A private mode for OpenID Connect

Sven Hammann   Ralf Sasse   David Basin

OAuth Security Workshop, July 2017

Brief Introduction to OAuth 2.0 and OpenID Connect

- OAuth 2.0: Authorizing third-party applications (relying parties) to access resources

Brief Introduction to OAuth 2.0 and OpenID Connect

- OAuth 2.0: Authorizing third-party applications (relying parties) to access resources

- Authorization Server hands out access token to the relying party (RP)

Brief Introduction to OAuth 2.0 and OpenID Connect

- OAuth 2.0: Authorizing third-party applications (relying parties) to access resources
- Authorization Server hands out access token to the relying party (RP)
  - RP must be registered at the authorization server
  - Used to access the resources at the resource provider
  - Authorization server and resource provider may be the same

Brief Introduction to OAuth 2.0 and OpenID Connect

- OpenID Connect builds an authentication layer on top (single sign-on)

Brief Introduction to OAuth 2.0 and OpenID Connect

- OpenID Connect builds an authentication layer on top (single sign-on)
- Authorization server is now also an identity provider (IdP)

Brief Introduction to OAuth 2.0 and OpenID Connect

- OpenID Connect builds an authentication layer on top (single sign-on)
- Authorization server is now also an identity provider (IdP)
- IdP hands out an id token

Brief Introduction to OAuth 2.0 and OpenID Connect

- OpenID Connect builds an authentication layer on top (single sign-on)
- Authorization server is now also an identity provider (IdP)
- IdP hands out an id token
  - Signed Json Web Token (JWT)
  - Asserts the user's identity at the IdP
  - Contains user info

Brief Introduction to OAuth 2.0 and OpenID Connect

- OpenID Connect builds an authentication layer on top (single sign-on)
- Authorization server is now also an identity provider (IdP)
- IdP hands out an id token
  - Signed Json Web Token (JWT)
  - Asserts the user's identity at the IdP
  - Contains user info
- Can be combined with standard OAuth 2.0
  - Both *token* (access token) and *id_token* handed out

Brief Introduction to OAuth 2.0 and OpenID Connect

Example *id_token*:

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

Motivation of our work

- The IdP learns at which Relying Parties (RPs) the user logs in

Motivation of our work

- The IdP learns at which Relying Parties (RPs) the user logs in
- This does not respect the user's privacy

Motivation of our work

- The IdP learns at which Relying Parties (RPs) the user logs in

- This does not respect the user's privacy
  - User's activities over multiple RPs can be tracked
  - User might not want anyone to know which service they are using
  - Especially if using the RP might provide sensitive information

Motivation of our work

- The IdP learns at which Relying Parties (RPs) the user logs in
- This does not respect the user's privacy
  - User's activities over multiple RPs can be tracked
  - User might not want anyone to know which service they are using
  - Especially if using the RP might provide sensitive information
    - Alcoholics Anonymous
    - Medical Forums

Motivation of our work

- The IdP learns at which Relying Parties (RPs) the user logs in
- This does not respect the user's privacy
  - User's activities over multiple RPs can be tracked
  - User might not want anyone to know which service they are using
  - Especially if using the RP might provide sensitive information
    - Alcoholics Anonymous
    - Medical Forums
- Our solution: We propose a new mode that hides the RP's identity from the IdP

Incentives for participants

- Incentives for RPs to support the mode

Incentives for participants

- Incentives for RPs to support the mode
  - Provide sensitive service to users: Interested in user's privacy
  - Protect their own data: Number of accesses

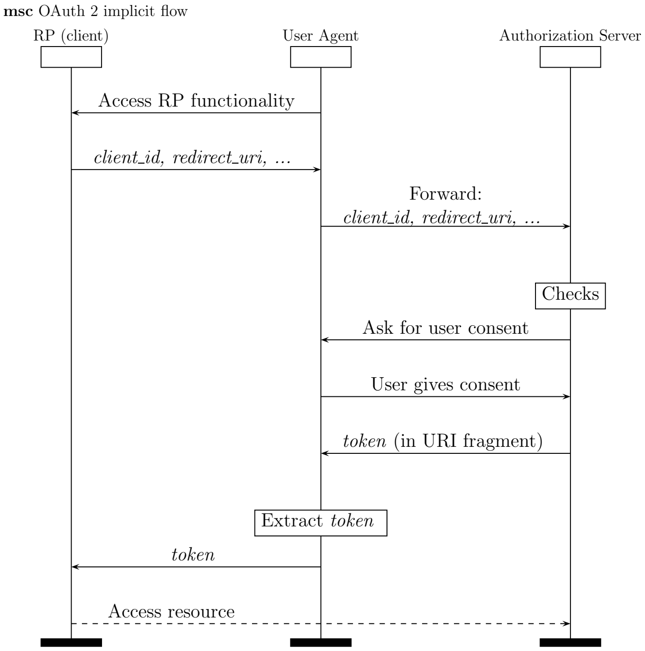
Incentives for participants

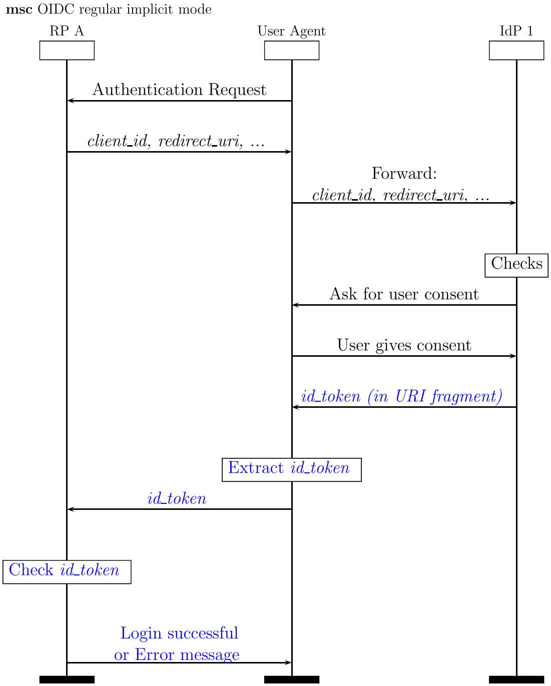
- Incentives for RPs to support the mode
  - Provide sensitive service to users: Interested in user's privacy
  - Protect their own data: Number of accesses
- Incentives for IdPs to support the mode

Incentives for participants

- Incentives for RPs to support the mode
    - Provide sensitive service to users: Interested in user's privacy
    - Protect their own data: Number of accesses

- Incentives for IdPs to support the mode
    - Data minimization (fulfill regulatory requirements)
    - Improve public perception
    - Distinguishing feature to attract privacy-interested users


msc OAuth 2 implicit flow
RP (client)
User Agent
Authorization Server
Access RP functionality
client_id, redirect_uri, ...
Forward:
client_id, redirect_uri, ...
Checks
Ask for user consent
User gives consent
token (in URI fragment)
Extract *token*
token
Access resource



msc OIDC regular implicit mode
RP A
User Agent
IdP 1
Authentication Request
client_id, redirect_uri, ...
Forward:
client_id, redirect_uri, ...
Checks
Ask for user consent
User gives consent
id_token (in URI fragment)
Extract *id_token*
id_token
Check *id_token*
Login successful
or Error message

Privacy and Security Goals

- Privacy towards IdP: IdP cannot distinguish between logins to different RPs

Privacy and Security Goals

- Privacy towards IdP: IdP cannot distinguish between logins to different RPs
  - IdP cannot link repeated logins to the same RP
  - IdP only sees that the user logs in to *some* RP

Privacy and Security Goals

- Privacy towards IdP: IdP cannot distinguish between logins to different RPs
  - IdP cannot link repeated logins to the same RP
  - IdP only sees that the user logs in to *some* RP
- Security: Equivalent security to the implicit mode

Privacy and Security Goals

- Privacy towards IdP: IdP cannot distinguish between logins to different RPs
  - IdP cannot link repeated logins to the same RP
  - IdP only sees that the user logs in to *some* RP
- Security: Equivalent security to the implicit mode
  - All checks are still made and provide the same guarantees
  - No RP should be able to use an *id_token* to impersonate the user at another RP

Attacker model

- Honest-but-curious IdP

Attacker model

- Honest-but-curious IdP
  - IdP does not collude with the RP
  - Trusted JavaScript on the IdP frontend

Attacker model

- Honest-but-curious IdP
  - IdP does not collude with the RP
  - Trusted JavaScript on the IdP frontend

- Malicious RPs

Attacker model

- Honest-but-curious IdP
  - IdP does not collude with the RP
  - Trusted JavaScript on the IdP frontend
- Malicious RPs
  - Regarding security properties, not privacy
  - IdP does not collude even with malicious RPs

Attacker model

- Honest-but-curious IdP
  - IdP does not collude with the RP
  - Trusted JavaScript on the IdP frontend
- Malicious RPs
  - Regarding security properties, not privacy
  - IdP does not collude even with malicious RPs
- Secure end-to-end channels (TLS)

Problems to Solve

1. *id_token* must only be valid for one RP

Problems to Solve

1. *id_token* must only be valid for one RP
    - Otherwise, any RP could forward it to impersonate the user at another RP

Problems to Solve

1. *id_token* must only be valid for one RP
    - Otherwise, any RP could forward it to impersonate the user at another RP
    - How can the IdP create an *id_token* for one audience RP without knowing for which RP?

Problems to Solve

1. *id_token* must only be valid for one RP
   - Otherwise, any RP could forward it to impersonate the user at another RP
   - How can the IdP create an *id_token* for one audience RP without knowing for which RP?

2. User must give consent and *redirect_uri* must be checked

Problems to Solve

1. *id_token* must only be valid for one RP
   - Otherwise, any RP could forward it to impersonate the user at another RP
   - How can the IdP create an *id_token* for one audience RP without knowing for which RP?

2. User must give consent and *redirect_uri* must be checked
   - Requires client (RP) metadata to be looked up by the IdP

Problems to Solve

1. *id_token* must only be valid for one RP
   - Otherwise, any RP could forward it to impersonate the user at another RP
   - How can the IdP create an *id_token* for one audience RP without knowing for which RP?

2. User must give consent and *redirect_uri* must be checked
   - Requires client (RP) metadata to be looked up by the IdP
   - How can this be done if the IdP does not know the RP's identity?

Solution for the first problem

- Use a hashed pseudonym for the *client_id*

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- $\textit{client\_id\_hash} := \textit{h(client\_id, rp\_nonce, user\_nonce)}$

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- *client_id_hash* := *h(client_id, rp_nonce, user_nonce)*
  - *rp_nonce* is the nonce sent by the RP (also exists in regular mode)
  - *user_nonce* is generated by the user agent

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- *client_id_hash* := *h(client_id, rp_nonce, user_nonce)*
  - *rp_nonce* is the nonce sent by the RP (also exists in regular mode)
  - *user_nonce* is generated by the user agent
- Only the *client_id_hash* is sent to the IdP server

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- *client_id_hash* := *h(client_id, rp_nonce, user_nonce)*
  - *rp_nonce* is the nonce sent by the RP (also exists in regular mode)
  - *user_nonce* is generated by the user agent
- Only the *client_id_hash* is sent to the IdP server
  - *client_id* and *rp_nonce* are sent by the RP in the URI fragment
  - They are not forwarded to the IdP server
  - Hash is computed in IdP JavaScript

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- *client_id_hash* := *h(client_id, rp_nonce, user_nonce)*
  - *rp_nonce* is the nonce sent by the RP (also exists in regular mode)
  - *user_nonce* is generated by the user agent
- Only the *client_id_hash* is sent to the IdP server
  - *client_id* and *rp_nonce* are sent by the RP in the URI fragment
  - They are not forwarded to the IdP server
  - Hash is computed in IdP JavaScript
- IdP hands out a *private_id_token*

Solution for the first problem

- Use a hashed pseudonym for the *client_id*
- *client_id_hash* := *h(client_id, rp_nonce, user_nonce)*
  - *rp_nonce* is the nonce sent by the RP (also exists in regular mode)
  - *user_nonce* is generated by the user agent
- Only the *client_id_hash* is sent to the IdP server
  - *client_id* and *rp_nonce* are sent by the RP in the URI fragment
  - They are not forwarded to the IdP server
  - Hash is computed in IdP JavaScript
- IdP hands out a *private_id_token*
  - Contains no *aud* field but a *private_aud* field containing the *client_id_hash*
  - Cannot be confused with a regular *id_token* since *aud* field is mandatory

Solution for the first problem

Example *private_id_token*:

```
{
    "iss": "https://server.example.com",
    "sub": "24400320",
    "private_aud": "96f6696e4024d65fcb018a8f71badd
313f06e1481f142b29d4ba6f307bfc00e0",
    "exp": 1311281970,
    "iat": 1311280970,
    "auth_time": 1311280969
  }
```

Solution for the second problem

- Enable the RP to provide its own client metadata

Solution for the second problem

- Enable the RP to provide its own client metadata
- To ensure its validity, it must be signed by the IdP

Solution for the second problem

- Enable the RP to provide its own client metadata
- To ensure its validity, it must be signed by the IdP
- New parameter sent by the RP: *client_id_binding*

Solution for the second problem

- Enable the RP to provide its own client metadata
- To ensure its validity, it must be signed by the IdP
- New parameter sent by the RP: *client_id_binding*
  - JWT signed by the IdP
  - Given to RP when it registers at the IdP
  - Contains a *client_id* with metadata belonging to that RP

Solution for the second problem

- Enable the RP to provide its own client metadata
- To ensure its validity, it must be signed by the IdP
- New parameter sent by the RP: *client_id_binding*
  - JWT signed by the IdP
  - Given to RP when it registers at the IdP
  - Contains a *client_id* with metadata belonging to that RP
- *client_id_binding* is used by user agent

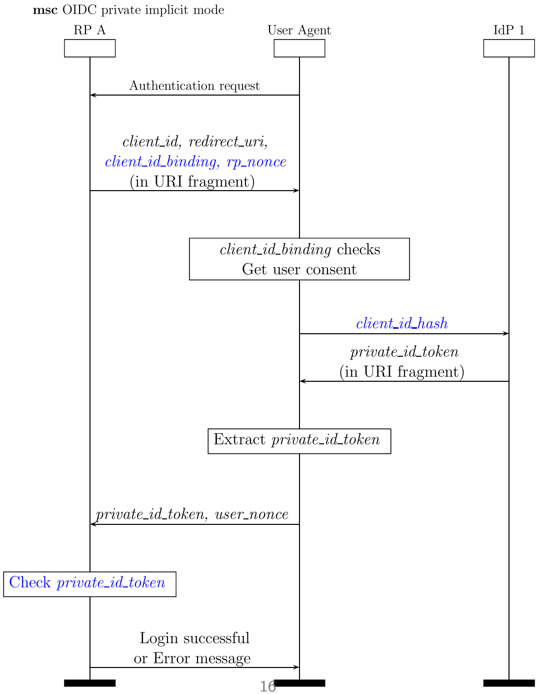
Solution for the second problem

- Enable the RP to provide its own client metadata
- To ensure its validity, it must be signed by the IdP
- New parameter sent by the RP: *client_id_binding*
  - JWT signed by the IdP
  - Given to RP when it registers at the IdP
  - Contains a *client_id* with metadata belonging to that RP
- *client_id_binding* is used by user agent
  - Sent in URI fragment
  - Checks done by IdP JavaScript can access *client_id_binding*
  - No need to look up metadata on the IdP server

Solution for the second problem

Example *client_id_binding*:

```
{
    "client_id": "s6BhdRkqt3",
    "client_name": "Example RP",
    "redirect_uris":
        ["https://rp.example.org/callback",
         "https://rp.example.org/callback2"],
     "logo_uri": "https://rp.example.org/logo.png"
  }
```


msc OIDC private implicit mode
RP A
User Agent
IdP 1
Authentication request
client_id, redirect_uri,
client_id_binding, rp_nonce
(in URI fragment)
client_id_binding checks
Get user consent
client_id_hash
private_id_token
(in URI fragment)
Extract private_id_token
private_id_token, user_nonce
Check private_id_token
Login successful
or Error message

Privacy result

- *client_id_hash* contains randomly generated *user_nonce*
    - Looks random to the IdP

Privacy result

- *client_id_hash* contains randomly generated *user_nonce*
  - Looks random to the IdP

- No other parameters sent to the IdP

Security preservation

- *redirect_uri* check equivalent to regular implicit mode

Security preservation

- *redirect_uri* check equivalent to regular implicit mode
- End-user consent equivalent to regular implicit mode

Security preservation

- *redirect_uri* check equivalent to regular implicit mode
- End-user consent equivalent to regular implicit mode
- Check of *private_aud* equivalent to check of *aud* in regular implicit mode

Security preservation

- *redirect_uri* check equivalent to regular implicit mode
- End-user consent equivalent to regular implicit mode
- Check of *private_aud* equivalent to check of *aud* in regular implicit mode
- *rp_nonce* not explicitly part of *private_id_token*, but contained in hash

Security preservation

- *redirect_uri* check equivalent to regular implicit mode
- End-user consent equivalent to regular implicit mode
- Check of *private_aud* equivalent to check of *aud* in regular implicit mode
- *rp_nonce* not explicitly part of *private_id_token*, but contained in hash
- Modes in parallel: Messages cannot be confused
  - *private_id_token* is not a valid *id_token*

Unsupportable OIDC Features

- OAuth access *token*

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy
  - *max_age, acr_values*: Could be (close to) unique for RP
  - *id_token_hint*: Allows logins to be linked together

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy
  - *max_age, acr_values*: Could be (close to) unique for RP
  - *id_token_hint*: Allows logins to be linked together
- Client metadata related to *id_token* generation

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy
  - *max_age*, *acr_values*: Could be (close to) unique for RP
  - *id_token_hint*: Allows logins to be linked together
- Client metadata related to *id_token* generation
  - e.g. *id_token_signed_response_alg*
  - IdP cannot look them up
  - Forwarding them could violate privacy
  - Default values are used

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy
  - *max_age*, *acr_values*: Could be (close to) unique for RP
  - *id_token_hint*: Allows logins to be linked together
- Client metadata related to *id_token* generation
  - e.g. *id_token_signed_response_alg*
  - IdP cannot look them up
  - Forwarding them could violate privacy
  - Default values are used
- Pairwise subject identifier

Unsupportable OIDC Features

- OAuth access *token*
  - Would require direct communication from RP to IdP
  - Not possible to preserve privacy
  - No UserInfo endpoint: Include all information in the *private_id_token*
- Parameters that could violate privacy
  - *max_age, acr_values*: Could be (close to) unique for RP
  - *id_token_hint*: Allows logins to be linked together
- Client metadata related to *id_token* generation
  - e.g. *id_token_signed_response_alg*
  - IdP cannot look them up
  - Forwarding them could violate privacy
  - Default values are used
- Pairwise subject identifier
  - Distinct *sub* identifier for each *(RP, user)* pair
  - To choose the right one the IdP must know the RP

Questions for the Audience

- Are there any fundamental problems with the approach?

Questions for the Audience

- Are there any fundamental problems with the approach?
- How important are the unsupported features?

Questions for the Audience

- Are there any fundamental problems with the approach?
- How important are the unsupported features?
  - Are there optional parameters that are often used in practice?
  - What privacy do we lose by not supporting the pairwise subject identifier?

Questions for the Audience

- Are there any fundamental problems with the approach?
- How important are the unsupported features?
  - Are there optional parameters that are often used in practice?
  - What privacy do we lose by not supporting the pairwise subject identifier?
- How realistic is the assumption to trust the JavaScript on the IdP frontend?

Questions for the Audience

- Are there any fundamental problems with the approach?
- How important are the unsupported features?
  - Are there optional parameters that are often used in practice?
  - What privacy do we lose by not supporting the pairwise subject identifier?
- How realistic is the assumption to trust the JavaScript on the IdP frontend?
  - Is there a better way to accomplish the checks in the user agent? (Browser extension probably not feasible)

Questions for the Audience

- Are there any fundamental problems with the approach?
- How important are the unsupported features?
  - Are there optional parameters that are often used in practice?
  - What privacy do we lose by not supporting the pairwise subject identifier?
- How realistic is the assumption to trust the JavaScript on the IdP frontend?
  - Is there a better way to accomplish the checks in the user agent? (Browser extension probably not feasible)
- Would people (users, RPs, IdPs) be interested in this?