Computer Security

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OAuth 2: case study
Authorization after Authentication

Authentication:

binding of an identifier to a subject

Authorization:

giving permission to an authenticated subject perform an action on an object

Access Control:

verifying that access to object is in accordance to authorization

OpenID Connect[1]

- focused on upper-level **federated** authentication
  - e.g. allows "Sign in with Google" across many different websites
  - handles trust relationship between a visited site and the *identity provider* that will perform user authentication (possibly, using FIDO2!)
  - "unfortunately", this identity layer is built on top of OAuth 2.0
    - so, terminology gets confusing because: "authorization" keeps appearing in control flow...

Typical OIDC flow

- *User* visits, with browser, website's *App*
- *App* redirects browser to OpenId(entity) Provider, OIdP[2]
- OIdP authenticates *User* and gives an *ID token*[3] to *App*
- (*...now, OAuth's authorization flow takes over for an eventual access to resource...*)

1 aka OIDC
2 trusted by *App*
3 A *token* is a small document, protected against forgery, modification and, sometimes, disclosure.

Entities

- user (if human, "E*nd user"*)
  - "Resource Owner" in OAuth 2.0 terminology
- browser (tool to access web service)
  - "User-Agent" in OAuth 2.0 terminology
- web application (needs users authentication -& authorization!- to access resources)
  - "Client" in OAuth 2.0 terminology
    - Relying Party, trusts Identity Provider for users authentication
- Identity Provider[1] (authenticates users, e.g. using FIDO)
  - "Authorization Server" in OAuth 2.0 terminology
  - issues ID Tokens[2]
    - *assert* who the user (in more or less extent)
    - protected by digital signature and, possibly, encipherment

1 here, OpenID Provider, OP
2 and *authorization grants*...

Terminology confusion

- arises because OpenId Connect uses OAuth 2.0 to handle authentication!
  - technically, the user **authorizes** the Identity Provider to release their identity information to the app!
- e.g. definition of *OpenID Provider (OP):* [1]
  - *OAuth 2.0* ***Authorization Server*** *that is capable of* ***Authenticating*** *the End-User and providing Claims*[2] *to a Relying Party about the* ***Authentication*** *event and the End-User.*

1 in https://openid.net/specs/openid-connect-core-1_0.html#Terminology
2 A Claim is a statement of the value of an attribute of an entity.

The OpenID Connect protocol, in abstract

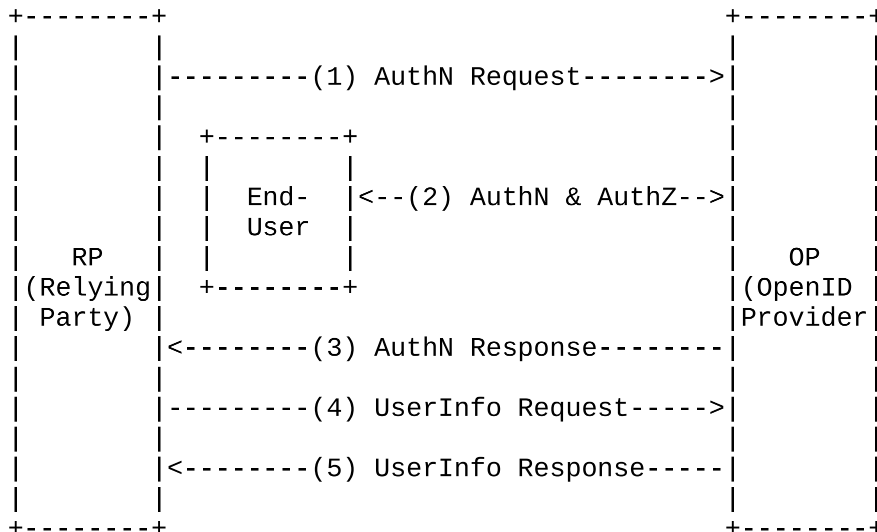


Fig. The OpenID Connect protocol as stated in OpenID Connect Core 1.0 (https://openid.net/specs/openid-connect-core-1_0.html)

Legend of previous Figure

- AuthN - Authentication
- AuthZ - Authorization

The OpenID Connect protocol, in abstract, follows the following steps.[1]

1. *The RP (Client) sends a request to the OpenID Provider (OP).*
2. *The OP authenticates the End-User and obtains authorization.*
3. *The OP responds with an ID Token and usually an Access Token.*
4. *The RP **can** send a request with the Access Token to the UserInfo Endpoint.*
5. *The UserInfo Endpoint returns Claims about the End-User.*

...OpenID Connect continues further down, after OAuth2 presentation...

1 https://openid.net/specs/openid-connect-core-1_0.html

OAuth 2.0

- open standard to authorization (not authentication)
  - RFC 6749: *The OAuth 2.0 Authorization Framework*
- specifically designed for use with HTTP![1]
  - extensive use of re-directions (imposed on User-Agent, e.g. web browser)
- more *Framework* than *Specification* with optional and undefined parts and many possible extensions, so that
  - is "*likely to produce a wide range of non-interoperable implementations*"!
- uses *authorization grants* and *access tokens* opaque to the applications
- not an authentication protocol, but implicitly includes it:[2]
  - OpenID Connect extends OAuth
    - supplies *identification tokens (*got from Authentication Providers)
      - that represent the user and contain user info (claims)

1 RFC 6749 (1. Introduction): «*This specification is designed for use with HTTP ([RFC2616]). The use of OAuth over any protocol other than HTTP is out of scope*.»

2 more than what one would say by "of course!..."

...OAuth 2.0...

Example of general usage:

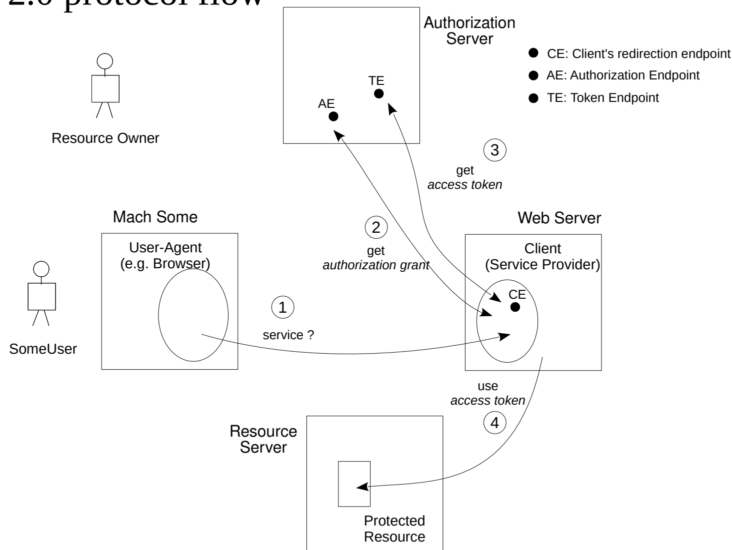
- Alice can grant a Printing service access to her protected photos stored at Bob's Photo-sharing service, without sharing her username and password with the Printing service:
  - *she authenticates herself with a server trusted by Bob's Photo-sharing service, authorizes the terms of the requested access to her photos and the server issues the Printing service delegation-specific credentials*

OAuth 1.0

- published as RFC 5849, was the result of a small *ad hoc* community effort
- OAuth 2.0 builds on OAuth 1.0 deployment experience, but is not backward compatible with it and shares with it very few implementation details.
  - «*When compared with OAuth 1.0, the 2.0 specification is more complex, less interoperable, less useful, more incomplete, and most importantly, less secure.*» (Eran Hammer, initial lead author and editor of OAuth 2.0 and lead author of OAuth 1.0)

Definitions

- **Entities**:[1] participating in OAuth's 2.0 protocol flow
  - Resource Owner[2]
  - Resource Server
  - Client (Application)
  - Authorization Server



1 *Roles* in RFC 6749's parlance
2 The SomeUser in the picture, do no need to be the Resource Owner; however, in practice, the workflows of OAuth2 make it mandatory.

- **(Authorization) Grants**: credentials that express consent from Resource Owner to access their Resource
  - authorization code type (preferred)
  - implicit type (not advised)
  - resource owner password credentials type (not advised)
  - client credentials type (preferred for Machine-to-Machine)
- **Token**: data object representing authenticated, authorized or delegated security state
  - Access Token
  - Bearer Token (variant of *access token*)
  - Refresh Token (for getting a new *access token*)
- **Endpoint**: HTTP resource[1] where exchange of security information takes place
  - Authorization endpoint (for getting grants)
  - Token endpoint (for getting tokens)
  - Client endpoint

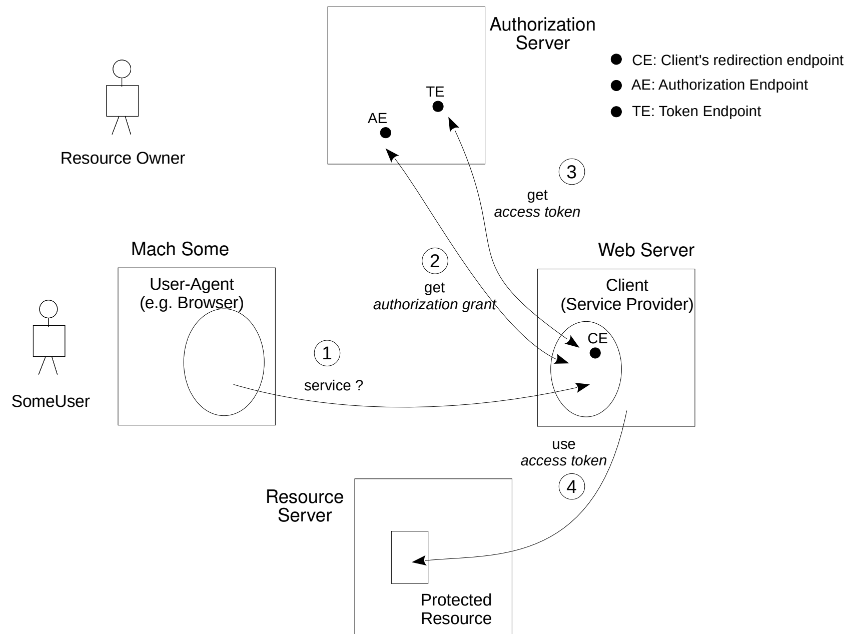
1 URI (Uniform Resource Identifier)

OAuth2's roles

- Resource Owner (if person: User, End-User)
    - determines who and how can access Resource (Object)
    - e.g. Alice has her photos stored in Bob's Photo-sharing service
- Resource Server
    - controls access to Resource by abiding Resource Owner's directives expressed in an access token
    - e.g. Bob's Photo-sharing service grants access to Alice's photos to whom presents a valid access token
- Client (Application)
    - may access protected resources if Resource Owner consents
    - e.g. Printing service accesses Alice's photos (in Bob's Photo-sharing service) only with Alice's consent (expressed in an access token)
    - ... *continues...*

...OAuth 2.0: roles...

- ... *continued*...
- Authorization Server
  - emits access token after Resource Owner's authentication and consent
  - e.g. Printing service asks Authorization Server for an access token to Alice's photos (stored in Bob's Photo-sharing service); Authorization Server will give the access token only after authenticating Alice[1] and getting Alice's consent



1 possibly in an Authentication Server

Authorization Grants

- Authorization Grant
  - credential representing the Resource Owner's authorization to access their protected resources
  - Client needs it for asking Access Token from Authorization Server
    - with Access Token, Client may access Resource
- Access flow depending on Grant types
  - authorization code:[1] 2 steps [FIG-G:AC]
    - 1st: Client gets *authorization code* from Authorization Server, through User-agent (redirect)
    - 2nd: Client gets *access token* from Authorization Server
  - ... *continues*...

1 Preferred, specially when paired with PKCE (Proof Key for Code Exchange) - see ahead.

...OAuth 2.0: access flow depending on Grant types...

- *... continued...*
- implicit:[1] 1 step [FIG-G:I]
  - Client gets *access token* from Authorization Server, through User-agent (redirect)
- resource owner password credentials:[2] 2 steps [FIG-G:ROC]
  - 1st: Client gets *Resource Owner credentials* from Resource Owner through User-agent (redirect)
  - 2nd: Client gets *access token* from Authorization Server
- client credentials:[3] 1 step [FIG-G:CC]
  - Client gets *access token* from Authorization Server, if had previous Grant or works for Resource Owner
- (other, anticipated by extensibility mechanism)

1 Not advised, as exposes tokens to unauthorized scripts, browser history logs and interception. Deprecated in OAuth 2.1.
2 Not advised, as the user's credentials are exposed to the client! Deprecated in OAuth 2.1.
3 Preferred for Machine-to-Machine (no User involved).

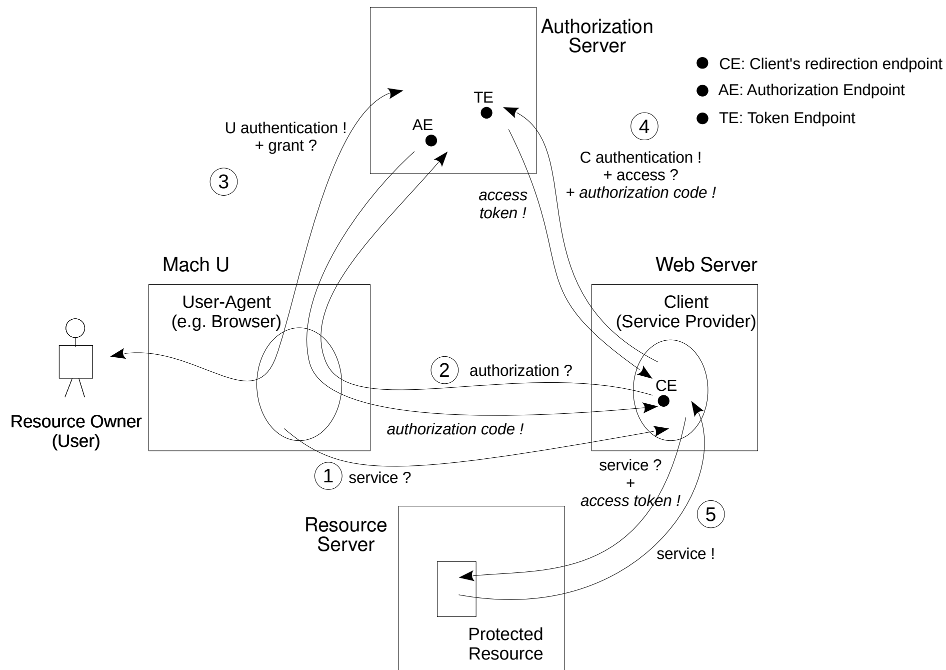


Fig-G:AC. OAuth 2.0 scenario with Grant type *authorization code*.

...OAuth 2.0: grant types…

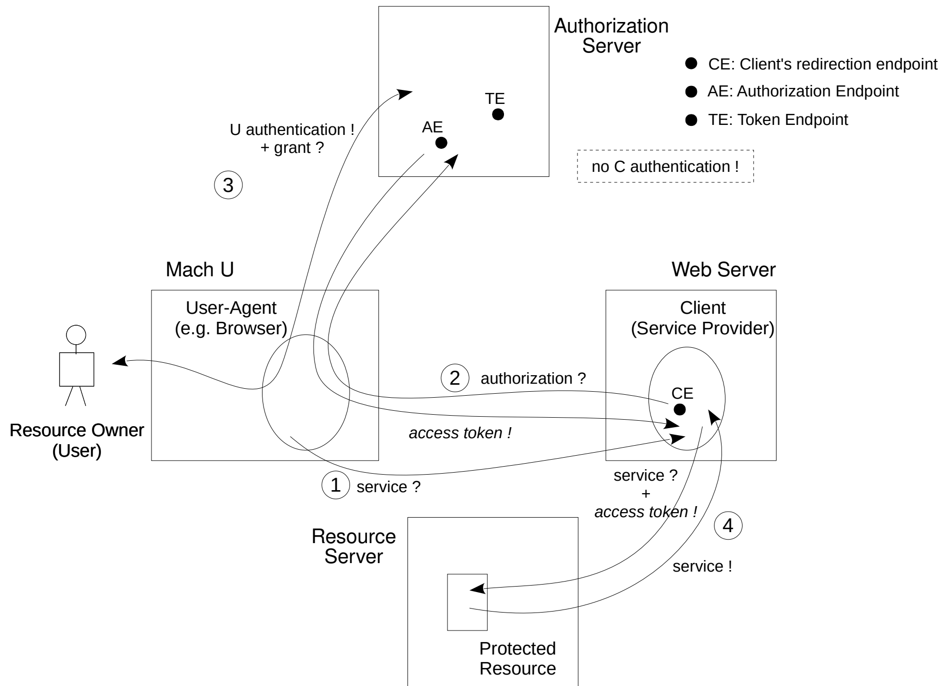


Fig-G:I. OAuth 2.0 scenario with Grant type *implicit*.

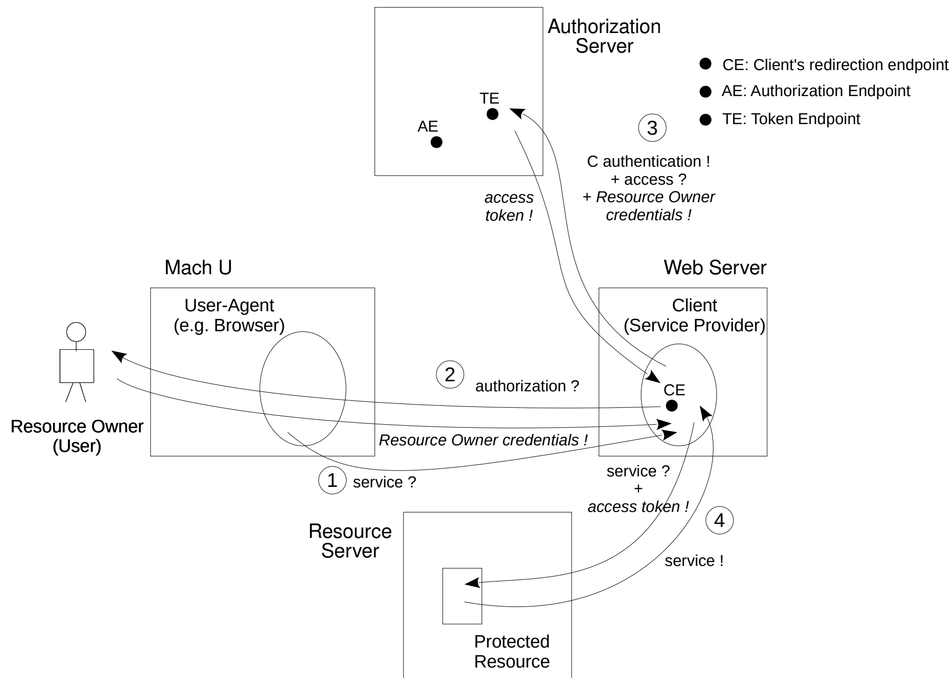


Fig-G:ROC. OAuth 2.0 scenario with Grant type *resource owner password credentials*.

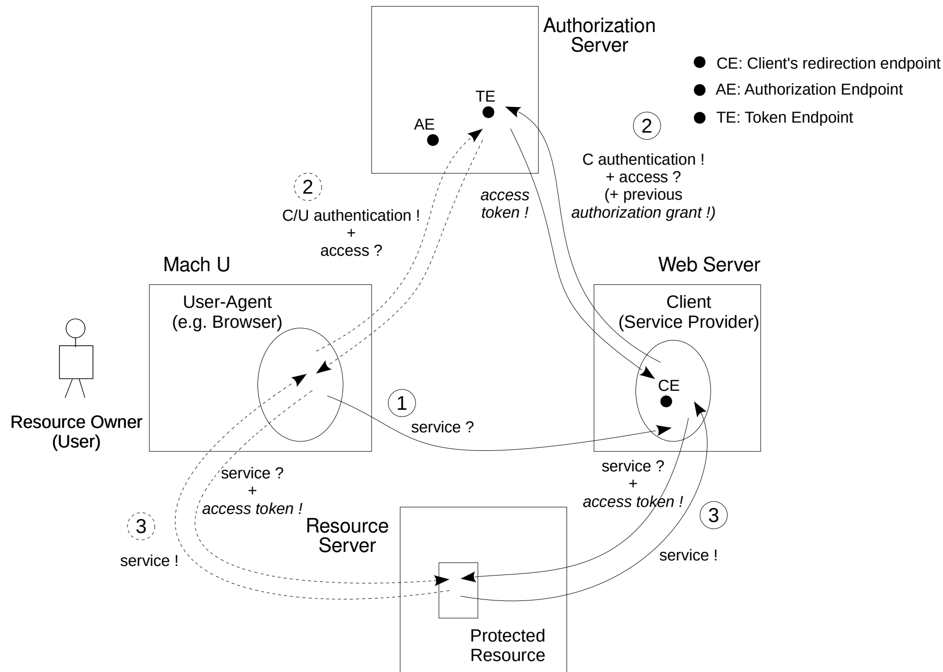


Fig-G:CC. OAuth 2.0 two scenarios with Grant type *client credentials*.

Endpoints

- HTTP resources (URI) where exchange of security information takes place
- Authorization Server endpoints:
  - 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
- Client endpoint:
  - Redirection endpoint
    - used by the Authorization Server to return responses containing authorization credentials to the Client via the Resource Owner's User-agent
    - presented when making the authorization request, OR
    - established during the (optional) client registration process

Tokens

- data objects representing authenticated, authorized or delegated security state
  - portable security items, carrying trust assertions, usable by other entities
- examples: Kerberos tickets, OAuth access tokens, OpenID Connect ID tokens

Token types

- Access Token
  - credential used to access a (protected) resource
    - contains:
      - delegated authorization
      - scopes/permissions of resource usage
      - validity date
    - generally, is opaque (to Client)
    - may be cryptographically signed

...OAuth 2.0: token types...

- Bearer Token
  - type of Access Token that
  - using it does not require any other proof, besides its possession!
- Refresh Token
  - credential used to obtain a new Access Token[1]
    - useful to extend the life of the initial Access Token
  - generated by the Authorization Server and given with the (initial) Access Token
    - used only with authorization servers (is not sent to Resource Servers)

1 identical to or with less privileges than the initial Access Token!

Clients

- applications that need to access protected Resources
  - for that they must get an *access token* from an Authorization Server
  - which, in general,[1] demands the Client to authenticate
- Client types depend on their ability to perform a secure authentication:[2]
  - confidential type - able to perform secure authentication
  - public type - unable to to perform secure authentication
- Client profiles
  - web application - confidential client running on a web server
  - user-agent-based application - public client running in User-agent[3]
  - native application - public client installed and executed on User device
- each Client gets an Identifier[4] from the Authorization Server upon Client registration

1 an exception arises with the *Implicit Grant* type
2 secure as specified by the Authorization Server
3 e.g. Java applets or JavaScript code
4 is not a secret!

...OAuth 2.0...

***Clients' Registration*[1]**

- is optional, except for
  - public clients or confidential clients using Implicit Grant type
- if not used
  - necessary operational details are beyond the scope of RFC 6749's specification
- if used, is done initially with the Authorization Server
  - Client will specify:
    - type
    - redirection endpoint, for receiving *access token*[2]
    - other information (e.g., application name, website, description...)
  - Authorization Server will return to Client:
    - Identifier - unique string; not a secret
    - Secret – to establish set of client credentials[3] for future authentications with the authorization server

1 with Authorization Server
2 from Authorization Server (via Resource Owner's User-agent), in response to requests with *Authorization Code Grant* or *Implicit Grant*
3 e.g., password, public/private key pair

Additional Security: Proof Key for Code Exchange (PKCE)[1]

- RFC 7636: extension to OAuth 2.0's Authorization Code flow to prevent interception attacks
- basically, connects Step 1, getting grant, to Step2, getting access token, in Authorization Code flow
- Client initiative, supported by Authorization Server [FIG]:[2]
  - nonce: *code_verifier*
    - 43-126 char random string
  - ~hash(nonce): *code_challenge*
    - `BASE64URL-ENCODE (SHA256 (ASCII (`*code_verifier*`)))`

1 pronounced "*pixie*"
2 RFC 7636's parlance: *code_verifier, code_challenge*

...OAuth 2.0: PKCE...

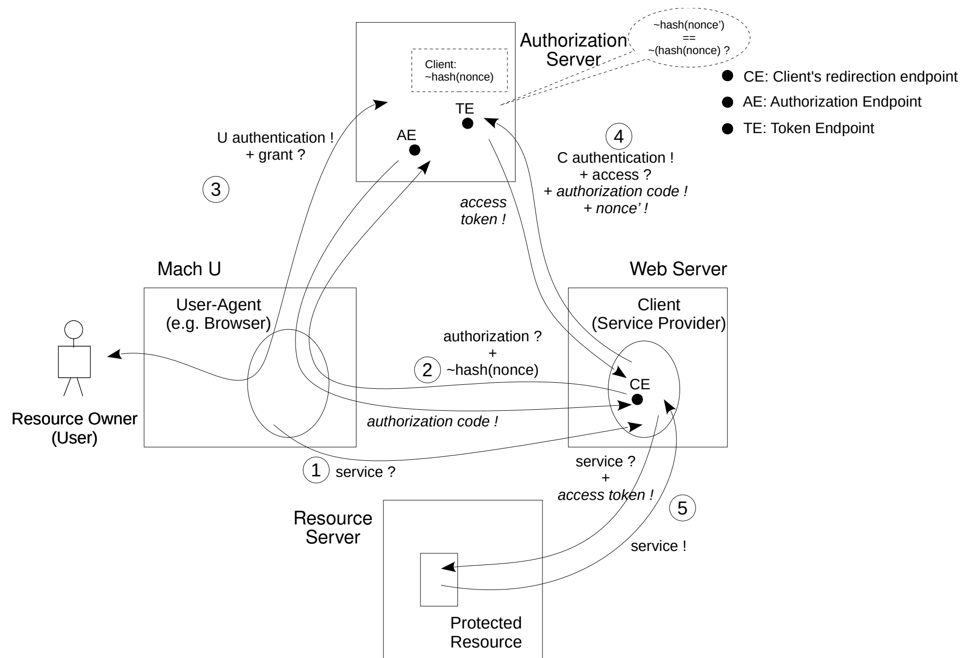


Fig. OAuth 2.0 scenario with Authorization Code grant protected with Proof Key for Code Exchange (PKCE).

Additional Security: Introspection Endpoint

- RFC 7662: extension to OAuth 2.0's to allow Resource Server to query the Authorization Server about opaque access tokens[1]
- basically,
  - when Client sends (opaque) access token to Resource Server,
  - Resource Server may send it to the Introspection Endpoint at the Authorization Server asking for additional info;
  - Authorization Server checks its database and responds;
  - if satisfied, Resource Server processes the access request to Resource.

Introspection Response example

```
HTTP/1.1 200 OK
Content-Type: application/json {
  "active": true,
  "scope": "read write",
  "client_id": "my_client_app",
  "username": "alice@example.com",
  "token_type": "Bearer",
  "exp": 1782570000,
  "sub": "user_12345"
}
```

1 e.g. know if they are (still) valid

OpenID Connect (cont.)

Authentication

- End-User
  - login (SSO)[1]
  - get user consent: interactive user interface
  - result is *ID Token*
- Client
  - "normal", diverse methods[2]

1 eventually, using FIDO2
2 HTTP Basic authentication scheme, shared key (client_secret), public key...

...OpenID Connect (cont.): authentication...

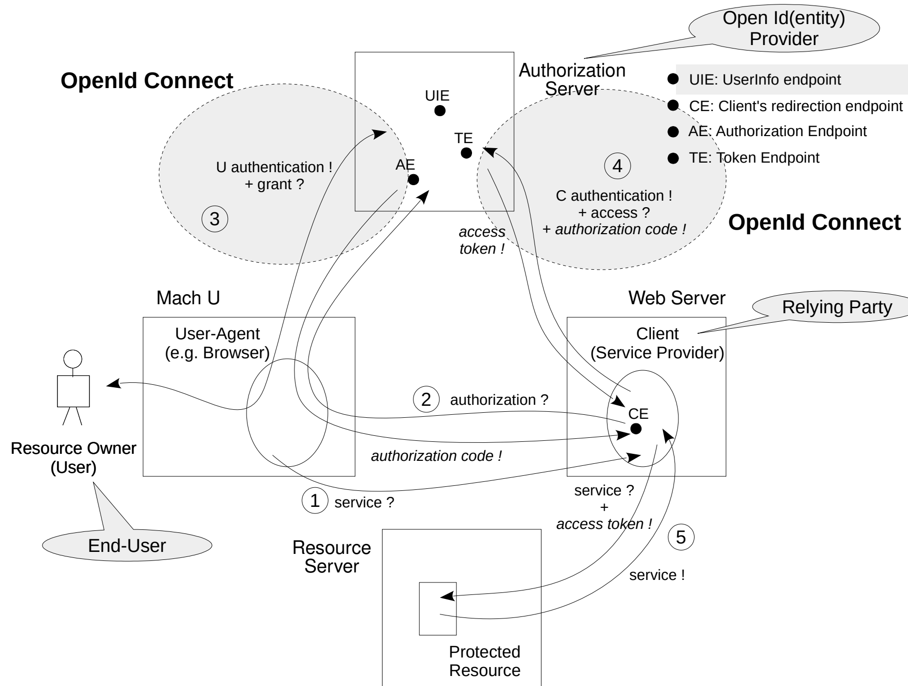


Fig. OpenId Connect meets OAuth2 in typical Authorization Code Grant workflow.

User info

ID Token

- security token given to Client/Relying Party with Claims about the End-User
- represented as JSON Web Token (JWT)

UserInfo Endpoint

- resides in Auhtorization Server/OpenId Provider
- known through *OpenID Provider's Discovery Metadata Document*[1]
- used by Client for getting some additional information about User (e.g. profile information, identity attributes)[2]
  - typical usage in FIG
- typical examples of user-related requests/ responses further down

1 e.g. in https://idp.example.com/.well-known/openid-configuration
2 For privacy and size reasons, Id Token does not contain all User information gathered during User authentication.

...OpenID Connect (cont.): UserInfo Endpoint...

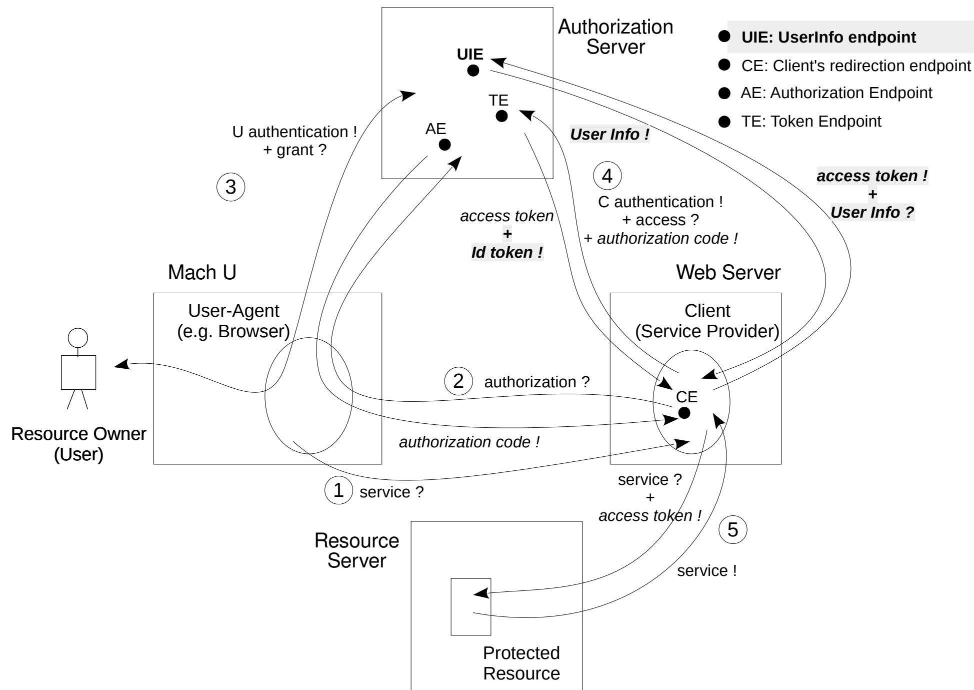


Fig. OpenId Connect meets OAuth2: getting additional User info.

...OpenID Connect (cont.): UserInfo Endpoint...

Id token example

```
{
  "iss": "https://server.example.com",
  "sub": "24400320",
  "aud": "s6BhdRkqt3",
  "nonce": "n-0S6_WzA2Mj",
  "exp": 1311281970,
  "iat": 1311280970,
  "auth_time": 1311280969,
  "acr": "urn:mace:incommon:iap:silver"
 }
```

UserInfo Request example

```
GET /userinfo HTTP/1.1
Host: server.example.com
Authorization: Bearer SlAV32hkKG
```

Successful UserInfo Response example

```
HTTP/1.1 200 OK
Content-Type: application/json {
  "sub": "248289761001",
  "name": "Jane Doe",
  "given_name": "Jane",
  "family_name": "Doe",
  "preferred_username": "j.doe",
  "email": "janedoe@example.com",
  "picture": "http://example.com/janedoe/me.jpg"
 }
```

Unsuccessful UserInfo Response example

```
HTTP/1.1 401 Unauthorized
 WWW-Authenticate: Bearer error="invalid_token",
   error_description="The Access Token expired"
```

OAuth 2.0: User ≠ Resource Owner

- standard OAuth 2.0 Authorization Code Flow *cannot function on its own* because the User Requester cannot log in to give consent on behalf of the Owner!
- solution:
  - Resource Delegation/Policy Creation (by Owner)
  - +
  - Resource Access (by Requester)
- main approach:
  - User-Managed Access (UMA 2.0)
- other, practical approaches:
  - Client Credentials with Internal ACL[1] - *Enterprise Way*
  - Shareable Invitation Links - *Consumer Way*

1 Access Control Lists

User-Managed Access (UMA 2.0)

- extension of OAuth 2.0 specifically designed for this exact scenario
- centralized Authorization Server acts as Policy Decision Point

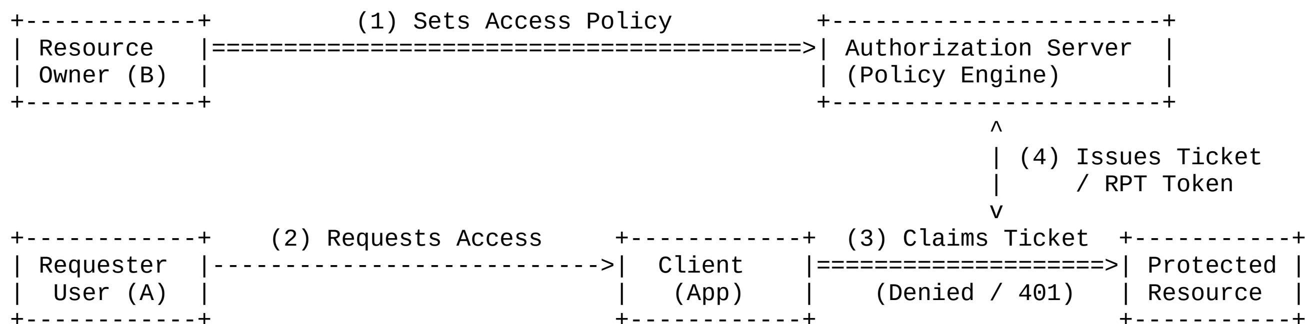


Fig. Basic interaction in User-Managed Access solution. (Explanation below.)

UMA's Flow:

1. Create Policy: Resource Owner (User B) logs into the Authorization Server and defines policies. E.g. *"Allow User A to read my file."*
2. Do Request: Requester (User A) uses Browser to contact Client App and access other user's resource. E.g. *"I want to access User B's file."*
3. Create Ticket: Client attempts to fetch resource from Resource Server; access is denied, as User A is not Owner, but a *Permission Ticket*[1] is returned.
4. Issue Token: Client takes Ticket to Authorization Server, which checks User B's saved policy against User A's identity. If permission criteria are met, Authorization Server issues special access token, *Requesting Party Token* (RPT).
5. Use Resource: (After some redirects with User A browser in between) Client uses RPT to "convince" Resource Server to let User B's resource be accessed.

1 unique tracking identifier

Client Credentials with Internal ACLs

- the *Enterprise Way*!
- both users in same platform:
  - no need for complex OAuth flows! Handle authorization internally.
- flow example:
  1. Do Request: User A asks the Client App to access User B's resource.
  2. App Authentication: Client uses own credentials[1] to bypass user-level login screen prompts
  3. Internal Check: Resource Server receives request, reads its internal database or Access Control List (ACL) and checks permissions. E.g. *"Is User A authorized by system rules to see User B's data?"*
  4. Use Resource: If permission is right, User B's resource is accessed.

1 similar to OAuth2 *Client Credentials Flow*!

Shareable Invitation Links

- the *Consumer Way*!
- commonly used in platforms like Google Drive and Dropbox:
  - no need for complex OAuth flows! Handle authorization current, available tools.
- flow example:
  1. Share Resource: Owner User B clicks webpage button "Share" and generates a unique, cryptographically signed URL or an internal invitation token for User A.
  2. Do Request: User A clicks the link using own Browser (getting invitation token).
  3. User Authentication: If needed, User A logs into Client/application, creating a session; anyway, invitation token is forwarded to Client/App.
  4. Use Resource: In Resource Server, Client binds User B's invitation token with User A's permission in database; if succesful, access to Resource is granted.

Pointers...

- “**OAuth 2.0 Authorization Framework**”, 2012 - D. Hardt (Editor)
  - tools.ietf.org/html/rfc6749
- “**Proof Key for Code Exchange by OAuth Public Clients**”, 2015 - N. Sakimura (Editor) et al.
  - tools.ietf.org/html/rfc7636
- “**OpenID Connect Core 1.0**”, incorporating errata set 2, 2023 - OpenID Foundation
  - openid.net/specs/openid-connect-core-1_0.html
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- “**User-Managed Access (UMA) 2.0 Grant for OAuth 2.0 Authorization**”, v.2, 2018 - M. Machulak, J. Richer (Eve Maler, Editor)
  - docs.kantarainitiative.org/uma/wg/rec-oauth-uma-grant-2.0.html