- [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, DOI 10.17487/RFC6125, March 2011, <<https://www.rfc-editor.org/info/rfc6125>>.
- [RFC6749] Hardt, D., Ed., "The OAuth 2.0 Authorization Framework", RFC 6749, DOI 10.17487/RFC6749, October 2012, <<https://www.rfc-editor.org/info/rfc6749>>.
- [RFC6750] Jones, M. and D. Hardt, "The OAuth 2.0 Authorization Framework: Bearer Token Usage", RFC 6750, DOI 10.17487/RFC6750, October 2012, <<https://www.rfc-editor.org/info/rfc6750>>.
- [RFC7159] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", RFC 7159, DOI 10.17487/RFC7159, March 2014, <<https://www.rfc-editor.org/info/rfc7159>>.
- [RFC7230] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing", RFC 7230, DOI 10.17487/RFC7230, June 2014, <<https://www.rfc-editor.org/info/rfc7230>>.
- [RFC7231] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content", RFC 7231, DOI 10.17487/RFC7231, June 2014, <<https://www.rfc-editor.org/info/rfc7231>>.
- [RFC7234] Fielding, R., Ed., Nottingham, M., Ed., and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Caching", RFC 7234, DOI 10.17487/RFC7234, June 2014, <<https://www.rfc-editor.org/info/rfc7234>>.
- [RFC7235] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Authentication", RFC 7235,

DOI 10.17487/RFC7235, June 2014, <<https://www.rfc-editor.org/info/rfc7235>>.

[RFC7595] Thaler, D., Ed., Hansen, T., and T. Hardie, "Guidelines and Registration Procedures for URI Schemes", BCP 35, RFC 7595, DOI 10.17487/RFC7595, June 2015, <<https://www.rfc-editor.org/info/rfc7595>>.

[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/info/rfc8174>>.

[RFC8252] Denniss, W. and J. Bradley, "OAuth 2.0 for Native Apps", BCP 212, RFC 8252, DOI 10.17487/RFC8252, October 2017, <<https://www.rfc-editor.org/info/rfc8252>>.

[RFC8259] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", STD 90, RFC 8259, DOI 10.17487/RFC8259, December 2017, <<https://www.rfc-editor.org/info/rfc8259>>.

[USASCII] Institute, A.N.S., "Coded Character Set -- 7-bit American Standard Code for Information Interchange, ANSI X3.4", 1986.

[W3C.REC-html401-19991224] Raggett, D., Hors, A., and I. Jacobs, "HTML 4.01 Specification", World Wide Web Consortium Recommendation REC-html401-19991224, 24 December 1999, <<https://www.w3.org/TR/1999/REC-html401-19991224>>.

[W3C.REC-xml-20081126] Bray, T., Paoli, J., Sperberg-McQueen, M., Maler, E., and F. Yergeau, "Extensible Markup Language (XML) 1.0 (Fifth Edition)", World Wide Web Consortium Recommendation REC-xml-20081126, 26 November 2008, <<https://www.w3.org/TR/2008/REC-xml-20081126>>.

12.2. Informative References

[CSP-2] "Content Security Policy Level 2", December 2016, <<https://www.w3.org/TR/CSP2>>.

[I-D.bradley-oauth-jwt-encoded-state] Bradley, J., Lodderstedt, D. T., and H. Zandbelt, "Encoding claims in the OAuth 2 state parameter using a JWT", Work in Progress, Internet-Draft, draft-bradley-oauth-jwt-encoded-state-09, 4

November 2018, <<https://www.ietf.org/archive/id/draft-bradley-oauth-jwt-encoded-state-09.txt>>.

[I-D.ietf-oauth-access-token-jwt]

Bertocci, V., "JSON Web Token (JWT) Profile for OAuth 2.0 Access Tokens", Work in Progress, Internet-Draft, draft-ietf-oauth-access-token-jwt-13, 25 May 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-access-token-jwt-13.txt>>.

[I-D.ietf-oauth-browser-based-apps] Parecki, A. and D. Waite, "OAuth 2.0 for Browser-Based Apps", Work in Progress, Internet-Draft, draft-ietf-oauth-browser-based-apps-08, 17 May 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-browser-based-apps-08.txt>>.

[I-D.ietf-oauth-dpop] Fett, D., Campbell, B., Bradley, J., Lodderstedt, T., Jones, M., and D. Waite, "OAuth 2.0 Demonstrating Proof-of-Possession at the Application Layer (DPoP)", Work in Progress, Internet-Draft, draft-ietf-oauth-dpop-03, 7 April 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-dpop-03.txt>>.

[I-D.ietf-oauth-par] Lodderstedt, T., Campbell, B., Sakimura, N., Tonge, D., and F. Skokan, "OAuth 2.0 Pushed Authorization Requests", Work in Progress, Internet-Draft, draft-ietf-oauth-par-10, 29 July 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-par-10.txt>>.

[I-D.ietf-oauth-rar] Lodderstedt, T., Richer, J., and B. Campbell, "OAuth 2.0 Rich Authorization Requests", Work in Progress, Internet-Draft, draft-ietf-oauth-rar-07, 12 September 2021, <<https://www.ietf.org/archive/id/draft-ietf-oauth-rar-07.txt>>.

[I-D.ietf-oauth-token-binding] Jones, M. B., Campbell, B., Bradley, J., and W. Denniss, "OAuth 2.0 Token Binding", Work in Progress, Internet-Draft, draft-ietf-oauth-token-binding-08, 19 October 2018, <<https://www.ietf.org/archive/id/draft-ietf-oauth-token-binding-08.txt>>.

[NIST800-63] Burr, W., Dodson, D., Newton, E., Perlner, R., Polk, T., Gupta, S., and E. Nabbus, "NIST Special Publication 800-63-1, INFORMATION SECURITY", December 2011, <<http://csrc.nist.gov/publications/>>.

[OMAP]

Huff, J., Schlacht, D., Nadalin, A., Simmons, J., Rosenberg, P., Madsen, P., Ace, T., Rickelton-Abdi, C., and B. Boyer, "Online Multimedia Authorization Protocol:

An Industry Standard for Authorized Access to Internet Multimedia Resources", April 2012, <<https://www.oatc.us/Standards/Download-Standards>>.

- [OpenID]** Sakimora, N., Bradley, J., Jones, M., de Medeiros, B., and C. Mortimore, "OpenID Connect Core 1.0", November 2014, <https://openid.net/specs/openid-connect-core-1_0.html>.
- [OpenID.Messages]** Sakimura, N., Bradley, J., Jones, M., de Medeiros, B., Mortimore, C., and E. Jay, "OpenID Connect Messages 1.0", June 2012, <http://openid.net/specs/openid-connect-messages-1_0.html>.
- [owasp_redirect]** "OWASP Cheat Sheet Series - Unvalidated Redirects and Forwards", 2020, <https://cheatsheetseries.owasp.org/cheatsheets/Unvalidated_Redirects_and_Forwards_Cheat_Sheet.html>.
- [RFC6265]** Barth, A., "HTTP State Management Mechanism", RFC 6265, DOI 10.17487/RFC6265, April 2011, <<https://www.rfc-editor.org/info/rfc6265>>.
- [RFC6819]** Lodderstedt, T., Ed., McGloin, M., and P. Hunt, "OAuth 2.0 Threat Model and Security Considerations", RFC 6819, DOI 10.17487/RFC6819, January 2013, <<https://www.rfc-editor.org/info/rfc6819>>.
- [RFC7009]** Lodderstedt, T., Ed., Dronia, S., and M. Scurtescu, "OAuth 2.0 Token Revocation", RFC 7009, DOI 10.17487/RFC7009, August 2013, <<https://www.rfc-editor.org/info/rfc7009>>.
- [RFC7519]** Jones, M., Bradley, J., and N. Sakimura, "JSON Web Token (JWT)", RFC 7519, DOI 10.17487/RFC7519, May 2015, <<https://www.rfc-editor.org/info/rfc7519>>.
- [RFC7591]** Richer, J., Ed., Jones, M., Bradley, J., Machulak, M., and P. Hunt, "OAuth 2.0 Dynamic Client Registration Protocol", RFC 7591, DOI 10.17487/RFC7591, July 2015, <<https://www.rfc-editor.org/info/rfc7591>>.
- [RFC7592]** Richer, J., Ed., Jones, M., Bradley, J., and M. Machulak, "OAuth 2.0 Dynamic Client Registration Management Protocol", RFC 7592, DOI 10.17487/RFC7592, July 2015, <<https://www.rfc-editor.org/info/rfc7592>>.
- [RFC7636]** Sakimura, N., Ed., Bradley, J., and N. Agarwal, "Proof Key for Code Exchange by OAuth Public Clients", RFC 7636,

DOI 10.17487/RFC7636, September 2015, <<https://www.rfc-editor.org/info/rfc7636>>.

- [RFC7662] Richer, J., Ed., "OAuth 2.0 Token Introspection", RFC 7662, DOI 10.17487/RFC7662, October 2015, <<https://www.rfc-editor.org/info/rfc7662>>.
- [RFC8414] Jones, M., Sakimura, N., and J. Bradley, "OAuth 2.0 Authorization Server Metadata", RFC 8414, DOI 10.17487/RFC8414, June 2018, <<https://www.rfc-editor.org/info/rfc8414>>.
- [RFC8628] Denniss, W., Bradley, J., Jones, M., and H. Tschofenig, "OAuth 2.0 Device Authorization Grant", RFC 8628, DOI 10.17487/RFC8628, August 2019, <<https://www.rfc-editor.org/info/rfc8628>>.
- [RFC8705] Campbell, B., Bradley, J., Sakimura, N., and T. Lodderstedt, "OAuth 2.0 Mutual-TLS Client Authentication and Certificate-Bound Access Tokens", RFC 8705, DOI 10.17487/RFC8705, February 2020, <<https://www.rfc-editor.org/info/rfc8705>>.
- [RFC8707] Campbell, B., Bradley, J., and H. Tschofenig, "Resource Indicators for OAuth 2.0", RFC 8707, DOI 10.17487/RFC8707, February 2020, <<https://www.rfc-editor.org/info/rfc8707>>.

Appendix A. Augmented Backus-Naur Form (ABNF) Syntax

This section provides Augmented Backus-Naur Form (ABNF) syntax descriptions for the elements defined in this specification using the notation of [RFC5234]. The ABNF below is defined in terms of Unicode code points [W3C.REC-xml-20081126]; these characters are typically encoded in UTF-8. Elements are presented in the order first defined.

Some of the definitions that follow use the "URI-reference" definition from [RFC3986].

Some of the definitions that follow use these common definitions:

```
VSCHAR      = %x20-7E
NQCHAR      = %x21 / %x23-5B / %x5D-7E
NQSCHAR     = %x20-21 / %x23-5B / %x5D-7E
UNICODECHARNOCRLF = %x09 /%x20-7E / %x80-D7FF /
                %xE000-FFFF / %x10000-10FFFF
```

(The UNICODECHARNOCRRLF definition is based upon the Char definition in Section 2.2 of [[W3C.REC-xml-20081126](#)], but omitting the Carriage Return and Linefeed characters.)

A.1. "client_id" Syntax

The client_id element is defined in [Section 2.4.1](#):

```
client-id = *VSCHAR
```

A.2. "client_secret" Syntax

The client_secret element is defined in [Section 2.4.1](#):

```
client-secret = *VSCHAR
```

A.3. "response_type" Syntax

The response_type element is defined in [Section 4.1.1](#) and [Section 6.4](#):

```
response-type = response-name *( SP response-name )
response-name = 1*response-char
response-char = "_" / DIGIT / ALPHA
```

A.4. "scope" Syntax

The scope element is defined in [Section 3.2.2.1](#):

```
scope = scope-token *( SP scope-token )
scope-token = 1*NQCHAR
```

A.5. "state" Syntax

The state element is defined in [Section 4.1.1](#), [Section 4.1.2](#), and [Section 4.1.2.1](#):

```
state = 1*VSCHAR
```

A.6. "redirect_uri" Syntax

The redirect_uri element is defined in [Section 4.1.1](#), and [Section 4.1.3](#):

```
redirect-uri = URI-reference
```

A.7. "error" Syntax

The error element is defined in Sections [Section 4.1.2.1](#), [Section 3.2.3.1](#), 7.2, and 8.5:

error = 1*NQSCHAR

A.8. "error_description" Syntax

The error_description element is defined in Sections [Section 4.1.2.1](#), [Section 3.2.3.1](#), and [Section 5.3](#):

error-description = 1*NQSCHAR

A.9. "error_uri" Syntax

The error_uri element is defined in Sections [Section 4.1.2.1](#), [Section 3.2.3.1](#), and 7.2:

error-uri = URI-reference

A.10. "grant_type" Syntax

The grant_type element is defined in Section [Section 3.2.2](#):

grant-type = grant-name / URI-reference
grant-name = 1*name-char
name-char = "-" / "." / "_" / DIGIT / ALPHA

A.11. "code" Syntax

The code element is defined in [Section 4.1.3](#):

code = 1*VSCHAR

A.12. "access_token" Syntax

The access_token element is defined in [Section 3.2.3](#):

access-token = 1*VSCHAR

A.13. "token_type" Syntax

The token_type element is defined in [Section 3.2.3](#), and [Section 6.1](#):

token-type = type-name / URI-reference
type-name = 1*name-char
name-char = "-" / "." / "_" / DIGIT / ALPHA

A.14. "expires_in" Syntax

The expires_in element is defined in [Section 3.2.3](#):

expires-in = 1*DIGIT

A.15. "refresh_token" Syntax

The refresh_token element is defined in [Section 3.2.3](#) and [Section 4.3](#):

```
refresh-token = 1*VSCHAR
```

A.16. Endpoint Parameter Syntax

The syntax for new endpoint parameters is defined in [Section 6.2](#):

```
param-name = 1*name-char  
name-char  = "-" / "." / "_" / DIGIT / ALPHA
```

A.17. "code_verifier" Syntax

ABNF for code_verifier is as follows.

```
code-verifier = 43*128unreserved  
unreserved = ALPHA / DIGIT / "-" / "." / "_" / "~"  
ALPHA = %x41-5A / %x61-7A  
DIGIT = %x30-39
```

A.18. "code_challenge" Syntax

ABNF for code_challenge is as follows.

```
code-challenge = 43*128unreserved  
unreserved = ALPHA / DIGIT / "-" / "." / "_" / "~"  
ALPHA = %x41-5A / %x61-7A  
DIGIT = %x30-39
```

Appendix B. Use of application/x-www-form-urlencoded Media Type

At the time of publication of this specification, the application/x-www-form-urlencoded media type was defined in Section 17.13.4 of [\[W3C.REC-html401-19991224\]](#) but not registered in the IANA MIME Media Types registry (<http://www.iana.org/assignments/media-types>). Furthermore, that definition is incomplete, as it does not consider non-US-ASCII characters.

To address this shortcoming when generating payloads using this media type, names and values MUST be encoded using the UTF-8 character encoding scheme [\[RFC3629\]](#) first; the resulting octet sequence then needs to be further encoded using the escaping rules defined in [\[W3C.REC-html401-19991224\]](#).

When parsing data from a payload using this media type, the names and values resulting from reversing the name/value encoding

consequently need to be treated as octet sequences, to be decoded using the UTF-8 character encoding scheme.

For example, the value consisting of the six Unicode code points (1) U+0020 (SPACE), (2) U+0025 (PERCENT SIGN), (3) U+0026 (AMPERSAND), (4) U+002B (PLUS SIGN), (5) U+00A3 (POUND SIGN), and (6) U+20AC (EURO SIGN) would be encoded into the octet sequence below (using hexadecimal notation):

```
20 25 26 2B C2 A3 E2 82 AC
```

and then represented in the payload as:

```
+%25%26%2B%C2%A3%E2%82%AC
```

Appendix C. Extensions

Below is a list of well-established extensions at the time of publication:

*[[RFC8628](#)]: OAuth 2.0 Device Authorization Grant

-The Device Authorization Grant (formerly known as the Device Flow) is an extension that enables devices with no browser or limited input capability to obtain an access token. This is commonly used by smart TV apps, or devices like hardware video encoders that can stream video to a streaming video service.

*[[RFC8414](#)]: Authorization Server Metadata

-Authorization Server Metadata (also known as OAuth Discovery) defines an endpoint clients can use to look up the information needed to interact with a particular OAuth server, such as the location of the authorization and token endpoints and the supported grant types.

*[[RFC8707](#)]: Resource Indicators

-Provides a way for the client to explicitly signal to the authorization server where it intends to use the access token it is requesting.

*[[RFC7591](#)]: Dynamic Client Registration

-Dynamic Client Registration provides a mechanism for programmatically registering clients with an authorization server.

*[\[RFC7592\]](#): Dynamic Client Management

-Dynamic Client Management provides a mechanism for updating dynamically registered client information.

*[\[I-D.ietf-oauth-access-token-jwt\]](#): JSON Web Token (JWT) Profile for OAuth 2.0 Access Tokens

-This specification defines a profile for issuing OAuth access tokens in JSON Web Token (JWT) format.

*[\[RFC8705\]](#): Mutual TLS

-Mutual TLS describes a mechanism of binding access tokens and refresh tokens to the clients they were issued to, as well as a client authentication mechanism, via TLS certificate authentication.

*[\[RFC7662\]](#): Token Introspection

-The Token Introspection extension defines a mechanism for resource servers to obtain information about access tokens.

*[\[RFC7009\]](#): Token Revocation

-The Token Revocation extension defines a mechanism for clients to indicate to the authorization server that an access token is no longer needed.

*[\[I-D.ietf-oauth-par\]](#): Pushed Authorization Requests

-The Pushed Authorization Requests extension describes a technique of initiating an OAuth flow from the back channel, providing better security and more flexibility for building complex authorization requests.

*[\[I-D.ietf-oauth-rar\]](#): Rich Authorization Requests

-Rich Authorization Requests specifies a new parameter `authorization_details` that is used to carry fine-grained authorization data in the OAuth authorization request.

Appendix D. Acknowledgements

TBD

Appendix E. Document History

[[To be removed from the final specification]]

-04

- * Added explicit mention of not sending access tokens in URI query string
- * Clarifications on definition of client types
- * Consolidated text around loopback vs localhost
- * Editorial clarifications throughout the document

-03

- * refactoring to collect all the grant types under the same top-level header
- * Better split normative and security consideration text into the appropriate sections
- * Incorporated many of the published errata on RFC6749
- * Updated references to various RFCs
- * Editorial clarifications throughout the document

-02

-01

-00

*initial revision

Authors' Addresses

Dick Hardt
Hello

Email: dick.hardt@gmail.com

Aaron Parecki
Okta

Email: aaron@parecki.com
URI: <https://aaronparecki.com>

Torsten Lodderstedt
yes.com

Email: torsten@lodderstedt.net