Middleware Architectures 2

Lecture 5: Security

doc. Ing. Tomáš Vitvar, Ph.D.

tomas@vitvar.com • @TomasVitvar • http://vitvar.com

Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • http://vitvar.com/courses/w20

Evropský sociální fond
Praha & EU: Investujeme do vaší budoucnosti

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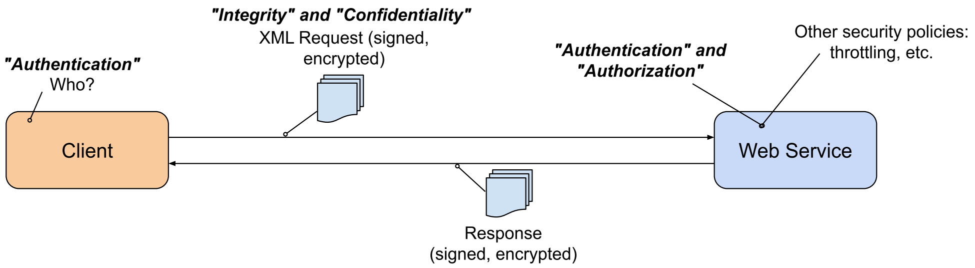
Overview

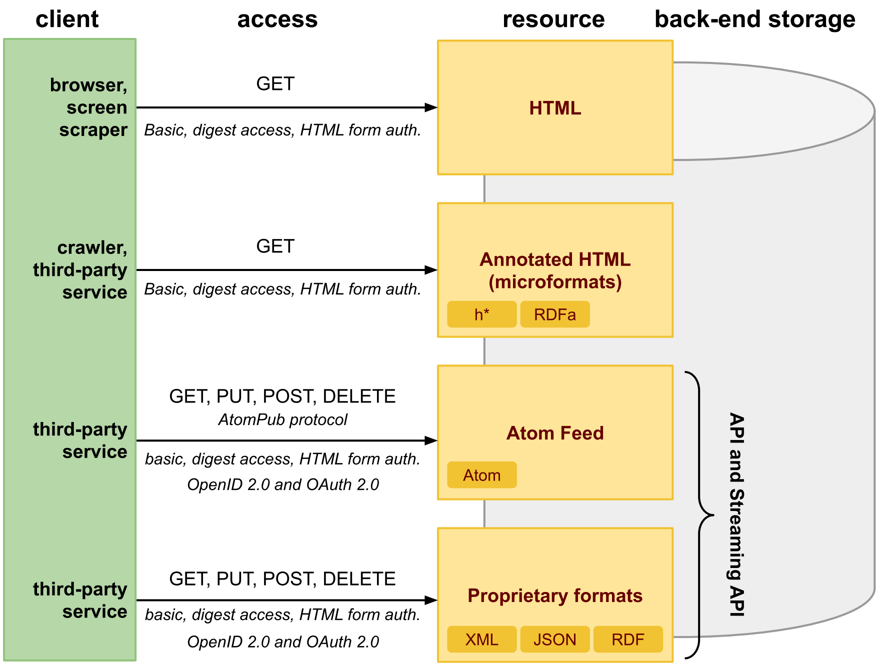
- Security Concepts
- Transport Level Security
- JSON Web Token
- OAuth 2.0
- OpenID

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*


"Authentication"
Who?
Client
"Integrity" and "Confidentiality"
XML Request (signed, encrypted)
"Authentication" and "Authorization"
Other security policies: throttling, etc.
Web Service
Response (signed, encrypted)

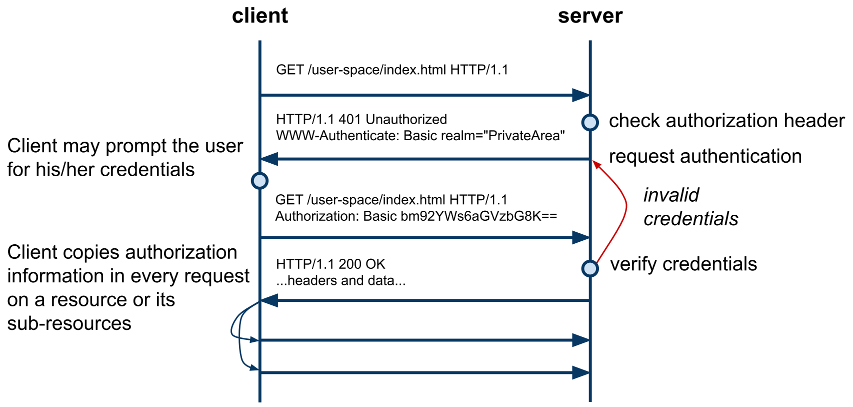
Data on the Web


client
access
resource
back-end storage
browser, screen scraper
GET
Basic, digest access, HTML form auth.
HTML
crawler, third-party service
GET
Basic, digest access, HTML form auth.
Annotated HTML (microformats)
h*
RDFa
third-party service
GET, PUT, POST, DELETE
AtomPub protocol
basic, digest access, HTML form auth.
OpenID 2.0 and OAuth 2.0
Atom Feed
Atom
third-party service
GET, PUT, POST, DELETE
basic, digest access, HTML form auth.
OpenID 2.0 and OAuth 2.0
Proprietary formats
XML
JSON
RDF
API and Streaming API

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



client
server
check authorization header
request authentication
invalid credentials
verify credentials
Client may prompt the user for his/her credentials
Client copies authorization information in every request on a resource or its sub-resources

```
GET /user-space/index.html HTTP/1.1
```

```
HTTP/1.1 401 Unauthorized
WWW-Authenticate: Basic realm="PrivateArea"
```

```
GET /user-space/index.html HTTP/1.1
Authorization: Basic bm92YWs6aGVzbG8K==
```

```
HTTP/1.1 200 OK
...headers and data...
```

- 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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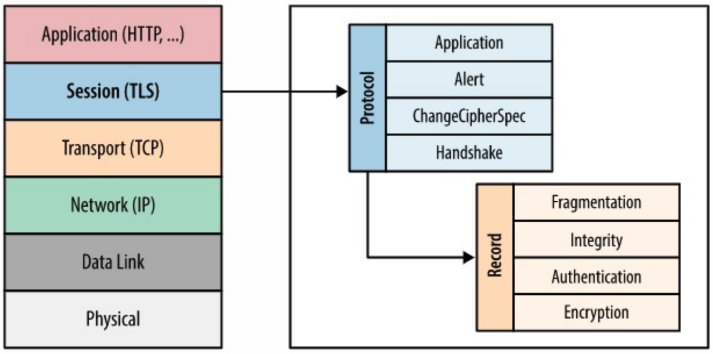
Overview

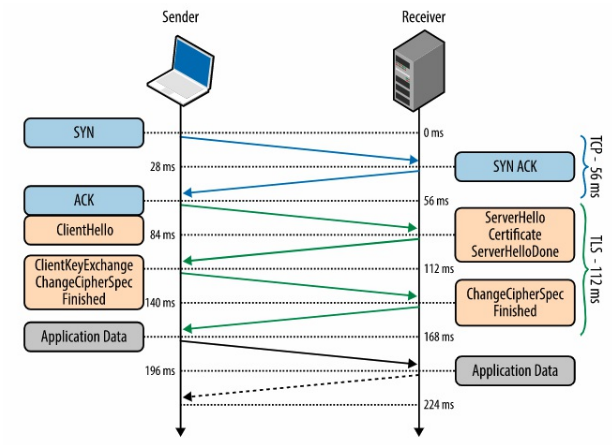
- SSL and TLS
  - *SSL and TLS is used interchangeably*
  - *SSL 3.0 developed by Netscape*
  - *IETF standardization of SSL 3.0 is TLS 1.0*
    - *→ TLS 1.0 is upgrade of SSL 3.0*
  - *Due to security flaws in TLS 1.0, TLS 1.1 and TLS 1.2 were created*
- TLS layer



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*
- Deffie-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.)

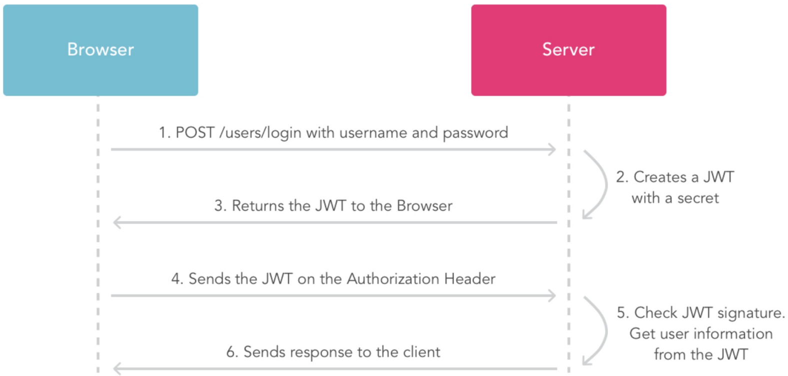
- Signature
  - *Signed encoded header, encoded payload and a secret.*
  - *For example, signature using HMAC SHA256 algorithm*

```
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



Browser

Server

1. POST /users/login with username and password

2. Creates a JWT with a secret

3. Returns the JWT to the Browser

4. Sends the JWT on the Authorization Header

5. Check JWT signature. Get user information from the JWT

6. Sends response to the client

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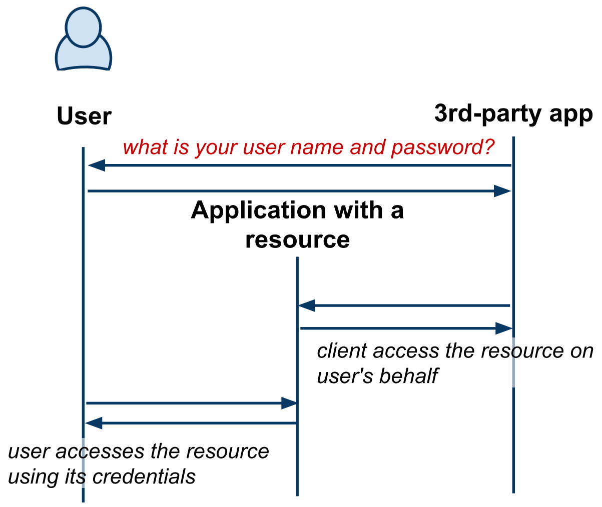
- OAuth 2.0
  - *Client-side Web Apps*
  - *Server-side Web Apps*
- OpenID

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



User

3rd-party app

what is your user name and password?

Application with a resource

client access the resource on user's behalf

user accesses the resource using its credentials

- 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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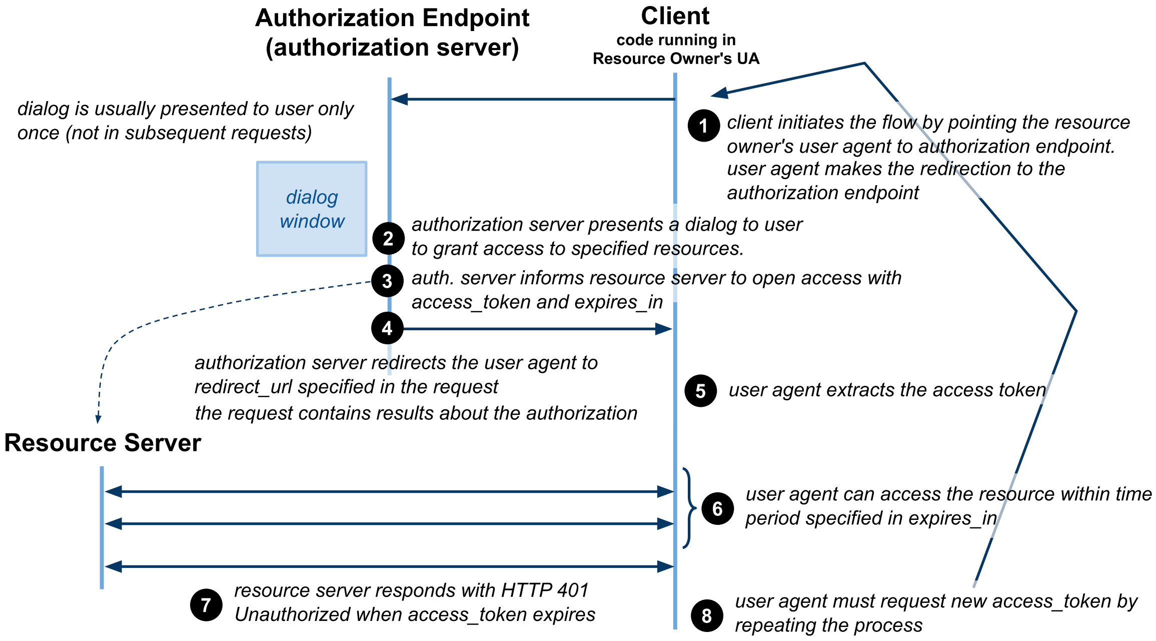
Client-side Web Apps

- 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



Authorization Endpoint (authorization server)

Client
code running in
Resource Owner's UA

dialog is usually presented to user only once (not in subsequent requests)

dialog window

1 client initiates the flow by pointing the resource owner's user agent to authorization endpoint. user agent makes the redirection to the authorization endpoint

2 authorization server presents a dialog to user to grant access to specified resources.

3 auth. server informs resource server to open access with access_token and expires_in

4 authorization server redirects the user agent to redirect_url specified in the request
the request contains results about the authorization

Resource Server

5 user agent extracts the access token

6 user agent can access the resource within time period specified in expires_in

7 resource server responds with HTTP 401 Unauthorized when access_token expires

8 user agent must request new access_token by repeating the process

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*

```
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=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`

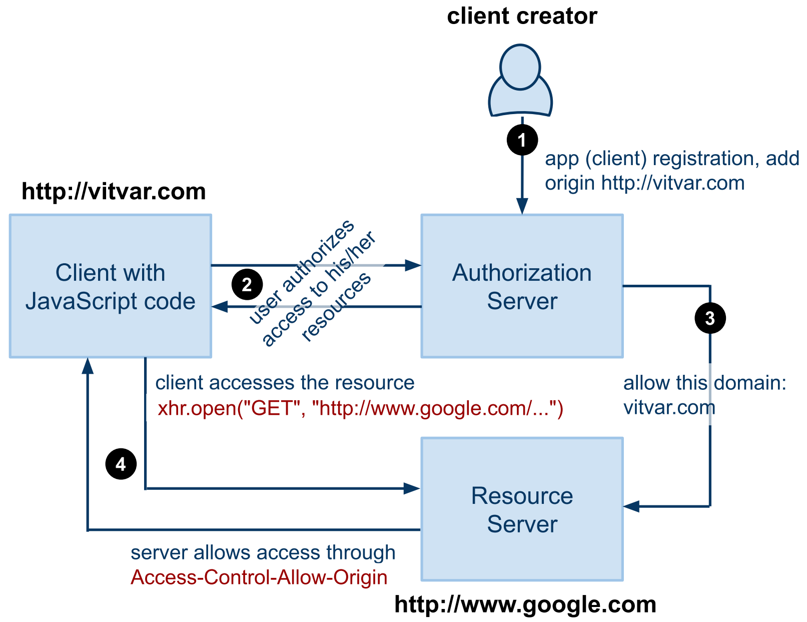
```
curl https://www.google.com/m8/feeds/contacts/default/full?
    oauth_token=1/dERFd34Sf
```

  - *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



client creator

1 app (client) registration, add origin http://vitvar.com

http://vitvar.com

Client with JavaScript code

2 user authorizes access to his/her resources

Authorization Server

3 allow this domain: vitvar.com

client accesses the resource xhr.open("GET", "http://www.google.com/...")

4

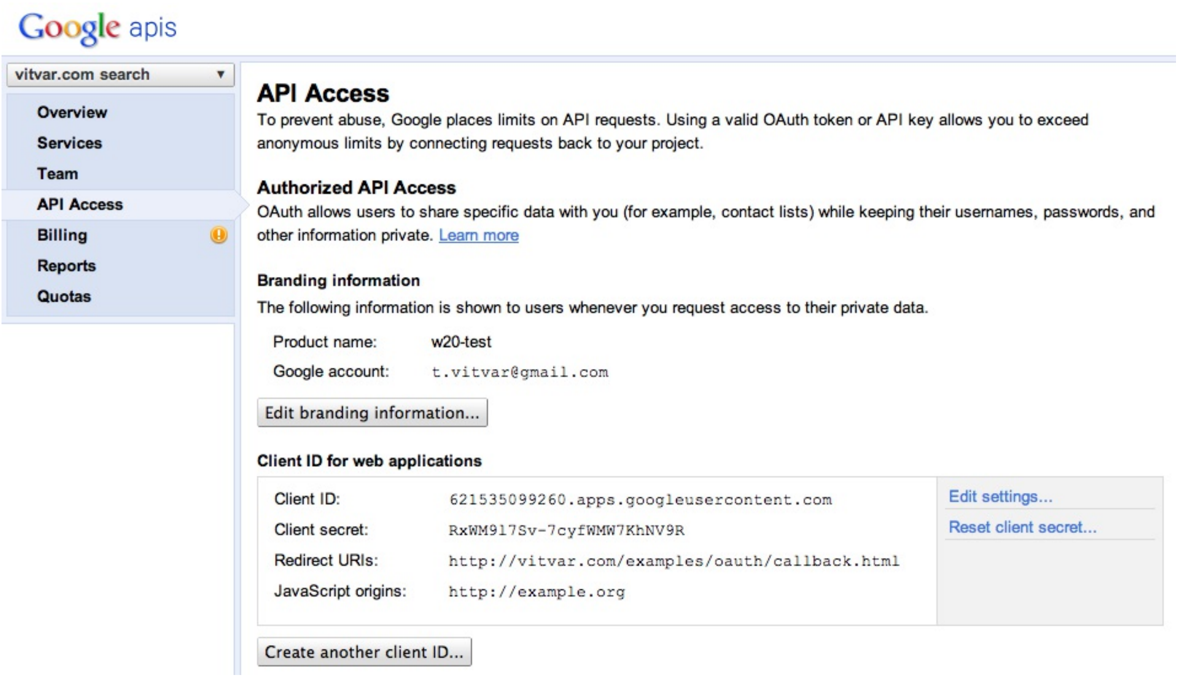
Resource Server

server allows access through Access-Control-Allow-Origin

http://www.google.com

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

Example Application Registration



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

Client ID for web applications

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

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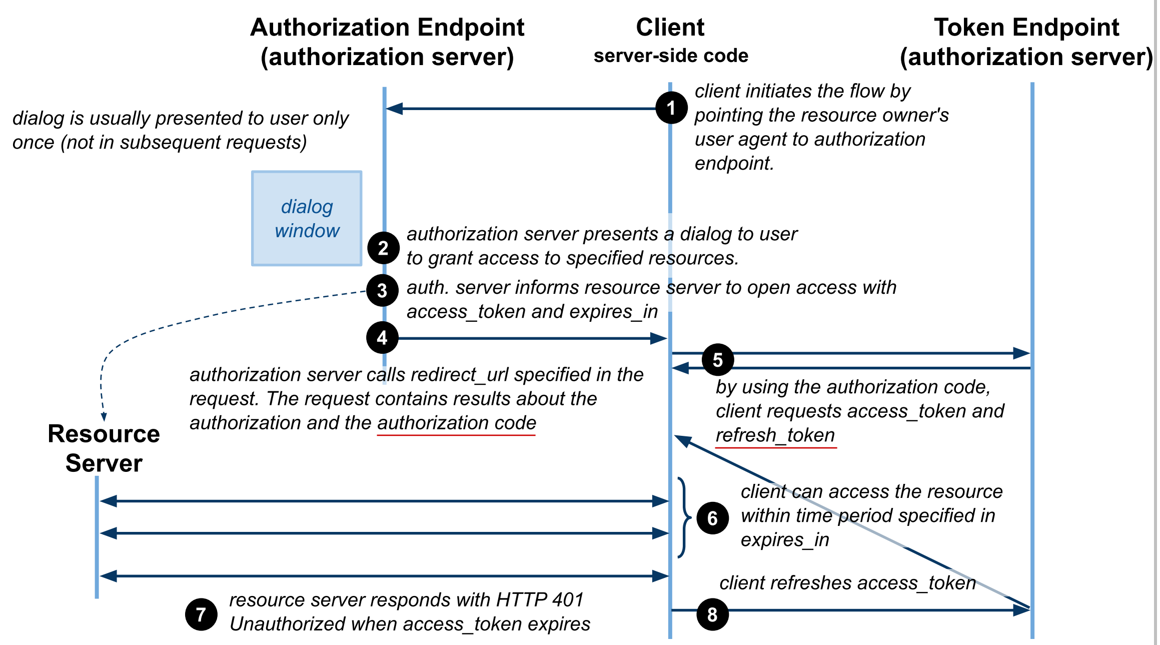
Server-side Web Apps

- 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



Authorization Endpoint (authorization server)

Client server-side code

Token Endpoint (authorization server)

1 client initiates the flow by pointing the resource owner's user agent to authorization endpoint.

dialog is usually presented to user only once (not in subsequent requests)

dialog window

2 authorization server presents a dialog to user to grant access to specified resources.

3 auth. server informs resource server to open access with access_token and expires_in

4 authorization server calls redirect_url specified in the request. The request contains results about the authorization and the authorization code

5 by using the authorization code, client requests access_token and refresh_token

Resource Server

6 client can access the resource within time period specified in expires_in

7 resource server responds with HTTP 401 Unauthorized when access_token expires

8 client refreshes access_token

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

```
POST /o/oauth2/token HTTP/1.1
Host: accounts.google.com
Content-Type: application/x-www-form-urlencoded

code=4/P7q7W91a-oMsCeLvIaQm6bTrgtp6&
client_id=621535099260.apps.googleusercontent.com&
client_secret=XTHhXh1S2UggvyWGwDk1EjXB8&
redirect_uri=http://w20.vitvar.com/examples/oauth/callback.html&
grant_type=authorization_code
```

Access Token (cont.)

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

```
{ "access_token"    : "1/fFAGRNJru1FTz70BzhT3Zg",
  "expires_in"      : 3920,
  "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

```
POST /o/oauth2/token HTTP/1.1
Host: accounts.google.com
Content-Type: application/x-www-form-urlencoded

client_id=21302922996.apps.googleusercontent.com&
client_secret=XTHhXh1SlUNgvyWGwDk1EjXB8&
refresh_token=1/6BMfW9j53gdGImsixUH6kU5RsR4zwI9lUVX-tqf8JXQ&
grant_type=refresh_token
```

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

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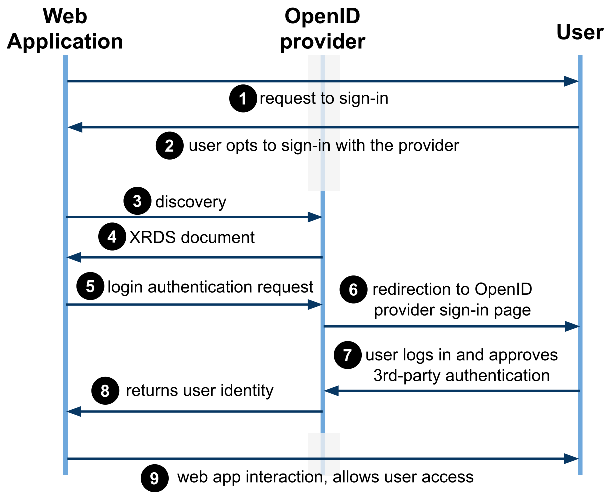
OpenID Protocol

- 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


Web Application
OpenID provider
User
1 request to sign-in
2 user opts to sign-in with the provider
3 discovery
4 XRDS document
5 login authentication request
6 redirection to OpenID provider sign-in page
7 user logs in and approves 3rd-party authentication
8 returns user identity
9 web app interaction, allows user access

- 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*