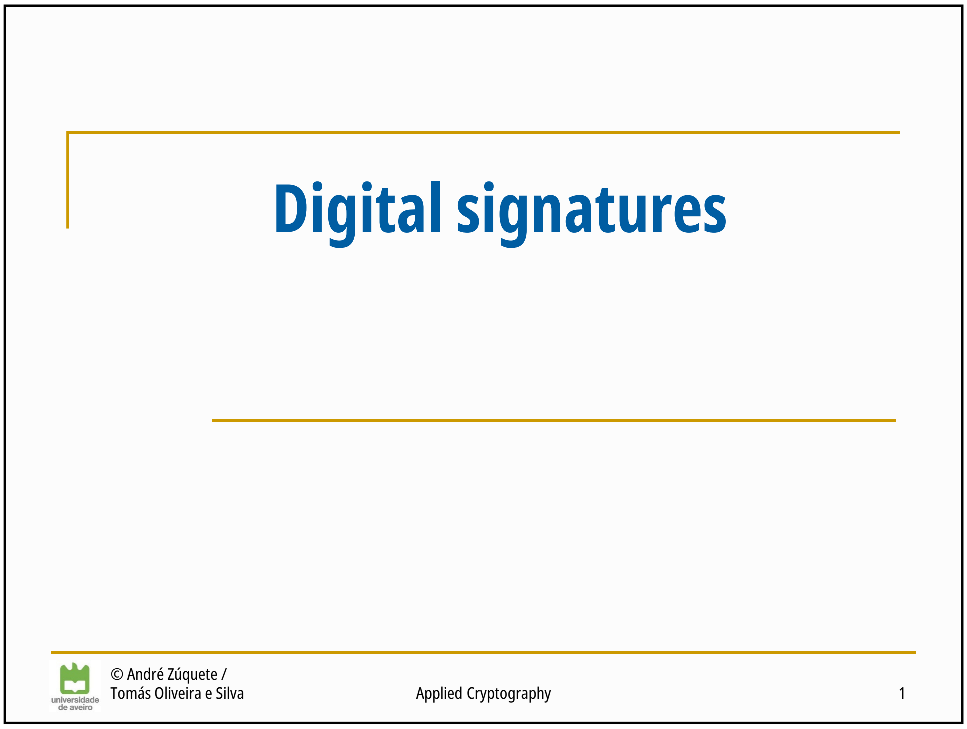
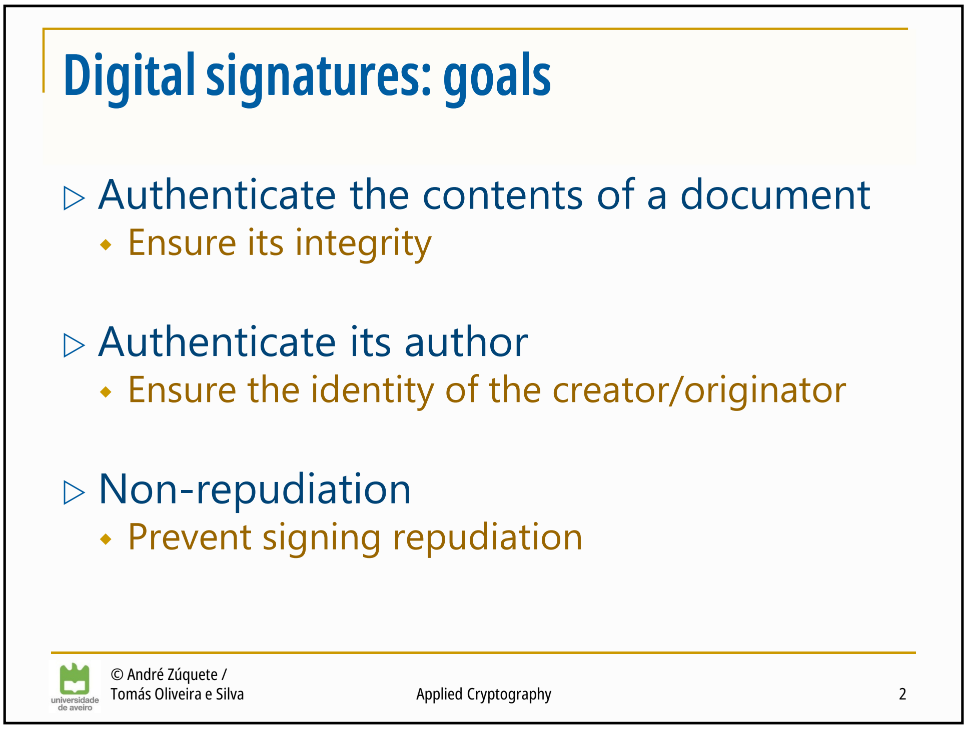
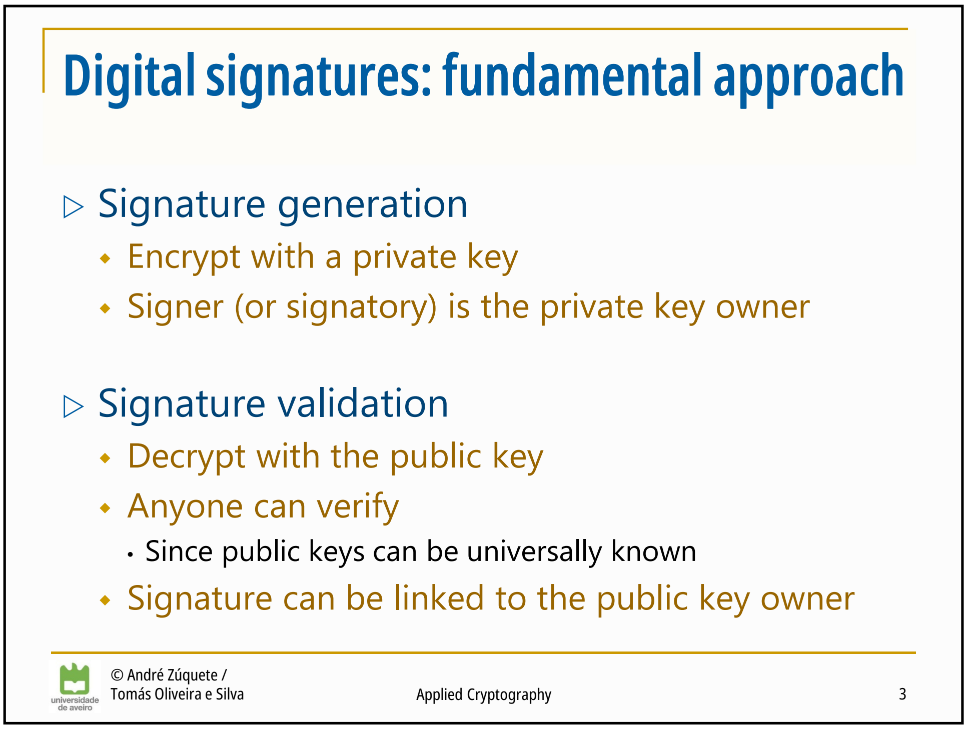


Digital signatures



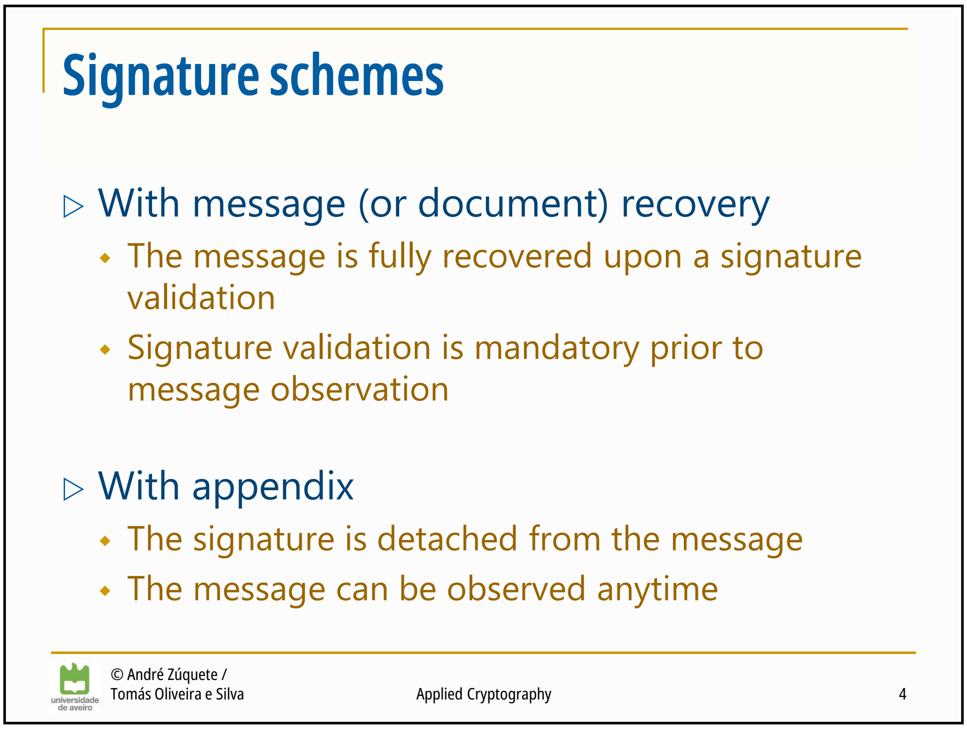
Digital signatures: goals

- ▷ Authenticate the contents of a document
  - Ensure its integrity
- ▷ Authenticate its author
  - Ensure the identity of the creator/originator
- ▷ Non-repudiation
  - Prevent signing repudiation



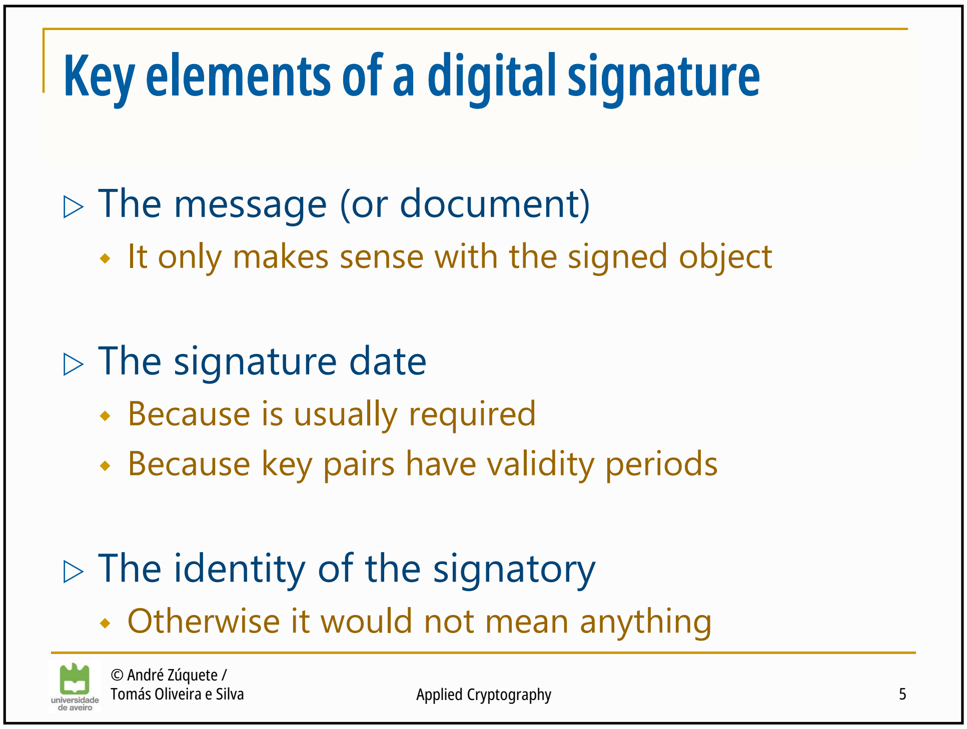
Digital signatures: fundamental approach

- ▷ Signature generation
  - Encrypt with a private key
  - Signer (or signatory) is the private key owner
- ▷ Signature validation
  - Decrypt with the public key
  - Anyone can verify
    - Since public keys can be universally known
  - Signature can be linked to the public key owner



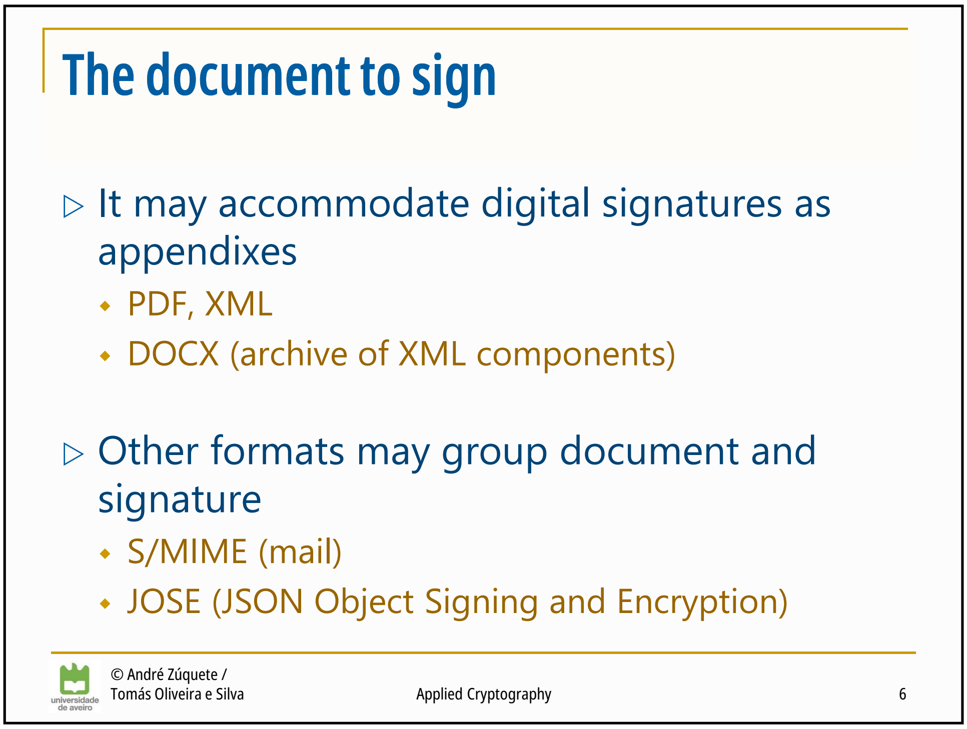
Signature schemes

- ▷ With message (or document) recovery
  - The message is fully recovered upon a signature validation
  - Signature validation is mandatory prior to message observation
- ▷ With appendix
  - The signature is detached from the message
  - The message can be observed anytime



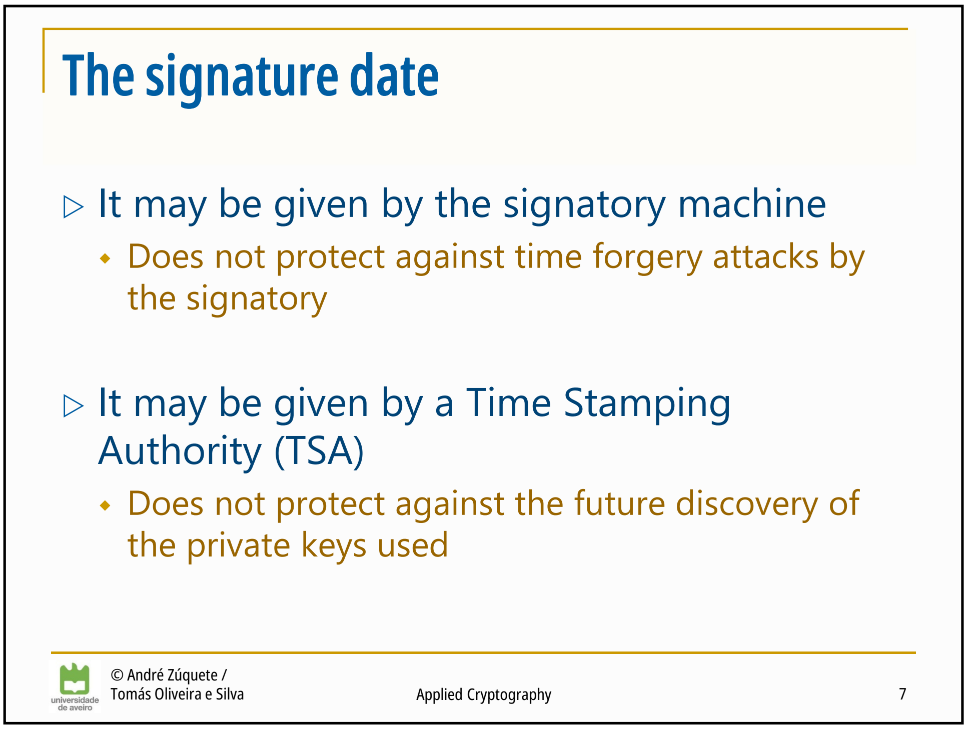
Key elements of a digital signature

- ▷ The message (or document)
  - It only makes sense with the signed object
- ▷ The signature date
  - Because is usually required
  - Because key pairs have validity periods
- ▷ The identity of the signatory
  - Otherwise it would not mean anything



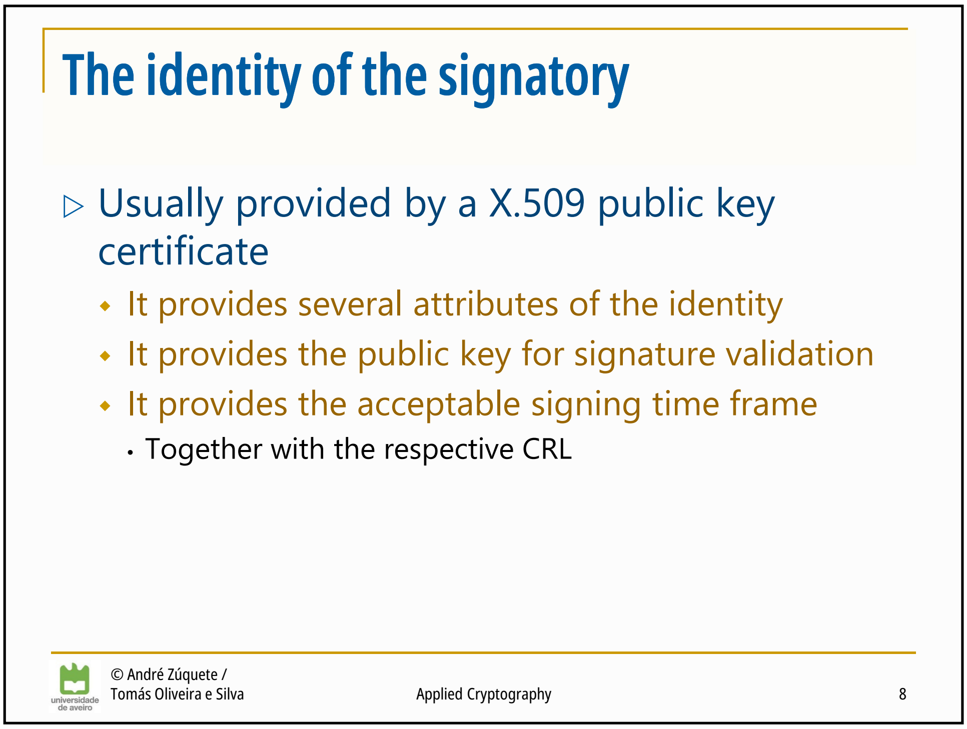
The document to sign

- ▷ It may accommodate digital signatures as appendixes
  - PDF, XML
  - DOCX (archive of XML components)
- ▷ Other formats may group document and signature
  - S/MIME (mail)
  - JOSE (JSON Object Signing and Encryption)



The signature date

- ▷ It may be given by the signatory machine
  - Does not protect against time forgery attacks by the signatory
- ▷ It may be given by a Time Stamping Authority (TSA)
  - Does not protect against the future discovery of the private keys used



The identity of the signatory

- ▷ Usually provided by a X.509 public key certificate
  - It provides several attributes of the identity
  - It provides the public key for signature validation
  - It provides the acceptable signing time frame
    - Together with the respective CRL

Optional elements of a digital signature

- Attributes that can help to interpret it
  - Location
    - Where it was signed
  - Reason
    - Why it was signed
  - Appearance
    - Handwritten signature (usually without legal value)
    - Name of the signatory
    - Date of signature
    - Some kind of logo

Digital signatures' algorithms

- Message recovery scheme
  - Asymmetric encryption and decryption
  - Only for RSA

- Signing

  $A_x(doc) = info + E(K_x^{-1}, doc)$

- Verification

  info→K_x

  $D(K_x, A_x(doc))$

  Check integrity of doc

- Message appendix scheme
  - Digest functions
  - Asymmetric signature and validation
  - RSA, ElGamal (DSA), EC

- Signing

  $A_x(doc) = info + E(K_x^{-1}, h(doc+info))$

  $A_x(doc) = info + S(K_x^{-1}, h(doc+info))$

- Verification

  info→K_x

  $D(K_x, A_x(doc)) \equiv h(doc + info)$

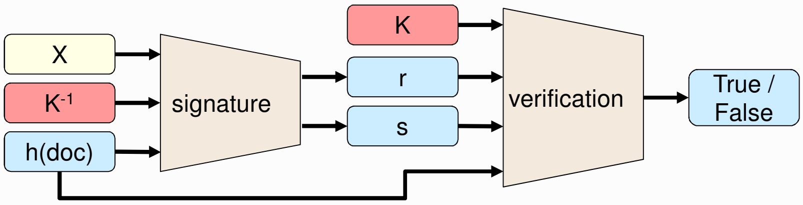
  $V(K_x, A_x(doc), h(doc + info)) = True$

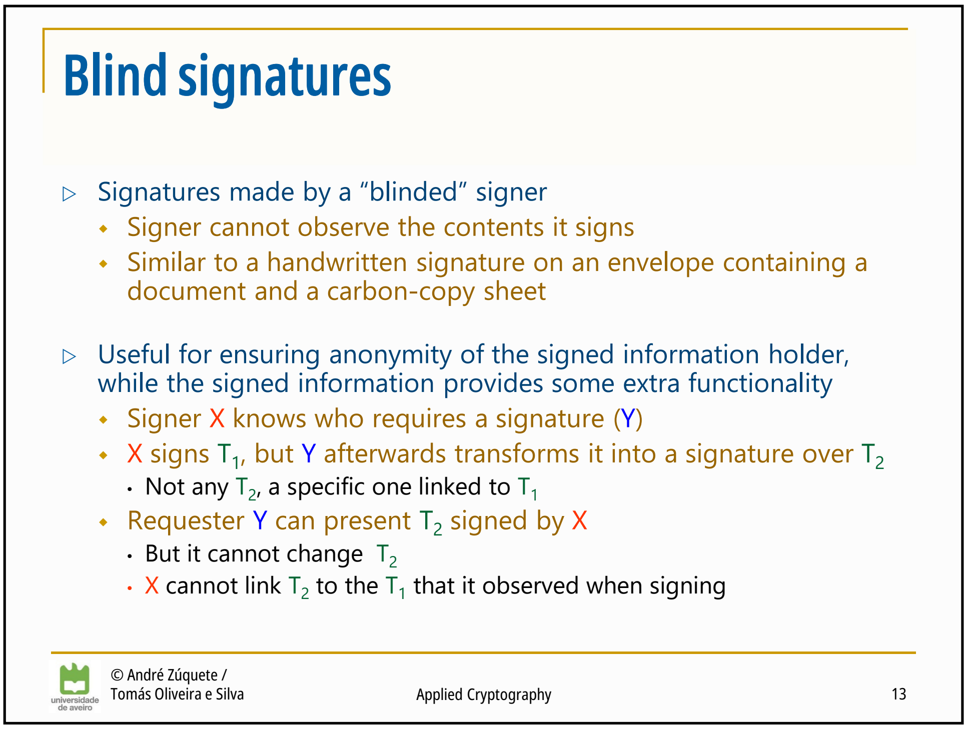
RSA signatures

- ▷ Creation with private key
  - Validation with the corresponding public key
- ▷ Special padding for Signature Scheme w/ Appendix
  - RSASSA-PKCS#1 (v1.5)
    - Deterministic
  - RSASSA-PSS (Probabilistic Signature Scheme)
    - Randomized (EMSA-PSS)
- ▷ Hash function prefixing
  - ASN.1 algorithm OID

Digital Signature Standard (DSS)

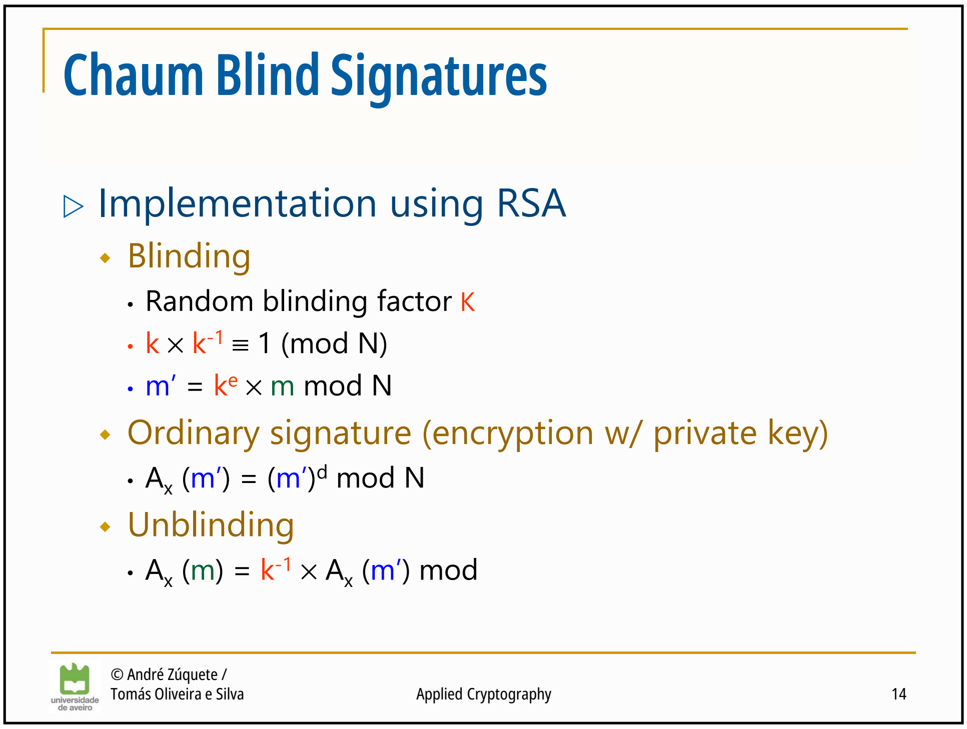
- ▷ With a variant of ElGamal
  - Digital Signature Algorithm (DSA)
  - Uses a random value **X**, and its multiplicative inverse, $\mathbf{X^{-1}}$
  - **r** depends on **X**, **s** depends on $\mathbf{X^{-1}}$
- ▷ With elliptic curves (ECDSA)
  - Similar to DSA with EC





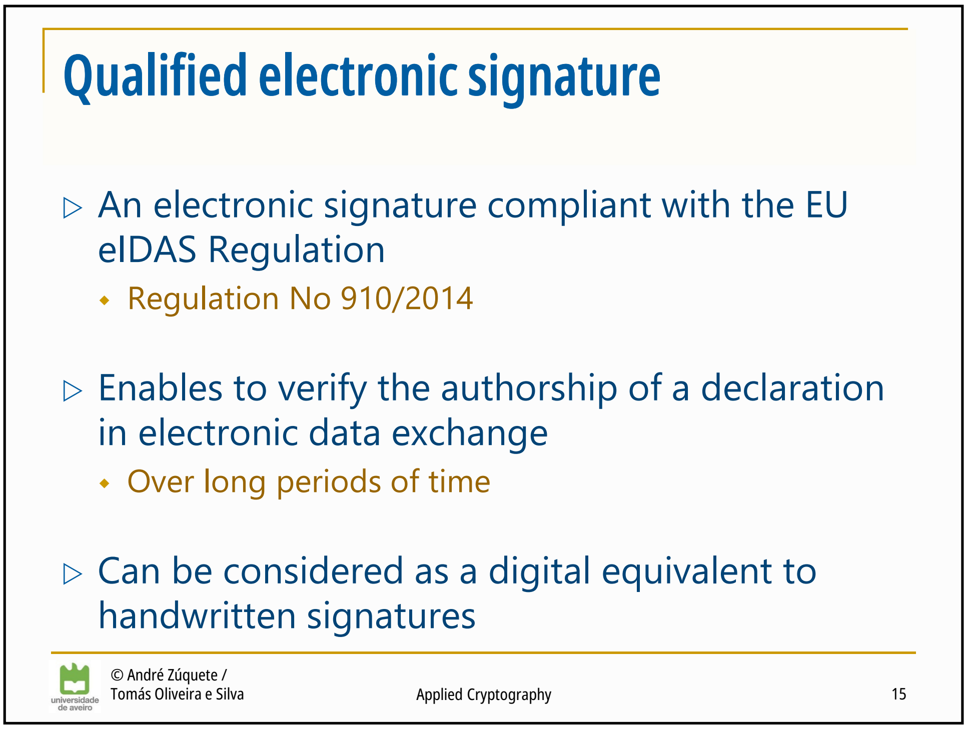
Blind signatures

- Signatures made by a “blinded” signer
  - Signer cannot observe the contents it signs
  - Similar to a handwritten signature on an envelope containing a document and a carbon-copy sheet
- Useful for ensuring anonymity of the signed information holder, while the signed information provides some extra functionality
  - Signer X knows who requires a signature (Y)
  - X signs T_1, but Y afterwards transforms it into a signature over T_2
    - Not any T_2, a specific one linked to T_1
  - Requester Y can present T_2 signed by X
    - But it cannot change T_2
    - X cannot link T_2 to the T_1 that it observed when signing



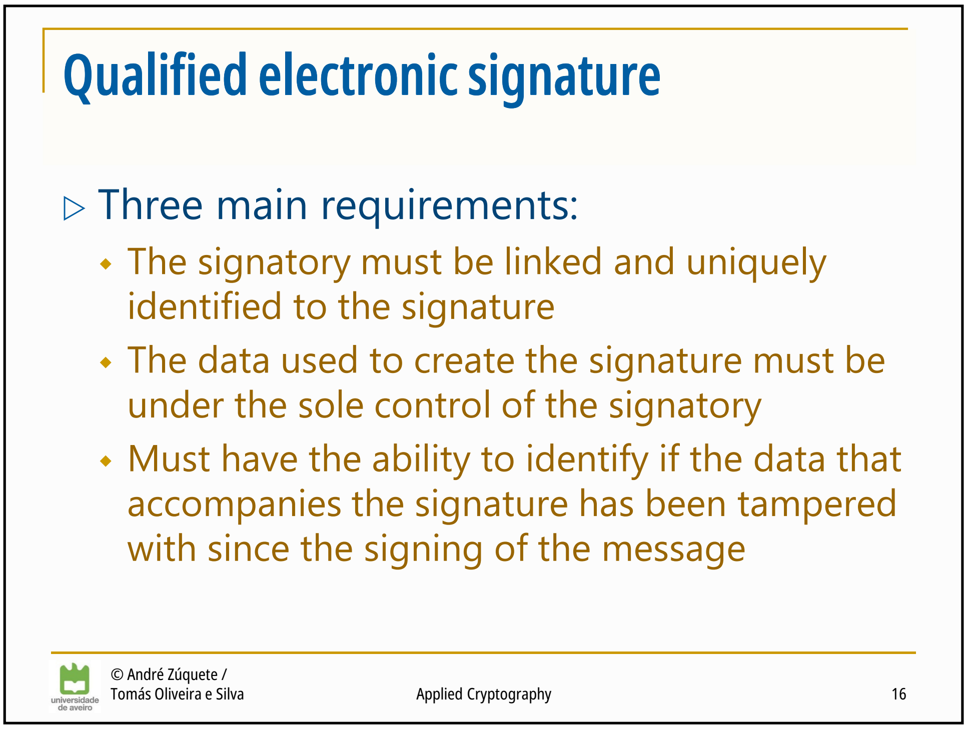
Chaum Blind Signatures

- Implementation using RSA
  - Blinding
    - Random blinding factor K
    - $k \times k^{-1} \equiv 1 \pmod{N}$
    - $m' = k^e \times m \bmod N$
  - Ordinary signature (encryption w/ private key)
    - $A_x(m') = (m')^d \bmod N$
  - Unblinding
    - $A_x(m) = k^{-1} \times A_x(m') \bmod$



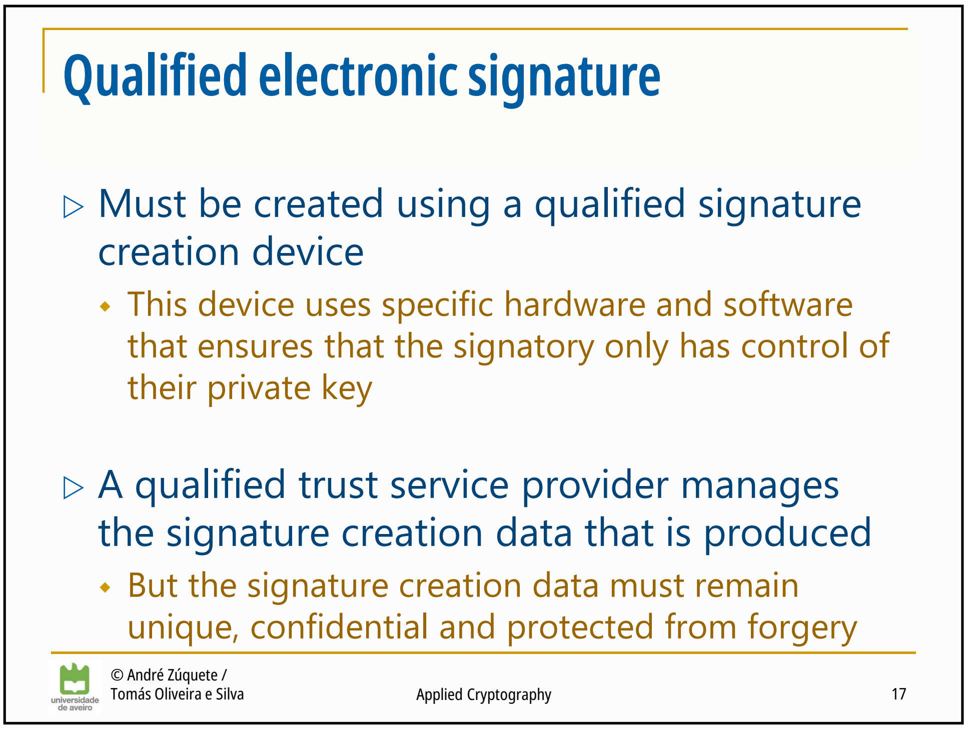
Qualified electronic signature

- An electronic signature compliant with the EU eIDAS Regulation
  - Regulation No 910/2014
- Enables to verify the authorship of a declaration in electronic data exchange
  - Over long periods of time
- Can be considered as a digital equivalent to handwritten signatures



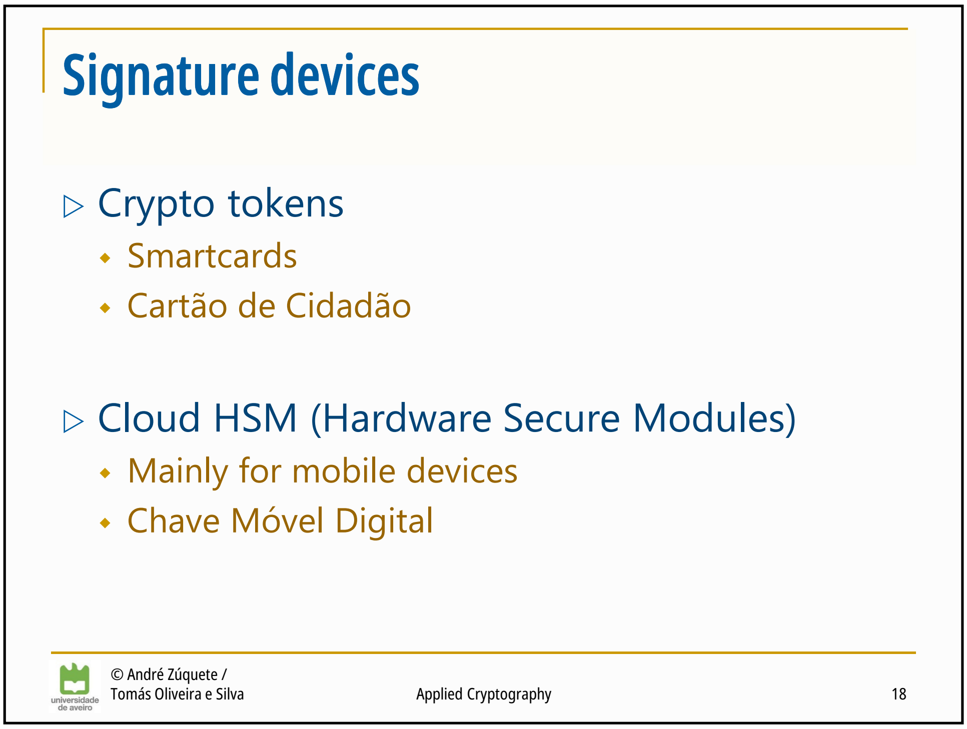
Qualified electronic signature

- Three main requirements:
  - The signatory must be linked and uniquely identified to the signature
  - The data used to create the signature must be under the sole control of the signatory
  - Must have the ability to identify if the data that accompanies the signature has been tampered with since the signing of the message



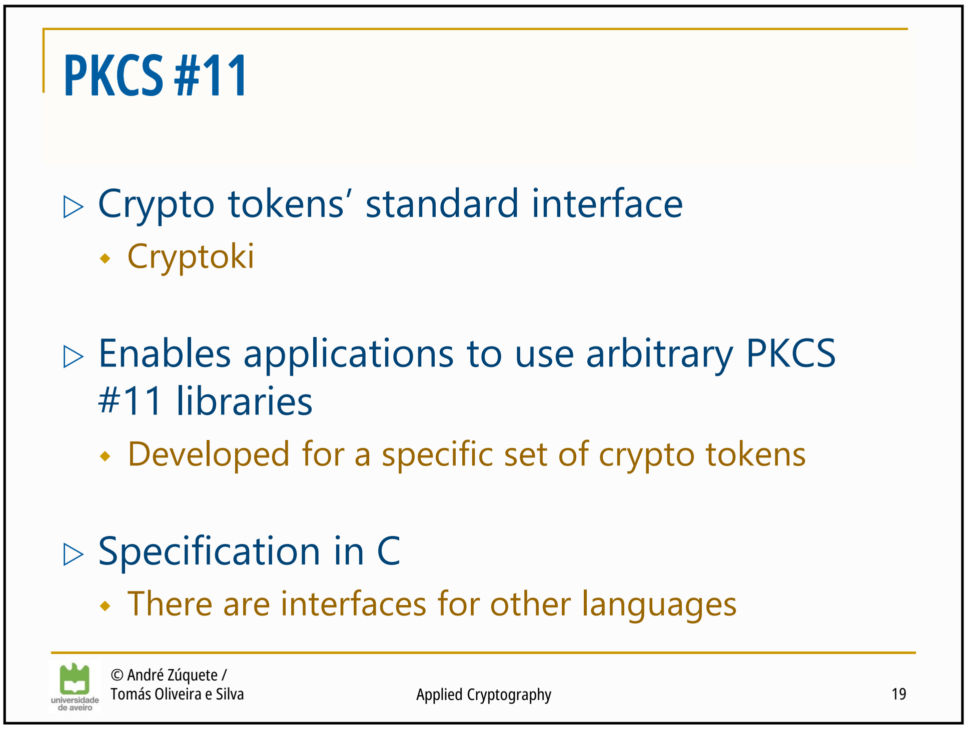
Qualified electronic signature

- Must be created using a qualified signature creation device
  - This device uses specific hardware and software that ensures that the signatory only has control of their private key
- A qualified trust service provider manages the signature creation data that is produced
  - But the signature creation data must remain unique, confidential and protected from forgery



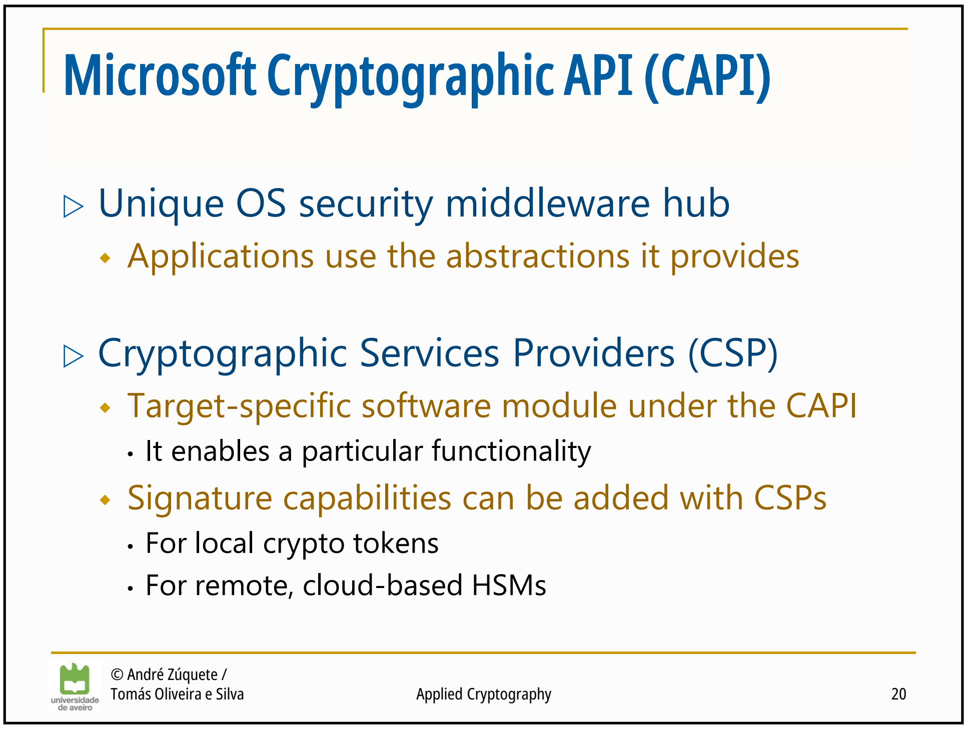
Signature devices

- Crypto tokens
  - Smartcards
  - Cartão de Cidadão
- Cloud HSM (Hardware Secure Modules)
  - Mainly for mobile devices
  - Chave Móvel Digital



PKCS #11

- ▷ Crypto tokens' standard interface
  - Cryptoki
- ▷ Enables applications to use arbitrary PKCS #11 libraries
  - Developed for a specific set of crypto tokens
- ▷ Specification in C
  - There are interfaces for other languages



Microsoft Cryptographic API (CAPI)

- ▷ Unique OS security middleware hub
  - Applications use the abstractions it provides
- ▷ Cryptographic Services Providers (CSP)
  - Target-specific software module under the CAPI
    - It enables a particular functionality
  - Signature capabilities can be added with CSPs
    - For local crypto tokens
    - For remote, cloud-based HSMs

Long-Term Validation (LTV)

- ▷ A document signature may become invalid upon an initial verification
  - Due to a late certification revocation
- ▷ Signature algorithms may become vulnerable
  - Allowing signatures with old credentials to be forged
- ▷ LTV attempts to handle both issues
  - With successive signature layers
  - Performed by signed documents' holders

LTV Advanced Electronic Signatures (AdES)

- ▷ PAdES
  - PDF Advanced Electronic Signature
- ▷ CAdES
  - Cryptographic Message Syntax Advanced Electronic Signatures
- ▷ XAdES
  - XML Advanced Electronic Signatures