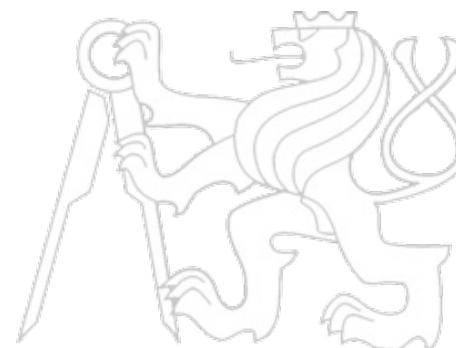


Middleware Architectures 2

Lecture 3: Security

doc. Ing. Tomáš Vitvar, Ph.D.

tomas@vitvar.com • @TomasVitvar • <https://vitvar.com>



Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • <https://vitvar.com/lectures>



Evropský sociální fond
Praha & EU investujeme do vaší budoucnosti

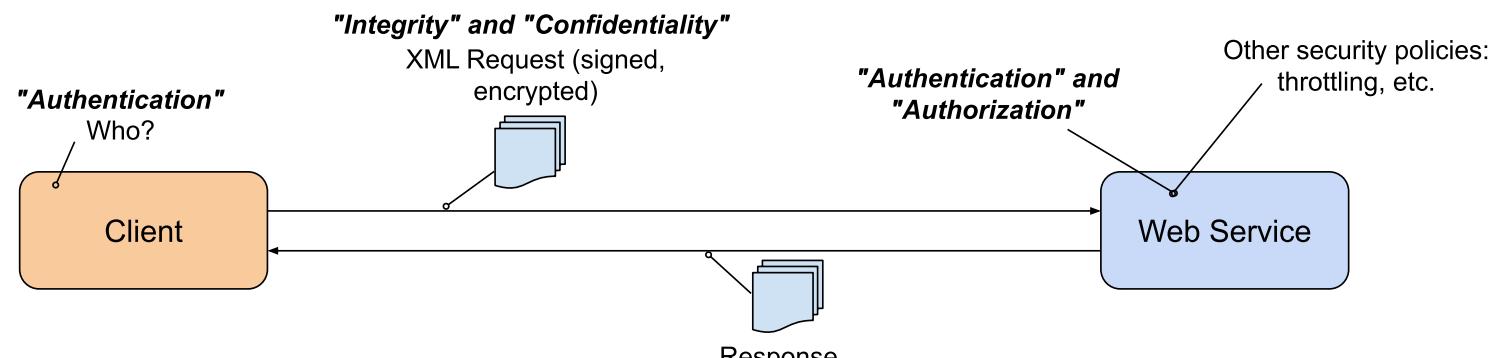
Modified: Mon Mar 10 2025, 06:59:34
Humla v1.0

Overview

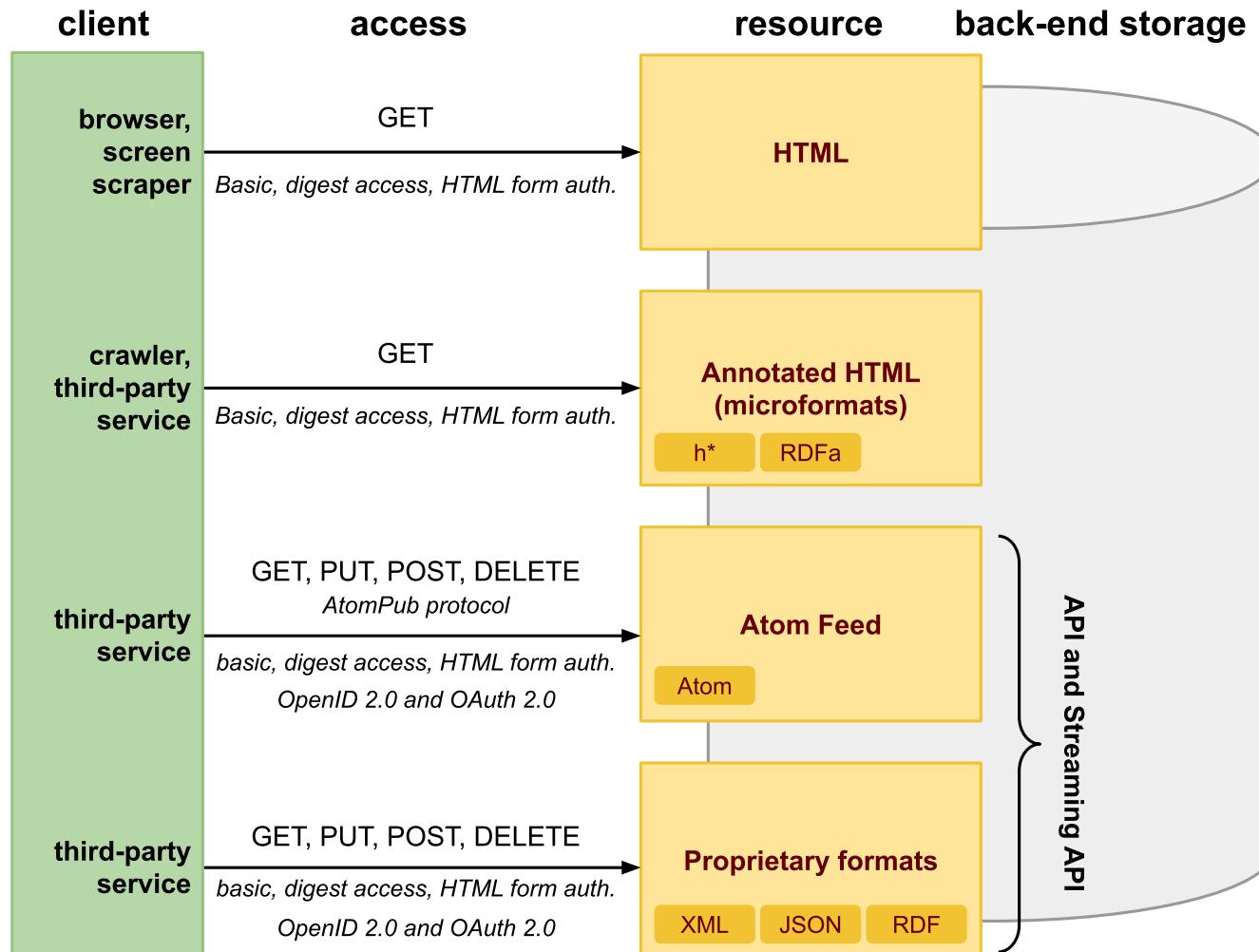
- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
- OpenID

Web Service Security Concepts

- Securing the client-server communication
 - *Message-level security*
 - *Transport-level security*
- Ensure
 - *Authentication* – verify a client's identity
 - *Authorization* – rights to access resources
 - *Message Confidentiality* – keep message content secret
 - *Message Integrity* – message content does not change during transmission
 - *Non-repudiation* – proof of integrity and origin of data



Data on the Web



Authentication and Authorization

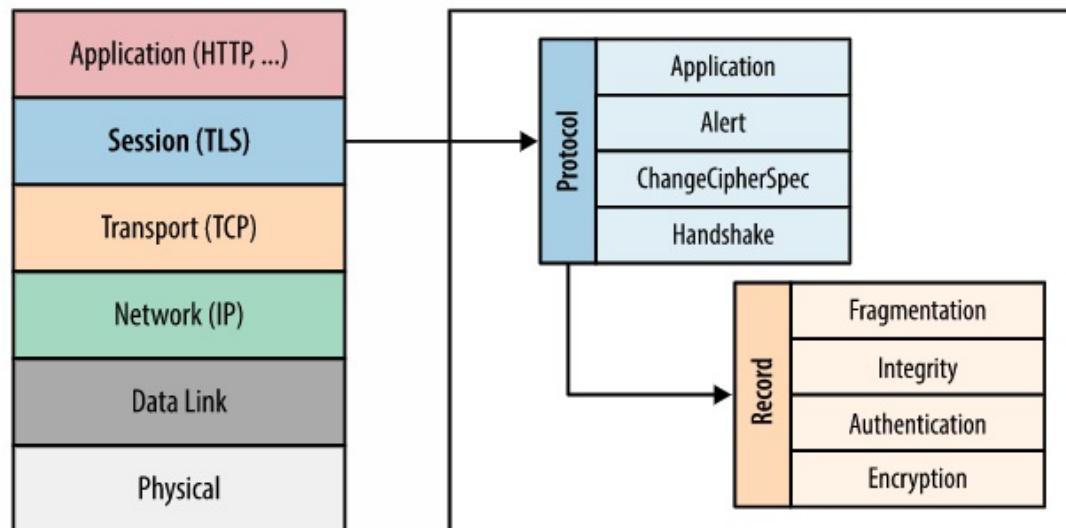
- Authentication
 - *verification of user's identity*
- Authorization
 - *verification that a user has rights to access a resource*
- Standard: HTTP authentication
 - *HTTP defines several main options*
 - *Basic Access Authentication*
 - *Digest Access Authentication*
 - *Bearer tokens to access OAuth 2.0-protected resources*
 - *Mutual authentication using password-based when server knows the user's encrypted password*
 - *Basic and Digest are defined in*
 - *RFC 2616: Hypertext Transfer Protocol – HTTP/1.1*
 - *RFC 2617: HTTP Authentication: Basic and Digest Access Authentication*
- Custom/proprietary: use of cookies

Overview

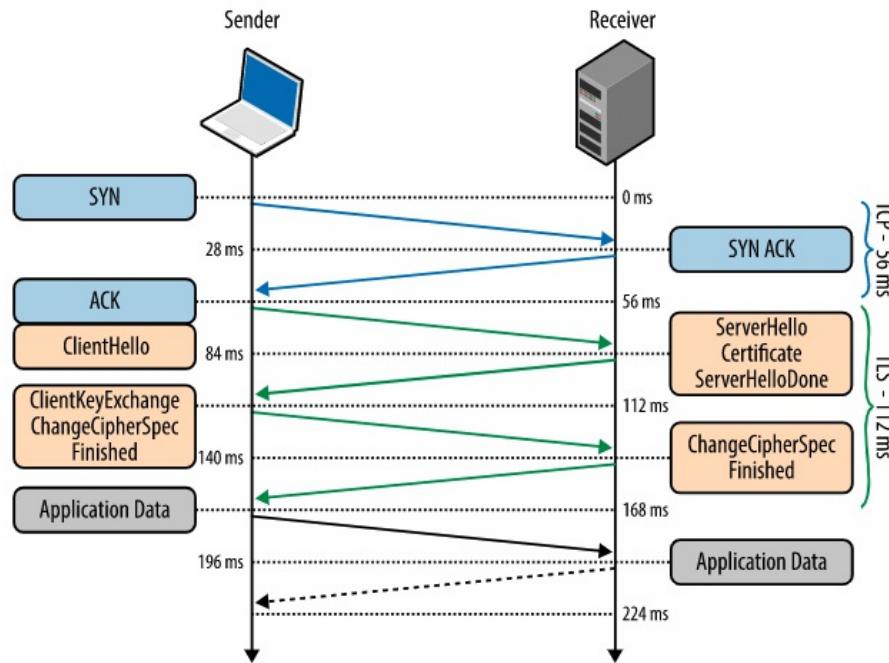
- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
- OpenID

Overview

- SSL and TLS
 - *SSL and TLS is used interchangeably*
 - *SSL 3.0 developed by Netscape*
 - *IETF standardization of SSL 3.0 is TLS 1.0*
→ *TLS 1.0 is upgrade of SSL 3.0*
 - *Due to security flaws in TLS 1.0, TLS 1.1 and TLS 1.2 were created*
- TLS layer



TLS Handshake Protocol



- TLS Handshake

56 ms: *ClientHello, TLS protocol version, list of ciphersuites, TLS options*

84 ms: *ServerHello, TLS protocol version, ciphersuite, certificate*

112 ms: *RSA or Diffie-Hellman key exchange*

140 ms: *Message integrity checks, sends encrypted "Finished" message*

168 ms: *Decrypts the message, app data can be sent*

TLS and Proxy Servers

- TLS Offloading
 - *Inbound TLS connection, plain outbound connection*
 - *Proxy can inspect messages*
- TLS Bridging
 - *Inbound TLS connection, new outbound TLS connection*
 - *Proxy can inspect messages*
- End-to-End TLS (TLS pass-through)
 - *TLS connection is passed-through the proxy*
 - *Proxy cannot inspect messages*
- Load balancer
 - *Can use TLS offloading or TLS bridging*
 - *Can use TLS pass-through with help of Server Name Indication (SNI)*

Overview

- Security Concepts
- Transport Level Security
- **JSON Web Token**
- OAuth 2.0
- OpenID

Overview

- JSON Web Token (JWT)
 - *Open standard (RFC 7519)*
 - *Mechanism to securely transmit information between parties as a JSON object.*
 - *Can be verified and trusted as it is digitally signed.*
- Basic concepts
 - *Compact*
 - *has a small size*
 - *can be transmitted via a URL, POST, HTTP header.*
 - *Self-contained*
 - *payload contains all required user information.*

Use of JWT

- Authentication
 - *After user logs in, following requests contain JWT token.*
 - *Single Sign On widely uses JWT nowadays*
- Information Exchange
 - *Signature ensures senders are who they say they are.*
 - *Message integrity – signature calculated using the header and the payload.*

JWT Structure

<header>.<payload>.<signature>

- Header

- Contains two parts, the type of the token (JWT) and the hashing algorithm being used (e.g. HMAC, SHA256, RSA).

```
{  
  "alg": "HS256",  
  "typ": "JWT"  
}
```

- Payload

- Contains the claims, i.e. statements about an entity (e.g. user).
 - Can be registered, public and private
 - Registered and public should be defined in IANA JSON Web Token Registry

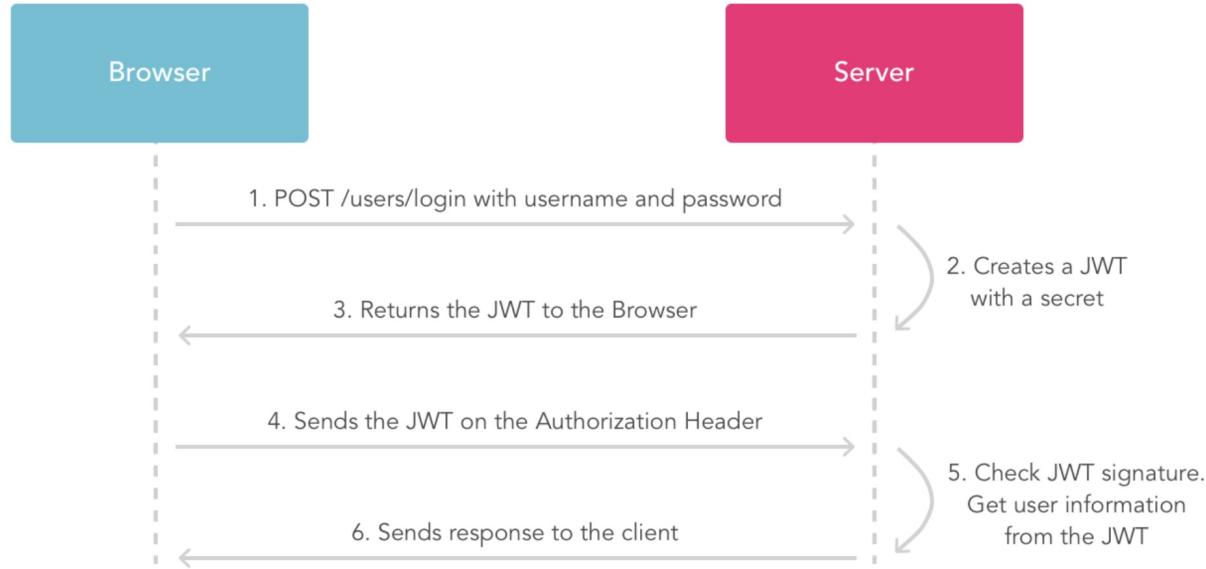
```
{  
  "sub": "1234567890",  
  "name": "John Doe",  
  "admin": true  
}
```

JWT Structure (Cont.)

- Signature
 - *Signed encoded header, encoded payload and a secret.*
 - *For example, signature using HMAC SHA256 algorithm*
- Example
 - *JWT is a three Base64-URL strings separated by dots*

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.  
eyJzdWIiOiIxMjM0NTY3ODkwIiwibmFtZSI6IkpvaG4  
gRG9lIiwiaXNTb2NpYWwiOnRydWV9.  
4pcPyMD09o1PSyXnrXCjTwXyr4BsezdI1AVTmud2fU4
```

How to use JWT



1. User sends username and password
2. Server verifies user, creates JWT token with a secret and a expiration time
3. Server sends JWT token back to the Browser
4. Browser sends JWT token on subsequent interations

Notes

- Authorization header does not behave the same as cookies!
- JWT should not contain secrets (passwords) as it can be read (on the client or if non-https connection is used)

Expiration and revocation

- Expiration
 - *Tokens should be valid for a limited time*
 - *Use exp claim*
 - *Timestamp of the token expiration*
 - *Token should be checked on every request*
- Revocation
 - *Tokens (access tokens) usually stored in memory*
 - *Tokens should be refreshed using refresh tokens*
 - *Refresh tokens are stored in the DB*
 - *When you need to revoke access tokens stored them in the DB*
 - *You can expire all tokens by changing the secret on the server*

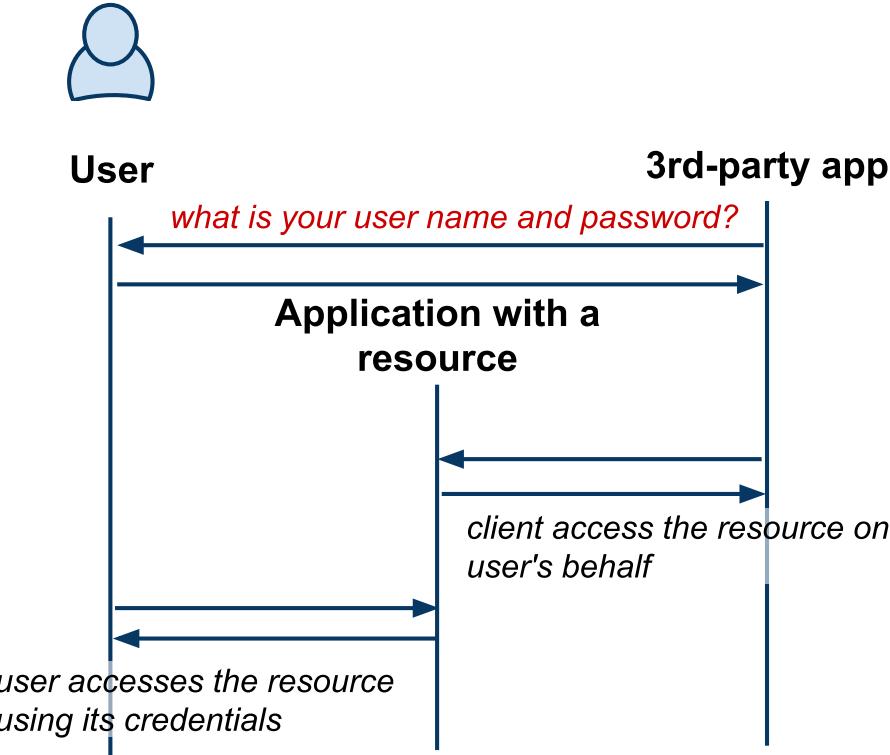
Overview

- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
 - *Client-side Web Apps*
 - *Server-side Web Apps*
- OpenID

Motivation

- Cloud Computing – Software as a Service
 - *Users utilize apps in clouds*
 - *they access resources via Web browsers*
 - *they store their data in the cloud*
 - *Google Docs, Contacts, etc.*
 - *The trend is that SaaS are open*
 - *can be extended by 3rd-party developers through APIs*
 - *attract more users ⇒ increases value of apps*
 - *Apps extensions need to have an access to users' data*
- Need for a new mechanism to access resources
 - *Users can grant access to third-party apps without exposing their users' credentials*

When there is no OAuth



- Users must share their credentials with the 3rd-party app
- Users cannot control what and how long the app can access resources
- Users must trust the app
 - *In case of misuse, users can only change their passwords*

OAuth 2.0 Protocol

- OAuth Objectives
 - users can grant access to third-party applications
 - users can revoke access any time
 - supports:
 - client-side web apps (implicit grant),
 - server-side apps (authorization code), and
 - native (desktop) apps (authorization code)
- History
 - Initiated by Google, Twitter, Yahoo!
 - Different, non-standard protocols first: ClientLogin, AuthSub
 - OAuth 1.0 – first standard, security problems, quite complex
 - OAuth 2.0 – new version, not backward compatible with 1.0
- Specifications and adoption
 - OAuth 2.0 Protocol [↗](#)
 - OAuth 2.0 Google Support [↗](#)

Terminology

- **Client**
 - *a third-party app accessing resources owned by resource owner*
- **Resource Owner (also user)**
 - *a person that owns a resource stored in the resource server*
- **Authorization and Token Endpoints**
 - *endpoints provided by an authorization server through which a resource owner authorizes requests.*
- **Resource Server**
 - *an app that stores resources owned by a resource owner*
 - *For example, contacts in Google Contacts*
- **Authorization Code**
 - *a code that a client uses to request access tokens to access resources*
- **Access Token**
 - *a code that a client uses to access resources*

Overview

- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
 - *Client-side Web Apps*
 - *Server-side Web Apps*
- OpenID

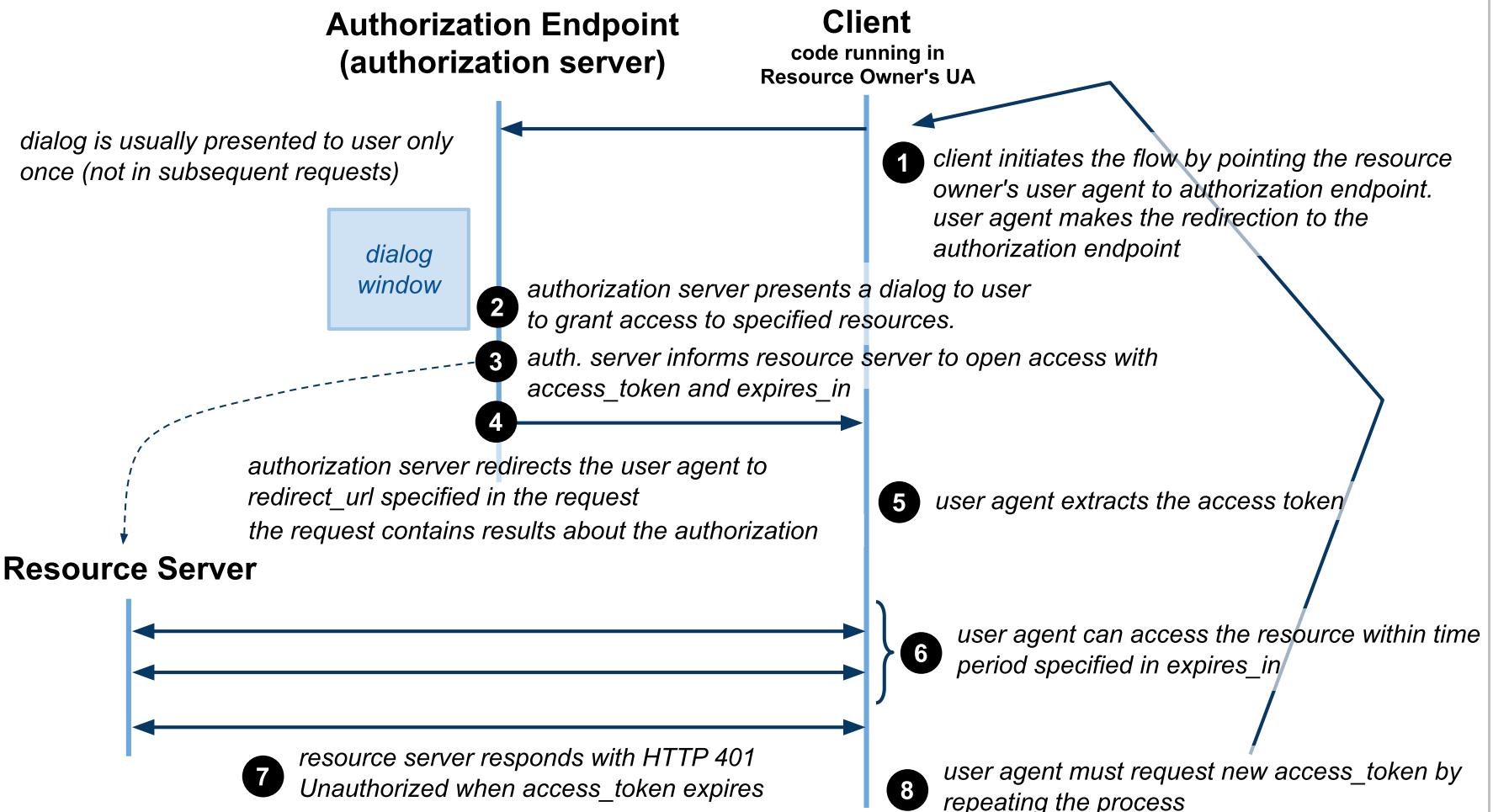
Client-side Web Apps

- Simplified version of OAuth 2.0 protocol
 - *JavaScript/AJAX apps running in a browser*
 - *Apps that cannot easily "remember" app state*
 - *limited number of interactions*
- Architecture
 - *User-agent processes a javascript/HTML code from the client*
 - *No need of authorization code*
- Basic Steps
 - *A client redirects a user agent to the authorization endpoint*
 - *A resource owner grants an access to the client*
 - or he/she rejects the request
 - *Authorization server provides an **access_token** to the client*
 - *Client access the resource with the **access_token***
 - *When the token expires, client requests a new token*

Demo – List of Contacts

- Display your Google contacts
 - *this demo requests authorization from you to access your Google contacts using client-side OAuth 2.0 protocol and then displays the contacts below. In order to transfer `access_token` from authorization window, it stores the `access_token` in a cookie.*
 - `access_token`
 - *Show contacts or revoke access*

Client-side Web Apps Protocol



Redirection – Step 1

- Methods and Parameters
 - *Methods: GET or POST*
 - *example authorization endpoint url (Google):*
`https://accounts.google.com/o/oauth2/auth`
 - *query string parameters or application/x-www-form-urlencoded*
 - `client_id` – *id of the client that was previously registered*
 - `redirect_uri` – *an URI that auth. server will redirect to when user grants/rejects*
 - `scope` – *string identifying resources/services to be accessed*
 - `response_type` – *type of the response (token or code)*
 - `state (optional)` – *state between request and redirect*
 - *Example*

```
1 | https://accounts.google.com/o/oauth2/auth?
2 | client_id=621535099260.apps.googleusercontent.com&
3 | redirect_uri=http://w20.vitvar.com/examples/oauth/callback.html&
4 | scope=https://www.google.com/m8/feeds&
5 | response_type=token
```

Callback – steps 4 and 5

- Resource owner grants the access
 - *authorization server calls back redirect_uri*
 - *client parses URL in JavaScript (Step 5)*
→ extracts `access_token` and `expires_in` (by using `window.location.hash`)
 - *Example:*

```
1 | https://w20.vitvar.com/examples/oauth/callback.html#
2 | access_token=1/QbZfgDNsnd&
3 | expires_in=4301
```

- Resource owner rejects the access
 - *authorization server calls back redirect_uri with query string parameter error=access_denied*
 - *Example:*

```
1 | http://w20.vitvar.com/examples/oauth/callback.html?
2 | error=access_denied
```

Accessing Resources – Step 6

- Request

- *client can access resources defined by scope*
 - *resources' URIs defined in a particular documentation*
 - *Example Google Contacts*
 - *to access all users' contacts stored in Google*
 - *scope is https://www.google.com/m8/feeds*
 - *Query string parameter oauth_token*

```
1 | curl https://www.google.com/m8/feeds/contacts/default/full?
2 |     oauth_token=1/dERFd34Sf
```

- *HTTP Header Authorization*

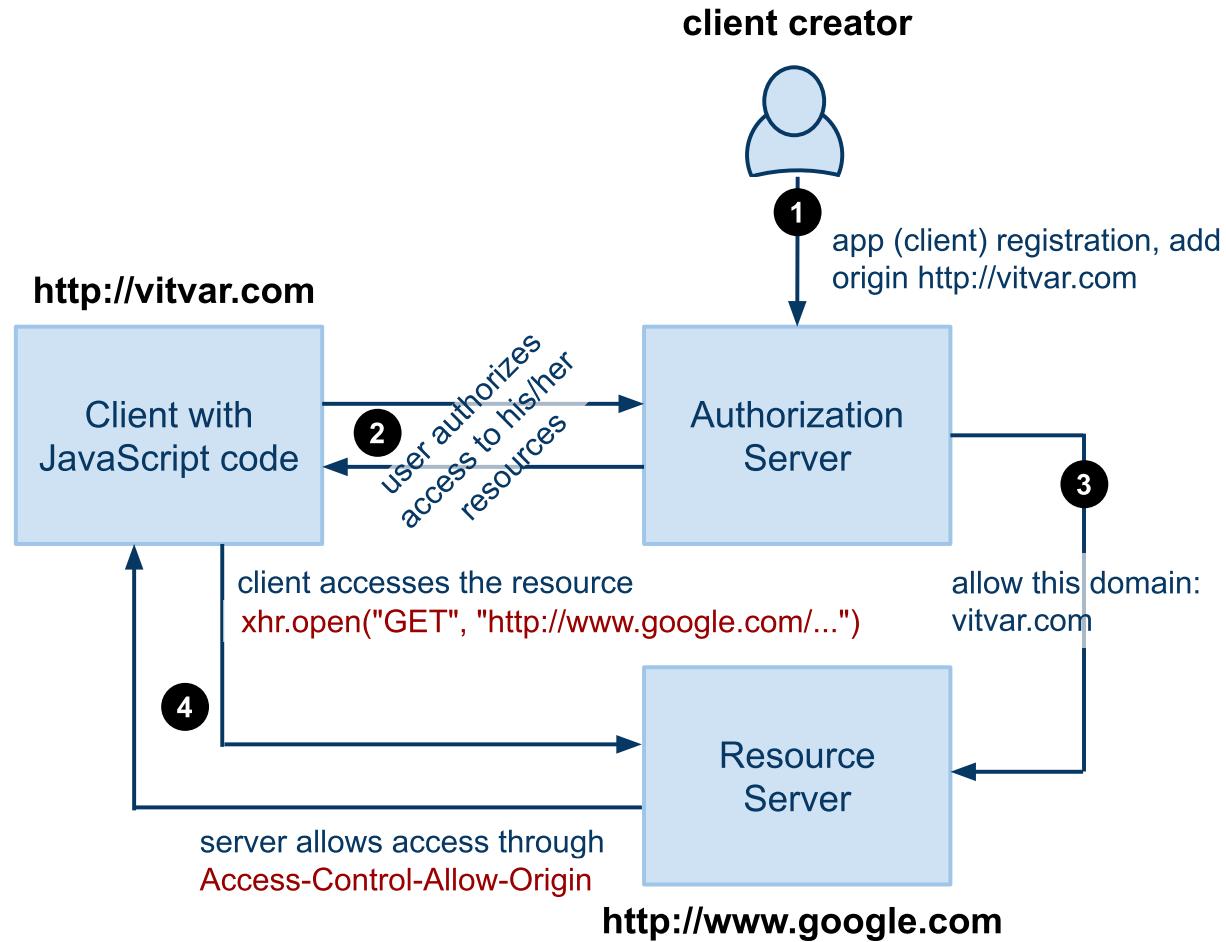
```
1 | curl -H "Authorization: OAuth 1/dERFd34Sf"
2 | https://www.google.com/m8/feeds/contacts/default/full
```

- *The client can do any allowed operations on the resource*

- Response

- *Success – 200 OK*
 - *Error – 401 Unauthorized when token expires or the client hasn't performed the authorization request.*

Cross-Origin Resource Sharing



– see *Same Origin and Cross-Origin* for details

Example Application Registration

The screenshot shows the Google API Access page for the project "vitvar.com search". The left sidebar lists navigation options: Overview, Services, Team, API Access (selected), Billing, Reports, and Quotas. The main content area has sections for API Access, Authorized API Access, Branding information, and Client ID for web applications.

API Access
To prevent abuse, Google places limits on API requests. Using a valid OAuth token or API key allows you to exceed anonymous limits by connecting requests back to your project.

Authorized API Access
OAuth allows users to share specific data with you (for example, contact lists) while keeping their usernames, passwords, and other information private. [Learn more](#)

Branding information
The following information is shown to users whenever you request access to their private data.

Product name: w20-test
Google account: t.vitvar@gmail.com

[Edit branding information...](#)

Client ID for web applications

Client ID:	621535099260.apps.googleusercontent.com	Edit settings...
Client secret:	RxWM917Sv-7cyfWMW7KhNV9R	Reset client secret...
Redirect URLs:	http://vitvar.com/examples/oauth/callback.html	
JavaScript origins:	http://example.org	

[Create another client ID...](#)

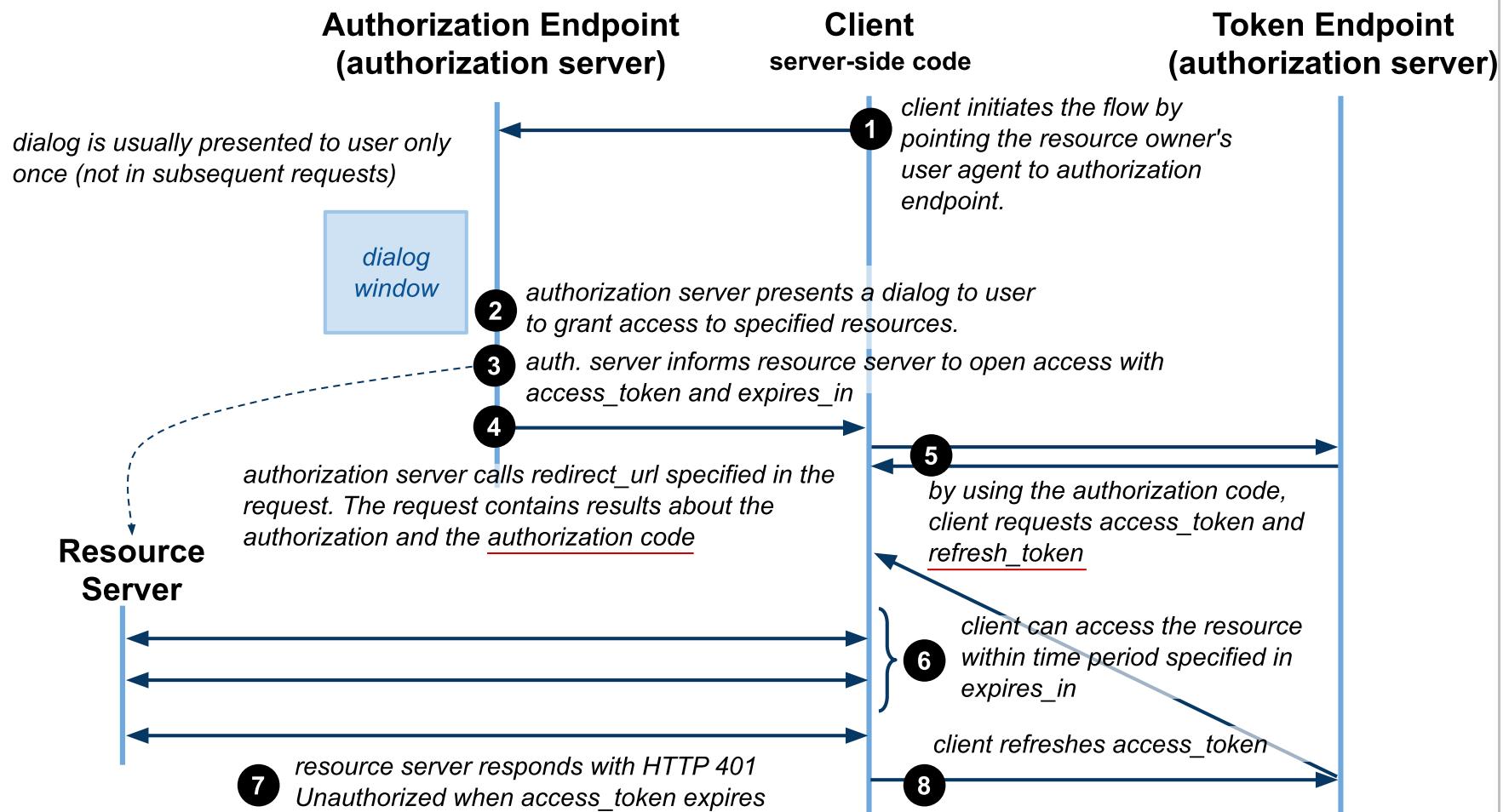
Overview

- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
 - *Client-side Web Apps*
 - *Server-side Web Apps*
- OpenID

Server-side Web Apps

- Additional interactions
 - *server-side code (any language), the app can maintain the state*
 - *additional interactions, authorization code*
- Architecture
 - *Client at a server requests, remembers and refresh access tokens*
- Basic steps
 - *Client redirects user agent to the authorization endpoint*
 - *Resource owner grants access to the client or rejects the request*
 - *Authorization server provides **authorization code** to the client*
 - *Client requests **access** and **refresh tokens** from the auth. server*
 - *Client access the resource with the access token*
 - *When the token expires, client refreshes a token with refresh token*
- Advantages
 - *Access tokens not visible to clients, they are stored at the server*
 - *more secure, clients need to authenticate before they can get tokens*

Server-side Web Apps Protocol



Redirection – Step 1

- Methods and Parameters
 - *same as for client-side app, except response_type must be code*
- Example

```
1 https://accounts.google.com/o/oauth2/auth?  
2 client_id=621535099260.apps.googleusercontent.com&  
3 redirect_uri=http://w20.vitvar.com/examples/oauth/callback.html&  
4 scope=https://www.google.com/m8/feeds&  
5 response_type=code
```

Callback + Access Token Request – steps 4, 5

- Callback
 - *authorization server calls back redirect_uri*
 - *client gets the code and requests access_token*
 - *example (resource owner grants access):*
`http://w20.vitvar.com/examples/oauth/callback.html?code=4/P7...`
 - *when user rejects → same as client-side access*
- Access token request
 - **POST** *request to token endpoint*
→ *example Google token endpoint:*
`https://accounts.google.com/o/oauth2/token`

```
1 POST /o/oauth2/token HTTP/1.1
2 Host: accounts.google.com
3 Content-Type: application/x-www-form-urlencoded
4
5 code=4/P7q7W91a-oMsCeLvIaQm6bTrgtp6&
6 client_id=621535099260.apps.googleusercontent.com&
7 client_secret=XTHhXh1S2UggvyWGwDk1EjXB&
8 redirect_uri=http://w20.vitvar.com/examples/oauth/callback.html&
9 grant_type=authorization_code
```

Access Token (cont.)

- Access token response
 - *Token endpoint responds with `access_token` and `refresh_token`*

```
1 { "access_token" : "1/fFAGRNJru1FTz70BzhT3Zg",
2   "expires_in"   : 3920,
3   "refresh_token": "1/6BMFW9j53gdGImsixUH6kU5RsR4zwI9lUVX-tqf8JXQ" }
```

- Refreshing a token
 - **POST** *request to the token endpoint with `grant_type=refresh_token` and the previously obtained value of `refresh_token`*

```
1 POST /o/oauth2/token HTTP/1.1
2 Host: accounts.google.com
3 Content-Type: application/x-www-form-urlencoded
4
5 client_id=21302922996.apps.googleusercontent.com&
6 client_secret=XTHhXh1SlUNgvyWGwDk1EjXB&
7 refresh_token=1/6BMFW9j53gdGImsixUH6kU5RsR4zwI9lUVX-tqf8JXQ&
8 grant_type=refresh_token
```

- Accessing a resource is the same as in the client-side app

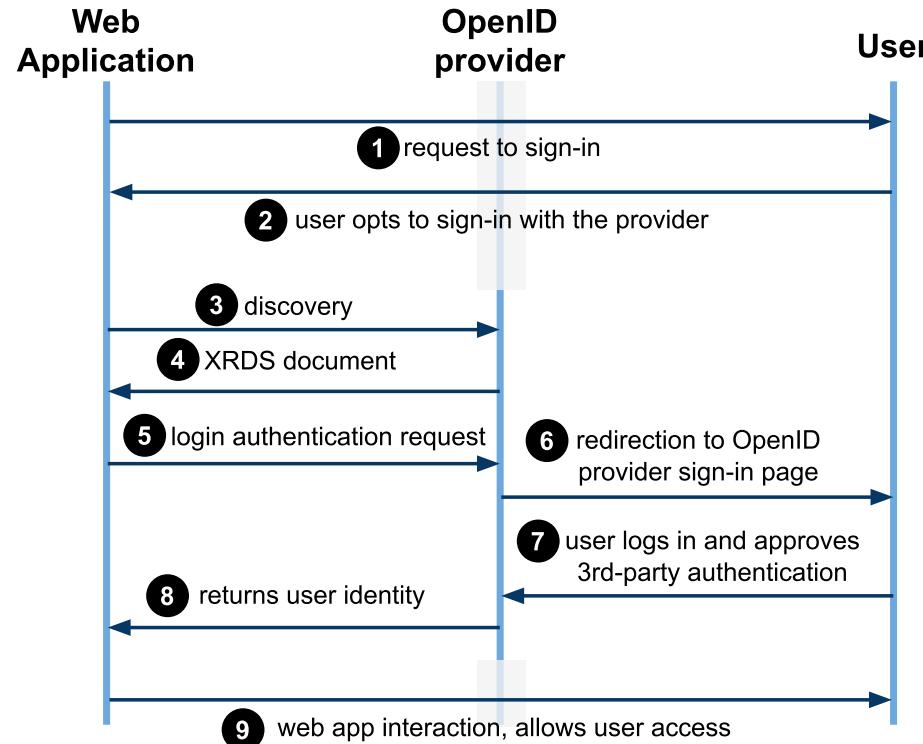
Overview

- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
- OpenID
 - *OpenID Connect*

OpenID Protocol

- Motivation – many user accounts
 - *users need to maintain many accounts to access various services*
 - *multiple passwords problem*
- Objectives
 - *allows apps to utilize an OpenID provider*
 - *a third-party authentication service*
 - *federated login*
 - *users have one account with the OpenID provider and use it for apps that support the provider*
- OpenID providers
 - *it is a protocol, anybody can build a provider*
 - *Google, Yahoo!, Seznam.cz, etc.*
- Specification
 - *OpenID Protocol* ↗

Interaction Sequence



- Discovery – discovery of a service associated with a resource
- XRDS – eXtensible Resource Descriptor Sequence
 - *format for discovery result*
 - *developed to serve resource discovery for OpenID*
 - *Web app retrieves endpoint to send login authentication requests*

Login Authentication Request – Step 5

- Example Google OpenID provider

```
1 | https://www.google.com/accounts/o8/id
2 | ?openid.ns=http://specs.openid.net/auth/2.0
3 | &openid.return_to=https://www.example.com/checkauth
4 | &openid.realm=http://www.example.com/
5 | &openid.assoc_handle=ABSmpf6DNMw
6 | &openid.mode=checkid_setup
```

- Parameters

- **ns** – protocol version (*obtained from the XRDS*)
 - **mode** – type of message or additional semantics (*checkid_setup indicates that interaction between the provider and the user is allowed during authentication*)
 - **return_to** – callback page the provider sends the result
 - **realm** – domain the user will trust, consistent with **return_to**
 - **assoc_handle** – "log in" for web app with openid provider
- * Not all fields shown, check the OpenID spec for the full list of fields and their values

Login Authentication Response – Step 8

- User logs in successfully

```
1 | http://www.example.com/checkauth
2 | ?openid.ns=http://specs.openid.net/auth/2.0
3 | &openid.mode=id_res
4 | &openid.return_to=http://www.example.com:8080/checkauth
5 | &openid.assoc_handle=ABSmpf6DNMw
6 | &openid.identity=https://www.google.com/accounts/o8/id/id=ACyQatiscWvwqs4UQV_U
```

- Web app will use **identity** to identify user in the application
 - response is also signed using a list of fields in the response (not shown in the listing)

- User cancels

```
1 | http://www.example.com/checkauth
2 | ?openid.mode=cancel
3 | &openid.ns=http://specs.openid.net/auth/2.0
```

- * Not all fields shown, check the OpenID spec for the full list of fields and their values

Overview

- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
- OpenID
 - *OpenID Connect*

OpenID Connect (OIDC)

- Simple identity layer on top of the OAuth 2.0 protocol
 - *Authorization Server to verify identity of users*
 - *Clients can obtain basic profile information about users*
- OIDC vs OpenID
 - *OIDC does many of the same tasks as OpenID 2.0*
 - *API-friendly*
 - *can be used by native and mobile applications*
 - *Robust signing and encryption mechanisms*
 - *Native integration with OAuth 2.0.*
- Defined by OpenID open standard
 - *OpenID Connect*

Interaction sequence

