# Middleware Architectures 2

## Lecture 3: Security

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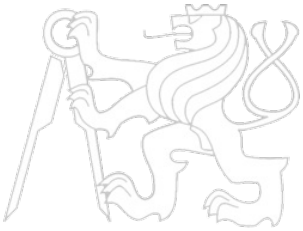

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Modified: Mon Mar 07 2022, 14:16:19
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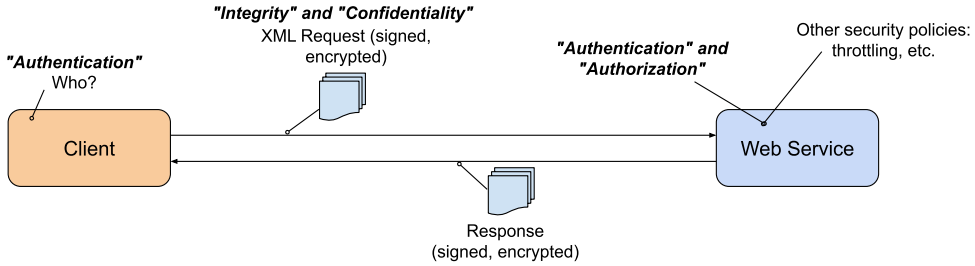
## Overview

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

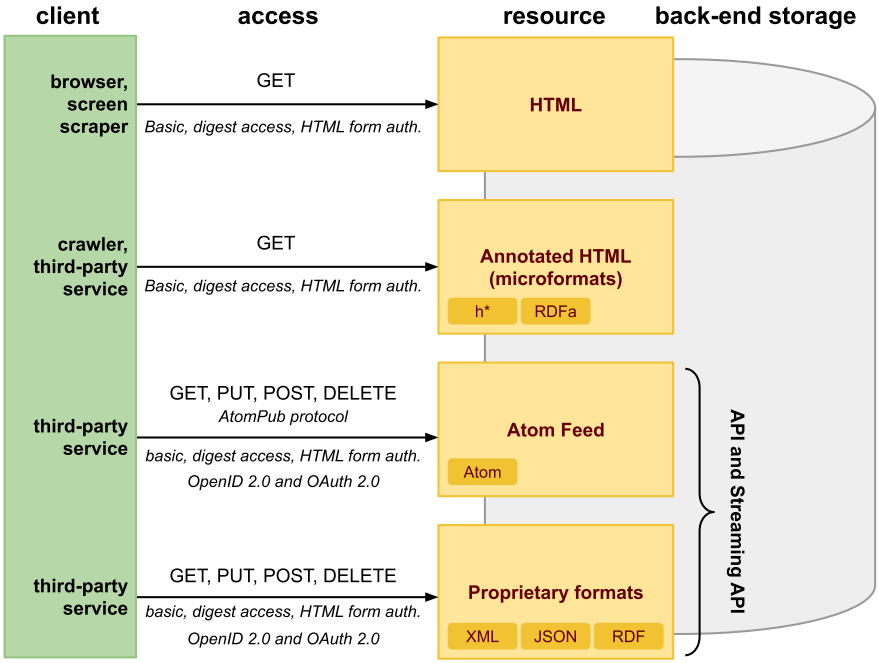
# Web Service Security Concepts

- Securing the client-server communcation
  - *Message-level security*
  - *Transport-level security*
- Ensure
  - *Authentication – verify a client's identity*
  - *Authorizaton – 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

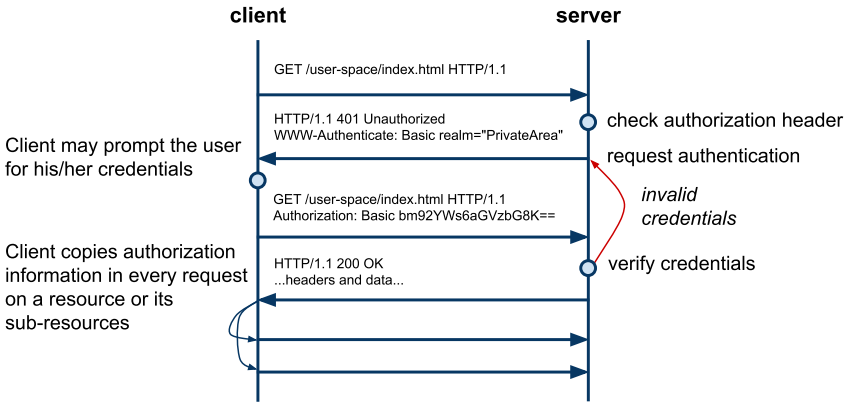


# Authentication and Authorization

- Authentication
  - *verification of user's identity*
- Authorization
  - *verification that a user has rights to access a resource*
- Standard: HTTP authentication
  - *HTTP defines two options*
    - → *Basic Access Authentication*
    - → *Digest Access Authentication*
  - *They 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



# Basic Access Authentication




- Realm
  - *an identifier of the space on the server (~ a collection of resources and their sub-resources)*
  - *A client may associate a valid credentials with realms such that it copies authorization information in requests for which server requires authentication (by* `WWW-Authenticate` *header)*

# Basic Access Authentication – Credentials

- Credentials
  - *credentials are base64 encoded*
  - *the format is:* `username:password`

```
# to encode in linux
echo "novak:heslo" | base64
> bm92YWs6aGVzbG8K

# and to decode
echo "bm92YWs6aGVzbG8K" | base64 -d # use capital "D" in OS X
> novak:heslo
```

- Comments
  - *When TLS is not used, the password can be read*
  - *An attacker can repeat interactions*



# Digest Access Authentication

- RFC 2617 – Basic and Digest Access Authentication
  - *No password between a client and a server but a hash value*
  - *Simple and advanced mechanisms (only server-generated nonce value – replay-attacks or with client-generated nonce value)*
- Basic Steps
  1. *Client accesses a protected area*

```
> GET / HTTP/1.1
```

  2. *Server requests authentication with* `WWW-Authenticate`

```
< HTTP/1.1 401 Unauthorized
< WWW-Authenticate: Digest realm="ProtectedArea",
  nonce="BbdQof3DBAA=a293ff3d724989371610f03015f2d23f3cd2c045",
  algorithm=MD5, domain="/", qop="auth"
```

  3. *Client calculates a response hash by using the realm, his/her username, the password, and the quality of protection (QoP) and requests the resource with* `authorization` *header*

```
> GET / HTTP/1.1
> Authorization: Digest username="novak", realm="ProtectedArea",
  nonce="BbdQof3DBAA=a293ff3d724989371610f03015f2d23f3cd2c045", uri="/",
  algorithm=MD5, response="c4ea2293aeb318826d1e533f363efd90", qop=auth,
  nc=00000001, cnonce="531ee8ba7f2a8fd1"
```

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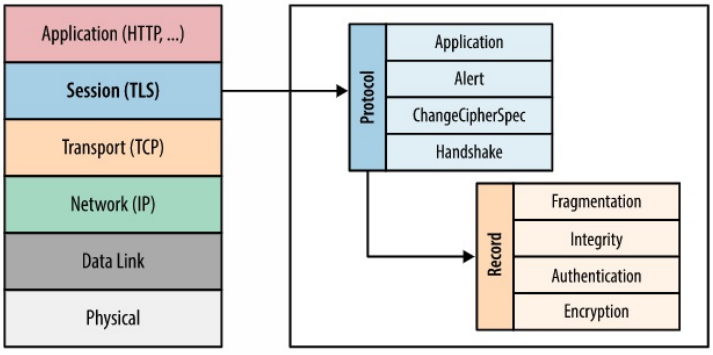
# Overview

- 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

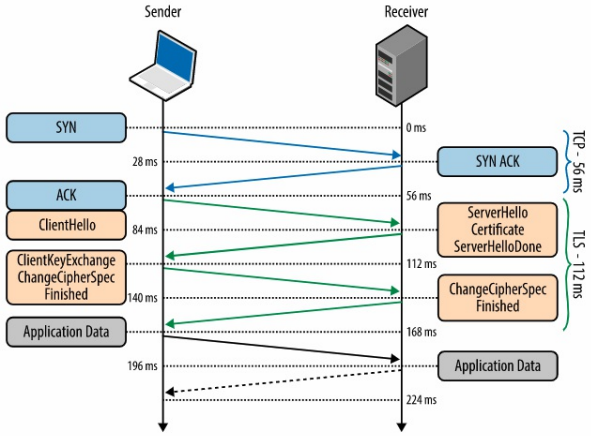


# TLS Services

- Encryption
  - *Peers must agree on ciphersuite and keys*
  - *This is achieved by **TLS handshake***
- Authentication
  - *Peers can authenticate their identity*
    - *→ The client can verify that the server is who it is claimed to be*
    - *→ Achieved by "Chain of Trust and Certificate Authoritites"*
    - *→ The server can also verify the client*
- Integrity
  - *TLS provives message framing mechanism*
  - *Every message is signed with Message Authentication Code (MAC)*
    - *→ MAC hashes data in a message and combines the resulting hash with a key (negotiated during the TLS handshake)*
    - *→ The result is a message authentication code sent with the message*



# 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*

# Key Exchange

- RSA key exhange(Rivest–Shamir–Adleman)
  - *The client generates a symetric key*
  - *The client encrypts the key with the server's public key*
  - *The client sends the encrpyed key to the server*
  - *The server uses its private key to decrypt the symetric key*
- RSA critical weekness
  - *The same public-private key pair is used to:*
    - → *authenticate the server (the server's private key is used to sign and verify the handshake)*
    - → *encrypt the symetric key*
  - *When an attacker gets hold of the server private key*
    - → *It can decrypt the entire session*
- Diffie-Hellman key exhange
  - *Client and server can negoriate shared secret without its explicit communication*
    - → *Attacker cannot get the key*
  - *Reduction of risk of compromising of the past communications*
    - → *New key can be generated as part of every key exchange*
    - → *Old keys can be discarded*



# 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)*

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## 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*

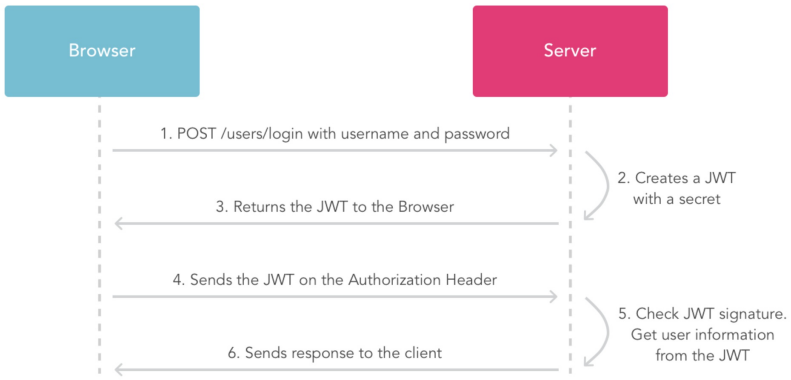
```
HMACSHA256(
    base64UrlEncode(header) + "." +
    base64UrlEncode(payload),
    secret)
```

- Example
  - *JWT is a three Base64-URL strings separated by dots*

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.
eyJzdWIiOiIxMjM0NTY3ODkwIiwibmFtZSI6IkpvaG4
gRG9lIiwiaXNTb2NpYWwiOnRydWV9.
4pcPyMD09olPSyXnrXCjTwXyr4BsezdI1AVTmud2fU4
```



# 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)*

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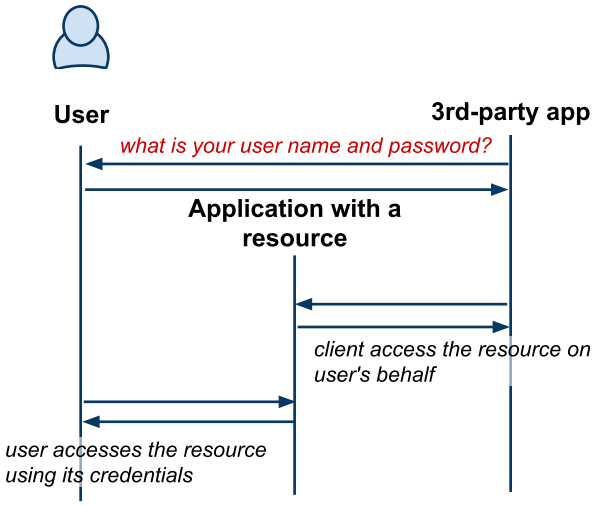
- JSON Web Token
- OAuth 2.0
  - *Client-side Web Apps*
  - *Server-side Web Apps*
- OpenID



## 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 compatibile 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*



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## Client-side Web Apps

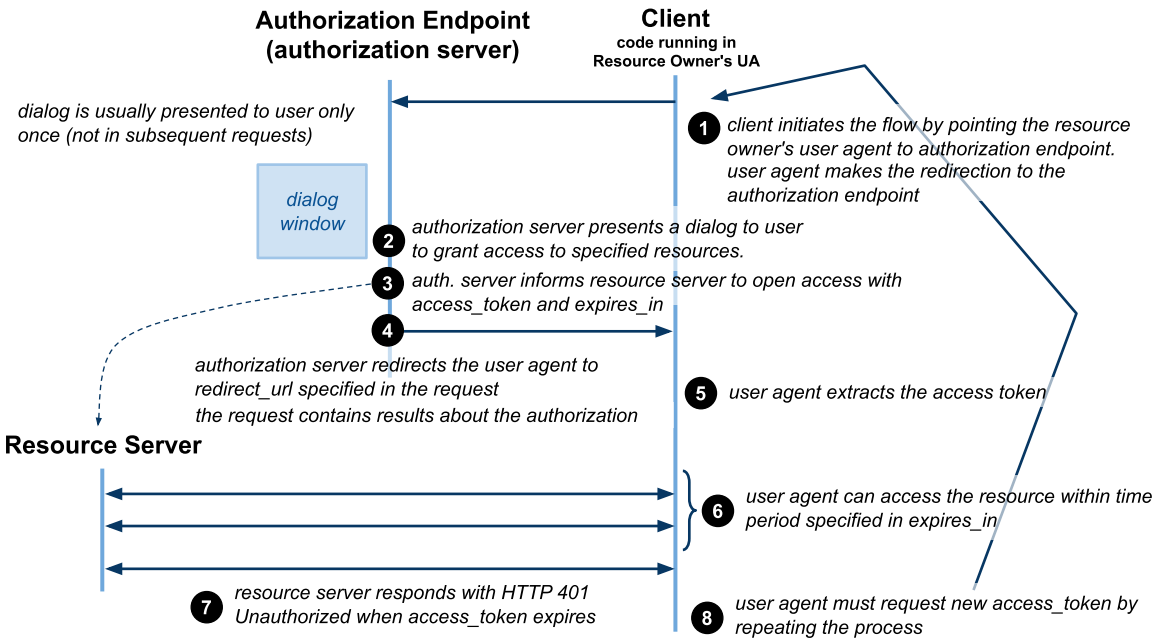
- Simplified version of OAuth 2.0 protocol
  - *JavaScript/AJAX apps running in a browser*
  - *Apps that cannot easily "remember" app state*
  - *limited number of interactions*
- Architecture
  - *User-agent processes a javascript/HTML code from the client*
  - *No need of authorization code*
- Basic 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 authorazation 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:*

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

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

```
hhttp://w20.vitvar.com/examples/oauth/callback.html?
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`

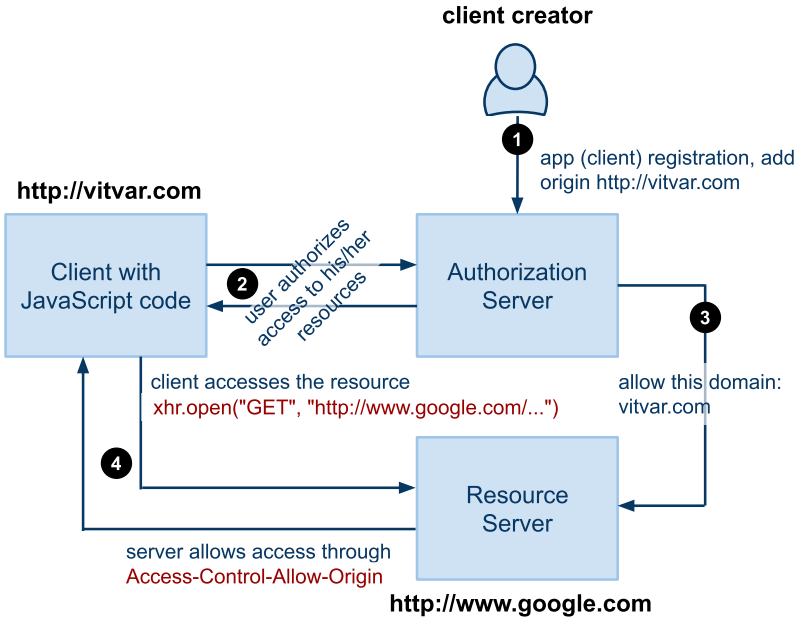
```
curl https://www.google.com/m8/feeds/contacts/default/full?
    oauth_token=1/dERFd34Sf
```

  - *HTTP Header* `Authorization`

```
curl -H "Authorization: OAuth 1/dERFd34Sf"
    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

Google apis

vitvar.com search

- Overview
- Services
- Team
- API Access
- Billing
- Reports
- Quotas

## 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

Client secret: RxWM9l7Sv-7cyfWMW7KhNV9R

Redirect URIs: http://vitvar.com/examples/oauth/callback.html

JavaScript origins: http://example.org

Edit settings...

Reset client secret...

Create another client ID...

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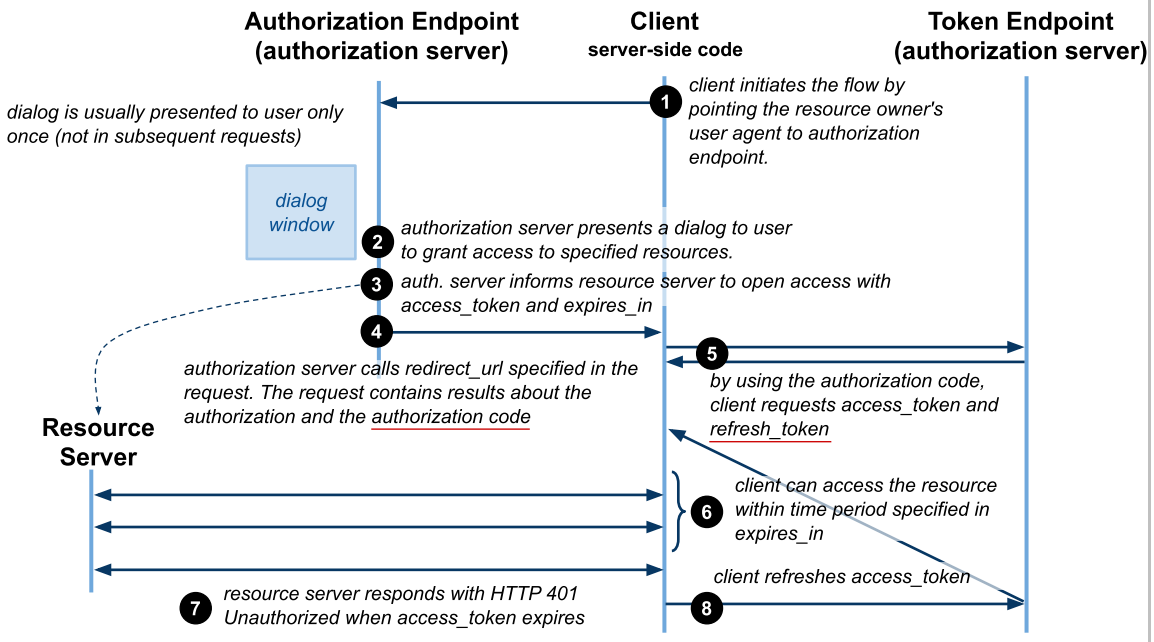
- OAuth 2.0
  - *Client-side Web Apps*
  - *Server-side Web Apps*
- OpenID



## 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

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

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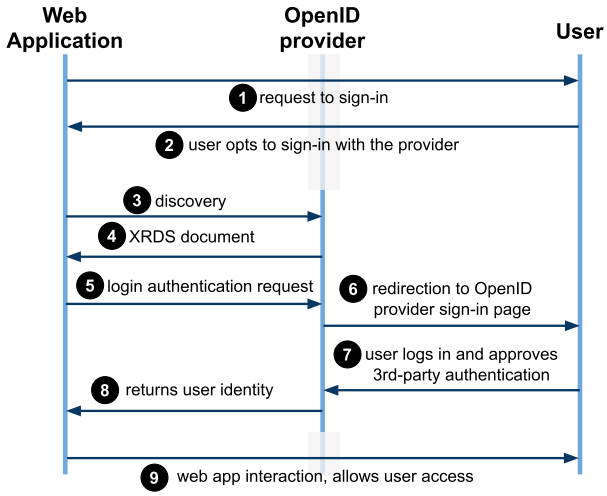
- OpenID
  - *OpenID Connect*



## 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

```
https://www.google.com/accounts/o8/id
?openid.ns=http://specs.openid.net/auth/2.0
&openid.return_to=https://www.example.com/checkauth
&openid.realm=http://www.example.com/
&openid.assoc_handle=ABSmpf6DNMw
&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 logins successfully

```
http://www.example.com/checkauth
?openid.ns=http://specs.openid.net/auth/2.0
&openid.mode=id_res
&openid.return_to=http://www.example.com:8080/checkauth
&openid.assoc_handle=ABSmpf6DNMw
&openid.identity=https://www.google.com/accounts/o8/id/id=ACyQatiscWvwqs4UQV_l
```

  - *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

```
http://www.example.com/checkauth
?openid.mode=cancel
&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