Authentication Mechanisms and Protocols

Authentication (Authn)

Proof that an entity has an attribute it claims to have

- Hi, I'm Joe
- Prove it!
- Here is my proof,
  calculated with Joe's credentials that I've agreed with you
- Proof accepted/not accepted

- Hi, I'm over 18
- Prove it!
- Here is a claim issued by a competent authority,
  which I can also prove that I'm the owner
- Proof and claim accepted/not accepted

Authn: Proof Types

Something we know
- A secret memorized (or written down…) by Joe

Something we have
- An object/token solely held by Joe

Something we are
- Joe's Biometry

Multi-factor authentication
- Simultaneous use of different proof types
- 2FA = Two Factor Authentication

Risk-based MFA
- Variable MFA
- Higher attack risk, more factors or less risky factors
- Lower attack risk, less or easier factors

Authn : Goals

Authenticate interactors
- People, services, servers, hosts, networks, etc.

Enable the enforcement of authorization policies and mechanisms
- Authorization ≠ authentication
- Authorization ⇒ authentication

Facilitate the exploitation of other security-related protocols
- e.g. key distribution for secure communication

Authn : Requirements

Trustworthiness

- How good is it in proving the identity of an entity?
- How difficult is it to be deceived?
- Level of Assurance (LoA)

Secrecy

- No disclosure of secret credentials used by legit entities

NIST 800-63				
LoA	**DESCRIPTION**	**TECHNICAL REQUIREMENTS**		
		IDENTITY PROOFING REQUIREMENTS	TOKEN (SECRET) REQUIREMENTS	AUTHENTICATION PROTECTION MECHANISMS REQUIREMENTS
1	Little or no confidence exists in the asserted identity; usually self-asserted; essentially a persistent identifier	Requires no identity proofing	Allows any type of token including a simple PIN	Little effort to protect session from off-line attacks or eavesdropper is required.
2	Confidence exists that the asserted identity is accurate; used frequently for self service applications	Requires some identity proofing	Allows single-factor authentication. Passwords are the norm at this level.	On-line guessing, replay and eavesdropping attacks are prevented using FIPS 140-2 approved cryptographic techniques.
3	High confidence in the asserted identity's accuracy; used to access restricted data	Requires stringent identity proofing	**Multi-factor authentication**, typically a password or biometric factor used in combination with a 1) software token, 2) hardware token, or 3) one-time password device token	On-line guessing, replay, eavesdropper, impersonation and man-in-the-middle attack are prevented. Cryptography must be validated at FIPS 140-2 Level 1 overall with Level 2 validation for physical security.
4	Very high confidence in the asserted identity's accuracy; used to access highly restricted data.	Requires in-person registration	**Multi-factor authentication** with a hardware crypto token.	On-line guessing, replay, eavesdropper, impersonation, man-in-the-middle, and session hijacking attacks are prevented. Cryptography in the hardware token must be validated at FIPS 140-2 level 2 overall, with level 3 validation for physical security.

Authn : Requirements

Robustness

- Prevent attacks to the protocol data exchanges
- Prevent on-line DoS attack scenarios
- Prevent off-line dictionary attacks

Simplicity

- It should be as simple as possible to prevent entities from choosing dangerous shortcuts

Deal with vulnerabilities introduced by people

- They have a natural tendency to facilitate or to take shortcuts
- Deal with phishing!

Authn: Entities and deployment model

Entities

People

Hosts

Networks

Services / servers

Deployment model

Along the time

- Only when interaction starts
- Continuously along the interaction

Directionality

- Unidirectional
- Bidirectional (Mutual)

Authn interactions: Basic approaches

Direct approach

1. Provide credentials
2. Wait for verdict

- Advantage: no computations by the presenter
- Disadvantage: credentials can be exposed to malicious validators

Challenge-response approach

1. Get challenge
2. Provide a response computed from the challenge and the credentials
3. Wait for verdict

- Advantage: credentials are not exposed to malicious validators
- Disadvantage: requires computations by the presenter

Authn of subjects: Direct approach w/ known password

A password is checked against a value previously stored

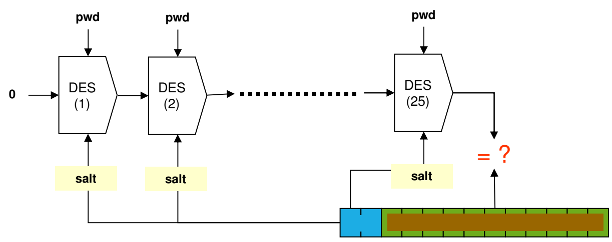
- For a claimed identity (username)

Personal stored value:

- Transformed by a unidirectional function
- Windows: digest function
- UNIX: DES hash + salt
- Linux: MD5 + salt
  - hash is configurable

Optimal: PBKDF2, Script with high complexity

Authentication of subjects: Direct approach w/ known password



DES hash = $DES_{pwd}^{25}(0)$

$DES_k^n(x) = DES_k(DES_k^{n-1}(x))$

Permutation of 12 subkeys´ bit pairs with salt (12 bits)

Authn of subjects: Direct approach w/ known password

Advantage

- Simplicity!

Problems

- Usage of weak passwords
  - Enable dictionary attacks
- Transmission of passwords along insecure communication channels
  - Eavesdroppers can easily learn the password
  - e.g. Unix remote services, PAP

Top Ten 2017 from Splashdata

1. 123456
2. Password
3. 12345678
4. qwerty
5. 12345
6. 123456789
7. letmein
8. 1234567
9. football
10. iloveyou

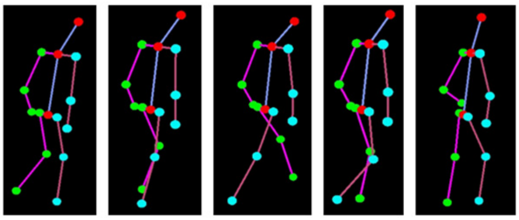
Authn of people:
Direct approach with biometrics

People get authenticated using body measures
- Biometric samples
- Fingerprint, iris, face geometry, voice timber, manual writing, vein matching, etc.

Measures are compared with personal records
- Biometric references (or template)
- Registered in the system with a previous enrolment procedure

Identification vs authentication
- Identification: 1-to-many check for a match
- Authentication: 1-to-1 check for a match



Authn of people:
Direct approach with biometrics

Advantages

- People do not need to use memory, or carry something
  - Just be their self
- People cannot choose weak passwords
  - In fact, they don't choose anything
- Authentication credentials cannot be transferred to others
  - One cannot delegate its own authentication

Authentication of people:
Direct approach with biometrics

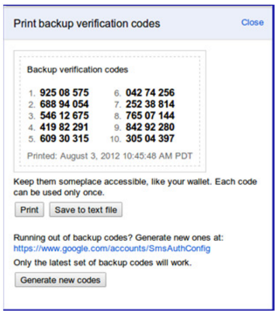
Problems

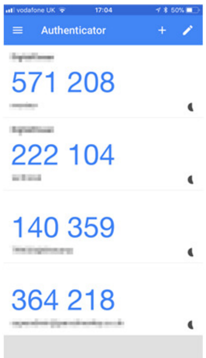
- Biometric methods are still incipient
  - In many cases it can be fooled with ease (Face Recognition, Fingerprint)
- People cannot change credentials
  - If the credentials or templates are stolen
- Credentials cannot be transferred between individuals
  - If it is required in extraordinary scenarios
- Can pose risks to individuals
  - Physical integrity can be compromised by an attacker in order to acquire biometric data
- It is not easy to be implemented in remote systems
  - It is mandatory to have secure and trusted biometric acquisition devices
- Biometrics can reveal other personal secrets
  - Diseases

Authn of subjects: Direct approach with one-time passwords

One-Time Passwords = Secrets that can be used only once
- Pre-distributed directly, or the result of a generator function

Example: Bank codes, Google Backup Codes





https://www.montepio.pt/SitePublico/pt_PT/particulares/montepio24/cartao-matriz.page?altcode=10006P

Authn of subjects: Direct approach with one-time passwords

Advantages
- Can be eavesdropped, allowing its use in channels without encryption
- Can be chosen by the authenticator, which may enforce a given complexity
- Can depend on a shared password

Problems
- Interacting entities need to know which password to use on each occasion
  - Implies some form of synchronization (e.g., index, coordinates)
- Individuals may require additional resources to store/generate the passwords
  - Sheet of paper, application, additional device, etc.

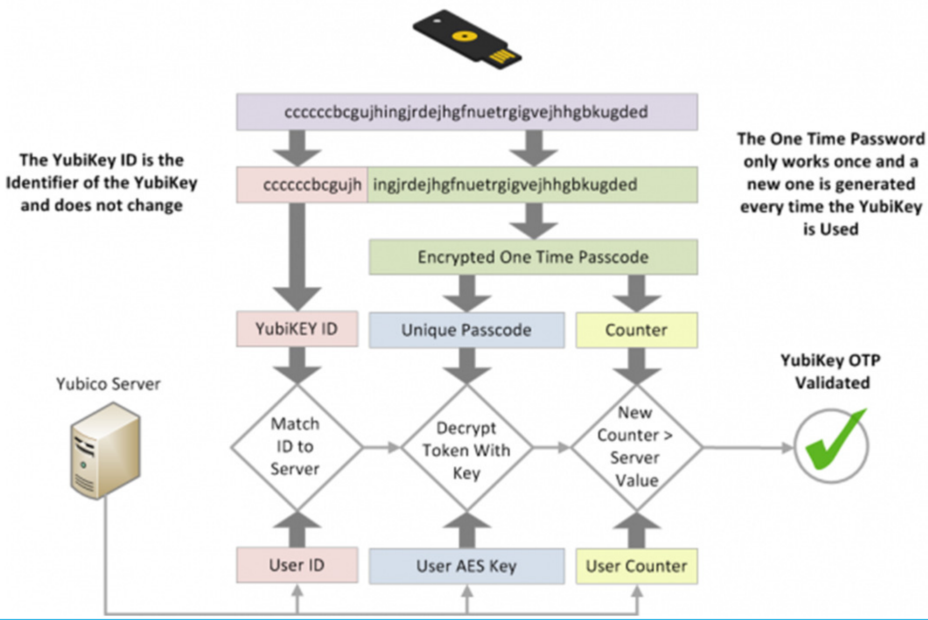
Yubikey

Personal Authentication Device

- USB, Bluetooth and/or NFC

Activation generates a 44 characters key

- Emulates a USB keyboard (besides an own API)
- Supports HOTP (events) or TOPT (Temporal)
- If a challenges is provided, user most touch the button to obtain a result
- Several algorithms, including AES 256



Challenge-response Approach

The authenticator provides a challenge
- A nonce (value not once used)
- Usually random
- Can be a counter

The authenticated entity transforms the challenge
- The transformation method is shared with the authenticator

The result is sent to the authenticator

The authenticator verifies the result
- Calculates a result using the same method and challenge
- Or produces a value from the result and evaluates if it is equal to the challenge, or to some related value

Challenge-Response Approach

Advantages
- Authentication credentials are not exposed
- An eavesdropper will see the challenge and the result
  - but has no knowledge about the transformation

Problems
- Authenticated entities must have the capability of calculating results to challenges
  - Hardware token ou software application
- The authenticator may need to keep shared secrets (in clear text)
  - Secrets can be stolen
  - Individuals may reuse secrets in other systems, enabling lateral attacks
- May be possible to calculate all results to a single (or all) challenge(s)
  - Can revel the secret used
- May be vulnerable to dictionary attacks
- Authenticator should NEVER issue the same challenge to the same user

Authn of Subjects: Challenge-Response with Smartcards

Authentication Credentials

- Having the smartcard
  - e.g., the Citizen Card
- The private key stored inside the smartcard
- The PIN code to access the key

The authenticator knows

- The user public key

Robust against:

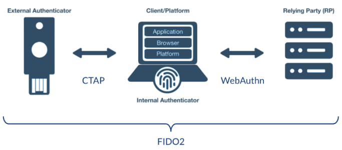
- Dictionary attacks
- Offline attacks to the database
- Insecure channels

Authn of Subjects: Challenge-Response with Smartcards

Challenge-Response Protocol

- The authenticator generates a challenge
- Smartcard owner ciphers the challenge with their private key
  - Stored in the smartcard, protected by the PIN code
  - In alternative, can sign the challenge
- The authenticator deciphers the result with the public key
  - If the decrypted result matches the challenge, the authentication is successful
  - In alternative, it can verify the signature (which is the same process)

Authn of Subjects: Challenge-Response with other tokens

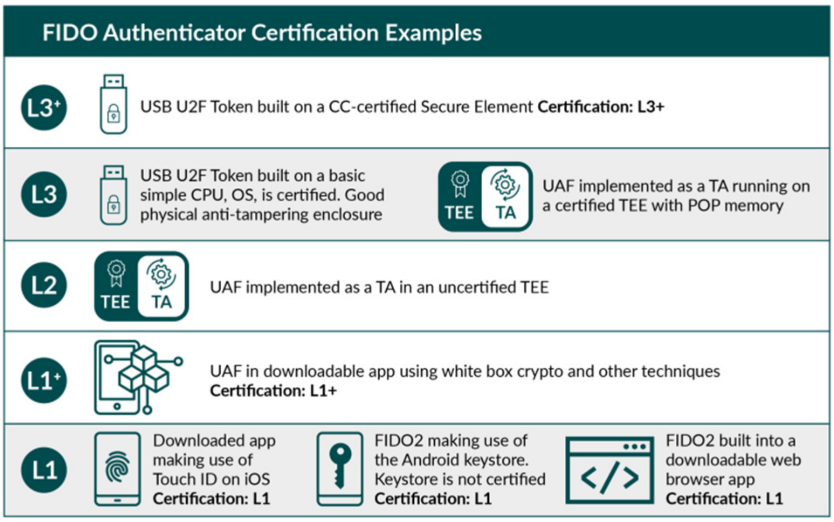


FIDO2 tokens (FIDO Alliance)

- For both mobile and desktop environments
- Web Authentication (WebAuthn) specification
- Client-to-Authenticator Protocol (CTAP)
- Security
  - Credentials never leave the user's device and are never stored on a server
  - No risks of phishing, no password theft (still, tokens can be stolen)
  - No replay attacks
  - Token certification levels
- Privacy
  - Credentials are unique per website
  - Tracking is not possible (different web sites, different public keys for the same token)
  - Biometric data, when used, never leaves the user's device

https://www.inovex.de/de/blog/fido2-webauthn-in-practice/

FIDO2 certification



Authn of Subjects: Challenge-Response with Shared Secret

Authentication Credentials

- Password selected by the individual

The authenticator knows:

- Bad approach: the shared password
- Better approach: A transformation of the shared password
  - The transformation should be unidirectional

Authentication of Subjects: Challenge-Response with Shared Secret

Basic Challenge-Response Protocol

- The authenticator generates a challenge
- The individual calculates a transformation of the challenge and the password
  - result = hash(challenge || password)
  - or... result = encrypt(challenge, password)
- The authenticator reverts the process and checks if the values match
  - result == hash(challenge || password)
  - or .... challenge == decrypt(result, password)
- Examples with shared passwords: CHAP, MS-CHAP v1/v2, S/Key
- Examples with shared keys: SIM & USIM (celular communications)

PAP and CHAP
(RFC 1334, 1992, RFC 1994, 1996)

Protocols user for PPP (Point-to-Point Protocol)

- Unidirectional authentication
  - The authenticator authenticates users, but users do not authenticate the authenticator

PAP (PPP Authentication Protocol)

- Simple presentation of a UID/password pair
- Insecure transmission (in clear text)

CHAP (CHallenge-response Authentication Protocol)

Aut → U : authID, challenge
U → Aut: authID, MD5(authID, secret, challenge), identity
Aut → U : authID, OK/not OK

- The authenticator can request further authentication at any time

Authentication of subjects: Challenge-Response with Shared Key

Uses a cryptographic key instead of a password

- Robust against dictionary attacks
- Requires a device to store the shared key

GSM Subscriber authentication

Uses a secret shared between the HLR and the subscriber phone

- Uses 128-bit shared key (not an asymmetric key pair)
- Key is stored in the SIM card
- SIM card is unlocked by a user PIN
- SIM card answers challenges using the shared key

Uses (initially unknown algorithms):

- A3 for authentication
- A8 to generate the session key
- A5 is a stream cipher for communication

A3 and A8 executed by the SIM, A5 executed by the baseband

- A3 and A8 can be chosen by the operator

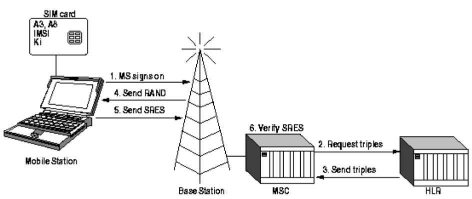
GSM Subscriber authentication

MSC requests triples from HLR/AUC

- RAND, SRES, Kc
- It can ask one or several

HLR generates RAND and the triples using the subscriber Ki

- RAND, random value (128 bits)
- SRES = A3 (Ki, RAND) (32 bits)
- Kc = A8 (Ki, RAND) (64 bits)



Frequently uses COMP128 for the A3/A8 algorithms

- Recommended by the GSM consortium
- [SRES, Kc] = COMP128 (Ki, RAND)

Authentication of Systems

By name (DNS) or MAC/IP address

- Extremely weak, without cryptographic proof
  - Still... it is used by some services
  - e.g., NFS, TCP wrappers

With cryptographic keys

- Secret keys, shared between entities that communicate frequently
- Asymmetric key pairs, one per host
  - Public keys pre-shared with entities that communicate frequently
  - Public keys certified by a third party (a CA)

Authentication of Services

Authentication of the host

- All services co-located in the same host are automatically and indirectly authenticated

Credentials exclusive to each service

Authentication:

- Secret keys shared with clients
  - When they require authentication of the clients
- Asymmetric key pairs by host/service
  - Certified by others or not

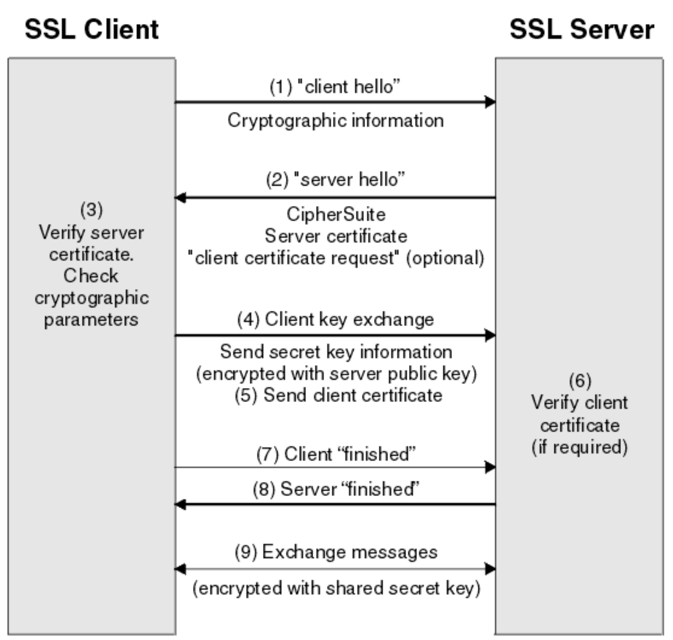
TLS (Transport Layer Security, RFC 2246)

Secure Communication Protocol over TCP/IP

- Evolved from the SSL V3 (Secure Sockets Layer) standard
- Manages secure sessions over TCP/IP, individual to each application
  - Initially designed for HTTP traffic
  - Currently used for many other types of traffic

Security mechanisms

- Confidentiality and integrity of the communication between entities
  - Key distribution, negotiation of ciphers, digests and other mechanisms
- Authentication of the intervenient entities
  - Servers, services, etc...
  - Clients (not so common)
  - Both executed with asymmetric keys and X.509 certificates



TLS Ciphersuites

If a server supports a single algorithm, it cannot expected for all clients to also support it
- More powerful/limited, older/newer

The Ciphersuite concept allows the negotiation of mechanisms between client and server
- Both send their supported ciphersuites, and select one they both share
- The server choses

Exemplo: ECDHE-RSA-AES128-GCM-SHA256

Format:
- Key negotiation algorithm: ECDHE (Elliptic Curve Ephemeral Diffie-Hellman)
- Authentication algorithm: RSA
- Cipher algorithm and cipher mode: AES-128 GCM
- Integrity control algorithm: SHA256

SSH (Secure SHell)

Manages secure console sessions over TCP/IP
- Initially designed to replace the Telnet application/protocol
- Currently used in many other applications
  - Execution of remote commands in a secure manner (rsh/rexec)
  - Secure copy of contents from/to remote hosts (rcp)
  - Secure FTP (sftp)
  - Secure (Generic) communication tunnels (carry standard IP packets)

Security Mechanisms
- Confidentiality and integrity of the communications
  - Key distribution
- Authentication of the intervenient entities
  - Server / Hosts
  - Client users
  - Both achieved through several, and differentiated mechanisms

SSH: Authentication Mechanisms

Server: a pair of asymmetric keys

- Keys are distributed during the interaction
  - Not certified!
- Clients store the public keys from previous interactions
  - Key should be stored in some trusted environment
  - If the key changes the client is warned
    - e.g., server is reinstalled, key is regenerated, an attacker is hijacking the connection
    - Client can refuse to continue with the authentication process

Clients: authentication is configurable

- Default: username and password
- Other: username + private key
  - The public key MUST be pre-installed in the server
- Other: integration with PAM for alternative authentication mechanisms

Centralized network authentication

Used for restricting network access to known clients

- In cabled networks
- In wireless networks
- In VPNs (Virtual Private Networks)

Usually implemented by a central service

- AAA server
  - Authentication, Authorization and Accounting
  - e.g. RADIUS and DIAMETER
- This server defines which network services the user can make use of

Authentication by an IdP

Unique, centralized authentication for a set of federated services

- The identity of a client, upon authentication, is given to all federated services
- The identity attributes given to each service may vary
- The authenticator is called **Identity Provider** (**IdP**)
- The federated service is called a **Relying Party** (**RP**)
- In some cases, the provided identity attributes are shown to the client

Examples

- Authentication at UA
  - Performed by a central, institutional IdP (idp.ua.pt)
  - The identity attributes are securely conveyed to the service accessed by the user
- Autenticação.gov (www.autenticacao.gov.pt)
  - Performed by a central, national IdP
  - The identity attributes are shown to the user
- Other:
  - Services used worldwide: Google, Facebook, etc.

Centralized authentication

Advantages:

- Can reuse same credentials over multiple systems/services
- Single secure repository for credentials
  - More difficult to steal credentials when used in many services
- Can implement restrictions to services/systems

Disadvantages:

- Requires additional servers
- Single point of failure: without authentication systems, no one will be authenticated
  - Important to also deploy local credentials for admins
- Introduces delays in the authentication process

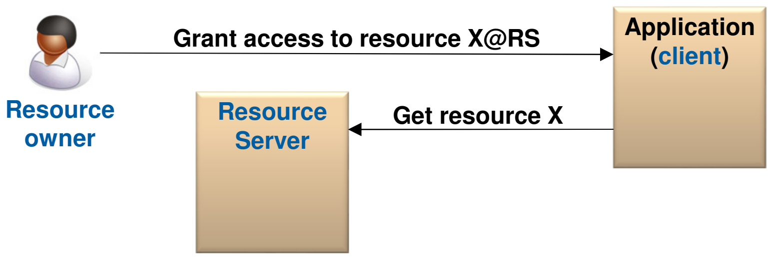
Single Sign-On

A facility usually associated with IdP
- Both not mandatory nor always appropriate

SSO exists for simplifying users' life
- They login just one for accessing several federated services during a given time period

OAuth 2.0: delegation (RFC 6749)

A framework to allow users to delegate access to their resources on their behalf



OAuth 2.0 roles

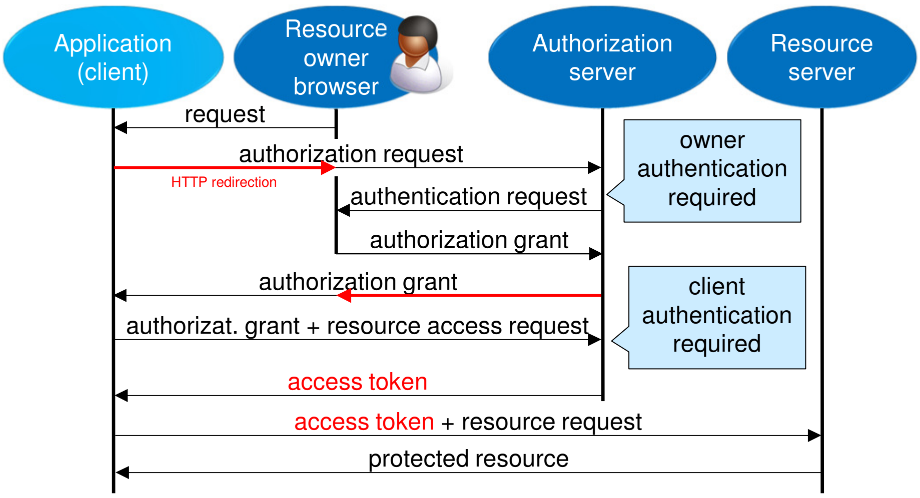
Resource owner
- An entity capable of granting access to a **protected resource**
- **End-user**: a resource owner that is a person

Client
- An **application** making requests for protected resources on behalf of the resource owner and with its authorization

Resource Server
- The server hosting protected resources
- Responds to protected resource requests using **access tokens**

Authorization Server
- The server issuing access tokens to clients after successfully **authenticating resource owners** and obtaining their **authorization** for the clients to access one of their (users) resources

Protocol flow



OpenID Connect (OIDC)

An identification layer on top of OAuth 2.0

- OAuth 2.0 provides the fundamental centralized authentication
- The protected resources are identity attributes
  - Packed in **scopes**
  - The attributes are called (identity) **claims**