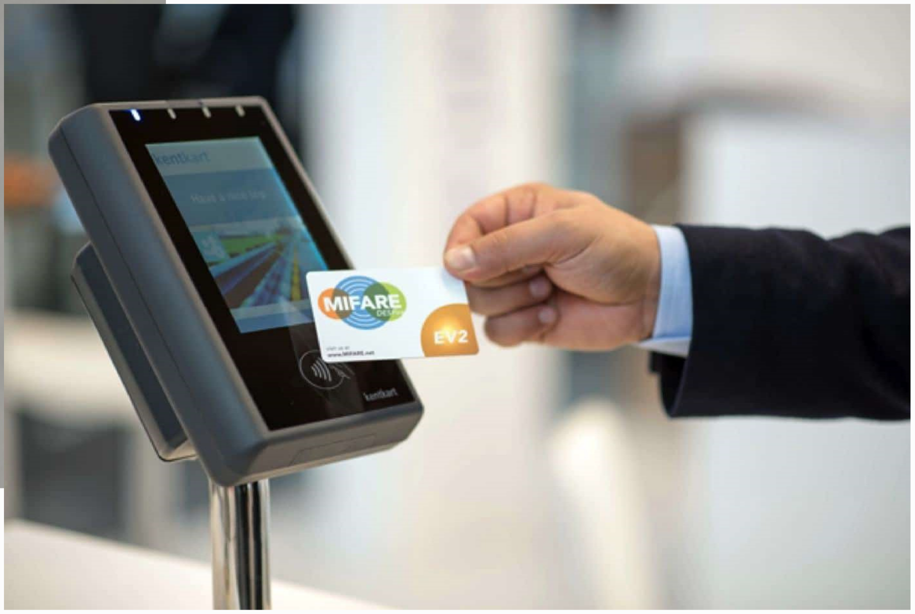
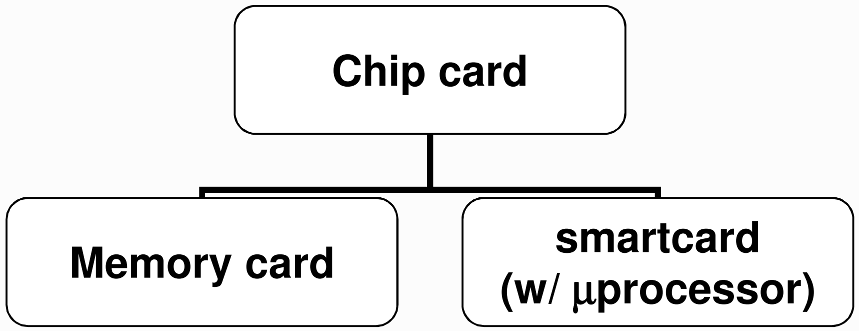
Smartcards



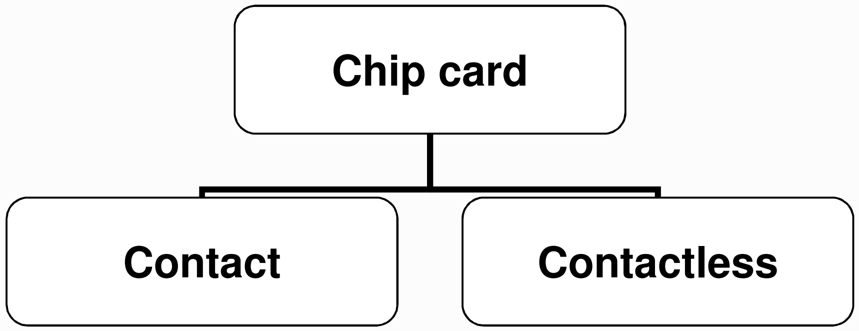
https://pplware.sapo.pt/informacao/saiba-como-renovar-online-o-seu-cartao-de-cidadao/
https://knowtechie.com/security-matters-5-benefits-of-contactless-smart-cards/

Smartcard: Definition

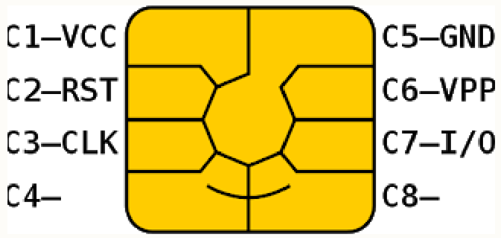
- ▷ Card with computing processing capabilities
  - CPU
  - ROM
  - EEPROM
  - RAM



- ▷ Interface
  - With contact
  - Contactless

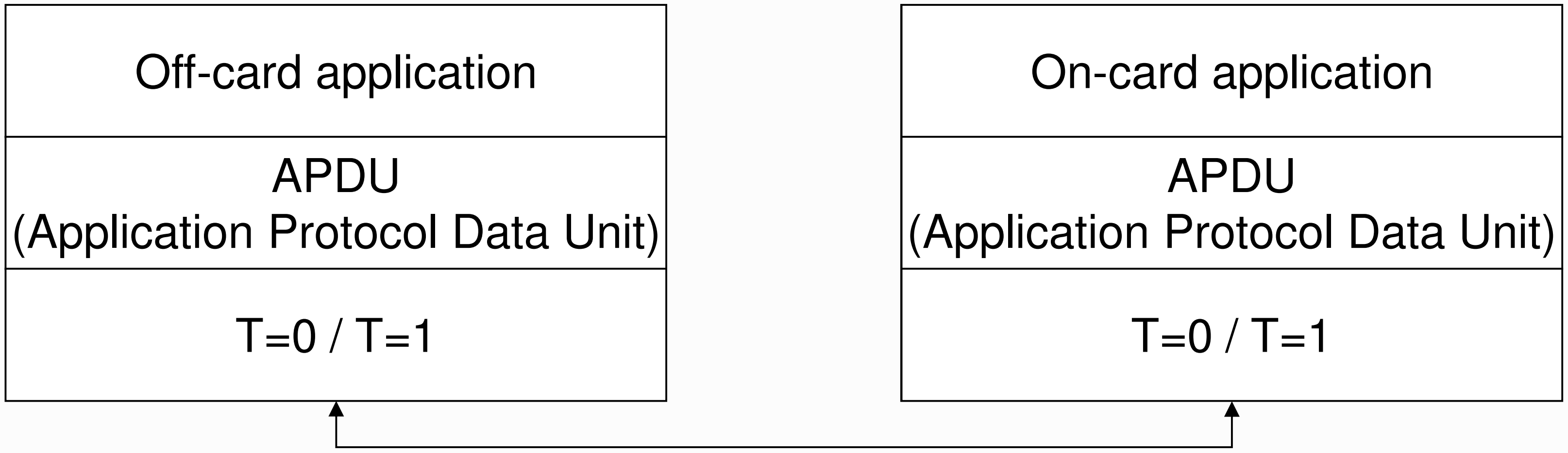


Smartcard: Components



- CPU
  - 8/16 bit
  - Crypto-coprocessor (opt.)
- ROM
  - Operating system
  - Communication
  - Cryptographic algorithms
- EEPROM
  - File system
    - Programs / applications
    - Keys / passwords
- RAM
  - Transient data
    - Erased on power off
- Mechanical contacts
  - ISO 7816-2
    - Power
    - Soft reset
    - Clock
    - Half duplex I/O
- Physical security
  - Tamperproof case
  - Resistance to side-channel attacks

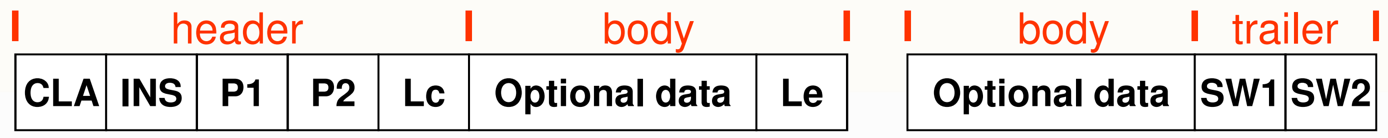
Smartcard applications: Communication protocol stack



T=0 and T=1

- T=0
  - Each byte transmitted separately
  - Slower
- T=1
  - Blocks of bytes transmitted
  - Faster
- ATR (ISO 7816-3)
  - Response of the card to a reset operation
  - Reports the protocol expected by the card

APDU (ISO 7816-4)



- Command APDU
  - CLA (1 byte)
    - Class of the instruction
  - INS (1 byte)
    - Command
  - P1 and P2 (2 bytes)
    - Command-specific parameters
  - Lc
    - Length of the optional command data
  - Le
    - Length of data expected in subsequent Response APDU
    - Zero (0) means all data available

- Response APDU
  - SW1 and SW2 (2 bytes)
    - Status bytes
    - 0x9000 means SUCCESS

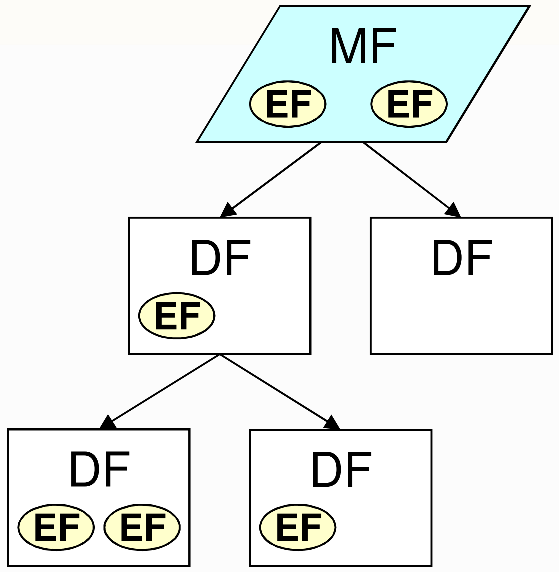
Encoding objects in smartcards: TLV and ASN.1 BER

- ▷ Tag-Length-Value (TLV)
  - Object description with a tag value, the length of its contents and the contents
  - Each element of TLV is encoded according with ASN.1 BER
- ▷ Values can contain other TLV objects
  - The structure can be recursive

Smartcard: File system (1/3)

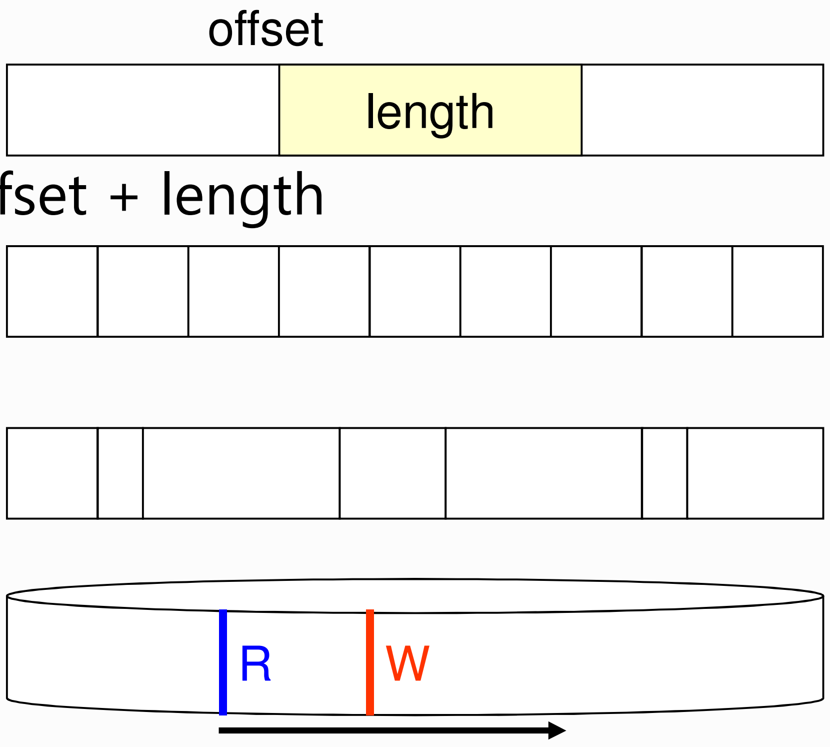
- File identification
  - Name or number

- File types
  - Master File (MF)
    - File system root, ID 0x3F00
  - Dedicated File (DF)
    - Similar to a directory
    - Can contain other EFs or DF
  - Elementary File (EF)
    - Ordinary data file
    - File size fixed and determined when created



Smartcard: File system (2/3)

- File system types
  - Transparent
    - Data blocks identified by offset + length
  - Fixed records
    - Indexed records
  - Variable records
    - Indexed records
  - Cyclic
    - Read pointer, write pointer
    - Cyclic increments

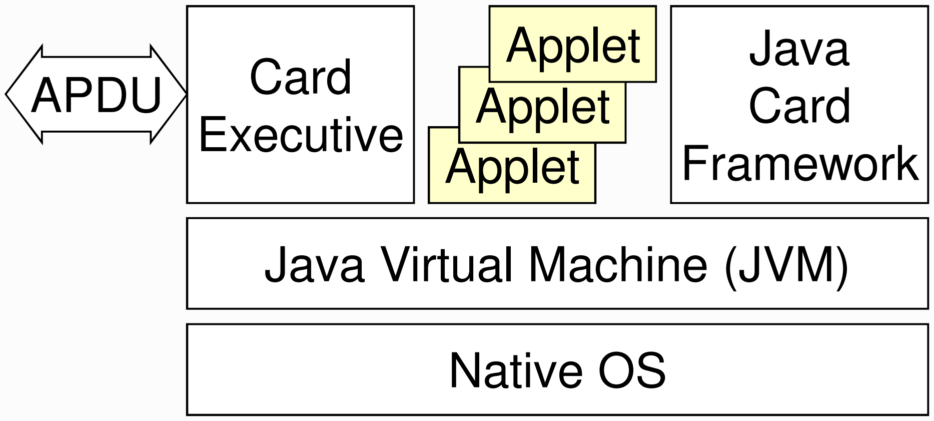


Smartcard: File system (3/3)

- Access control
  - No restrictions
  - Protected
    - The file access APDU must contain a MAC computed with a key shared between the card and the off-card application
  - External authentication
    - The file access APDU is only allowed if the card already checked the existence of a common shared key with the off-card application
    - Previous login

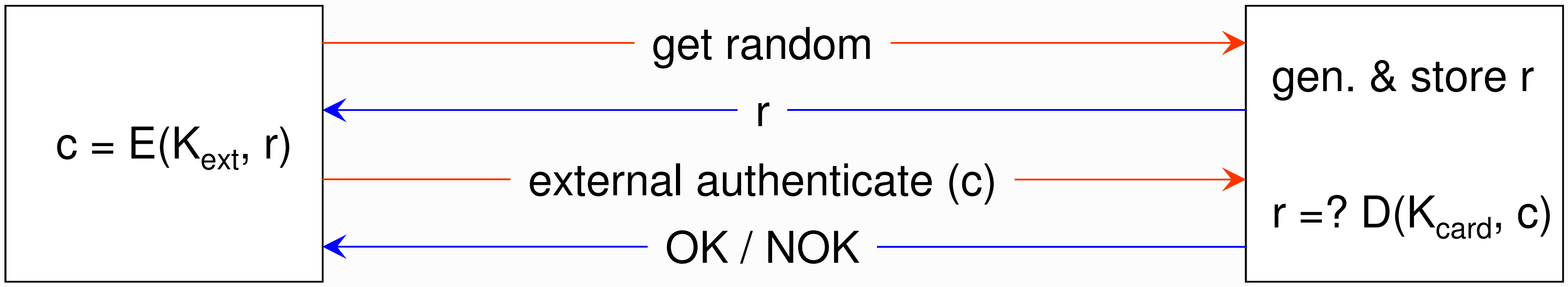
Java cards

- Smartcards that run Java Applets
  - That use the JCRE
  - The JCRE runs on top of a native OS
- JCRE (Java Card Runtime Environment)
  - Java Virtual Machine
  - Card Executive
    - Card management
    - Communications
  - Java Card Framework
    - Library functions



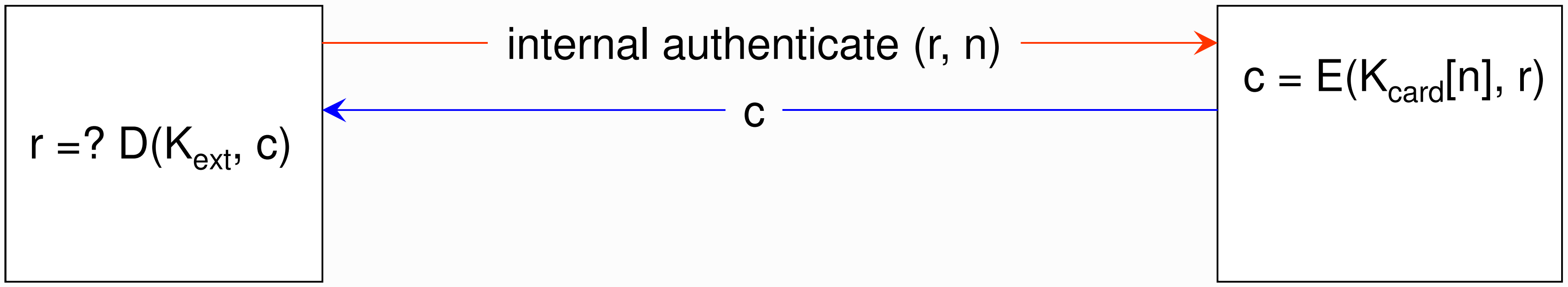
Smartcard: Cryptographic protocols (1/6)

- External authentication
  - The smartcard authenticates the off-card application
  - Challenge-response protocol with random number
    - Initiated by the off-card application



Smartcard: Cryptographic protocols (2/6)

▷ Internal authentication
- The off-card application authenticates the smartcard
- Challenge-response protocol with random number and key number
  - Initiated by the off-card application

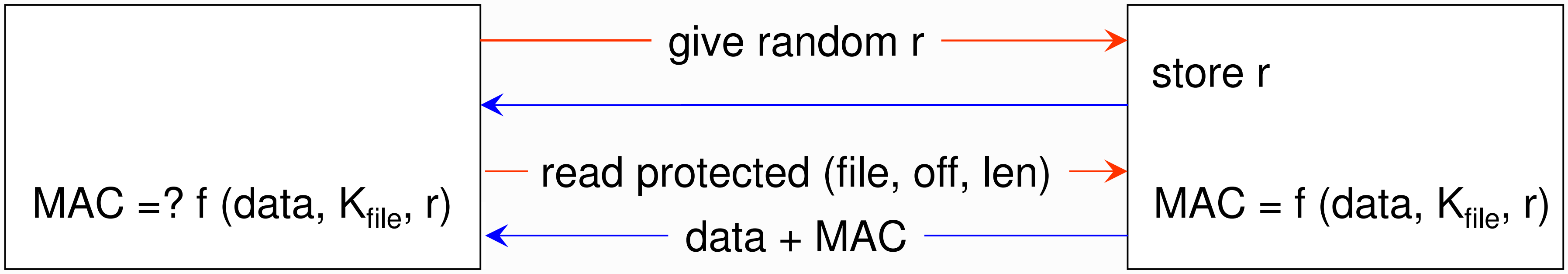


Smartcard: Cryptographic protocols (3/6)

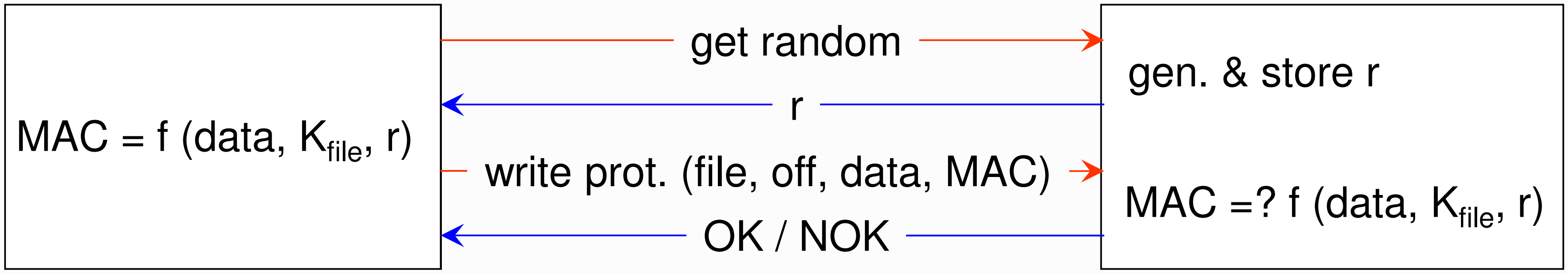
- Secure messaging
  - Protect data red from the smartcard
  - Protect data written into the smartcard
  - Protection forms
    - Authentication with MAC
    - Authentication with MAC and data encryption

Smartcard: Cryptographic protocols (4/6)

- Authenticated readings

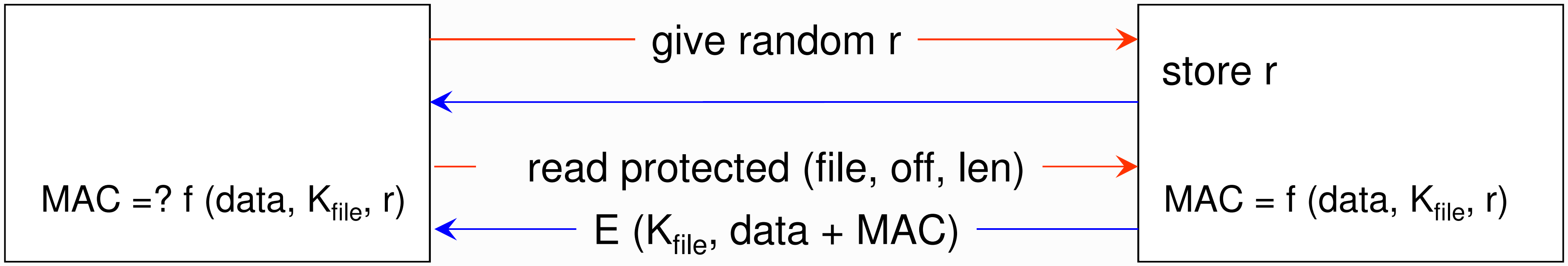

give random r
store r
read protected (file, off, len)
MAC =? f (data, K_{file}, r)
MAC = f (data, K_{file}, r)
data + MAC

- Authenticated writings

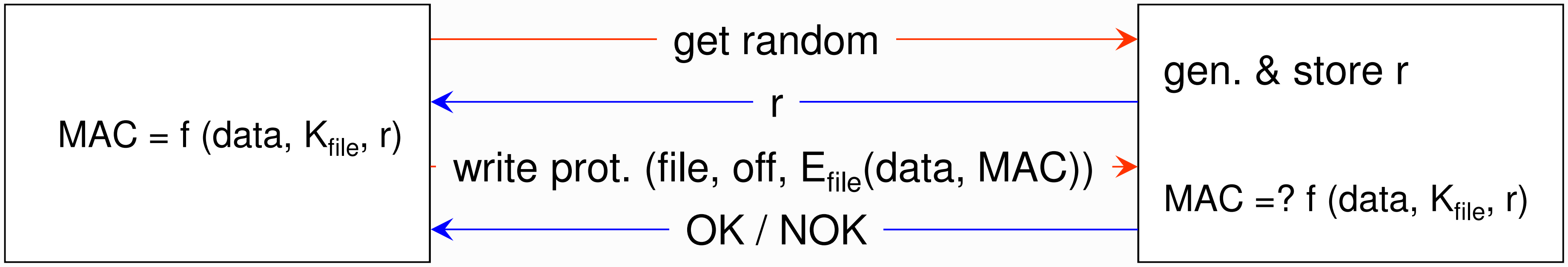

get random
gen. & store r
r
MAC = f (data, K_{file}, r)
write prot. (file, off, data, MAC)
MAC =? f (data, K_{file}, r)
OK / NOK

Smartcard: Cryptographic protocols (5/6)

▷ Authenticated and confidential readings

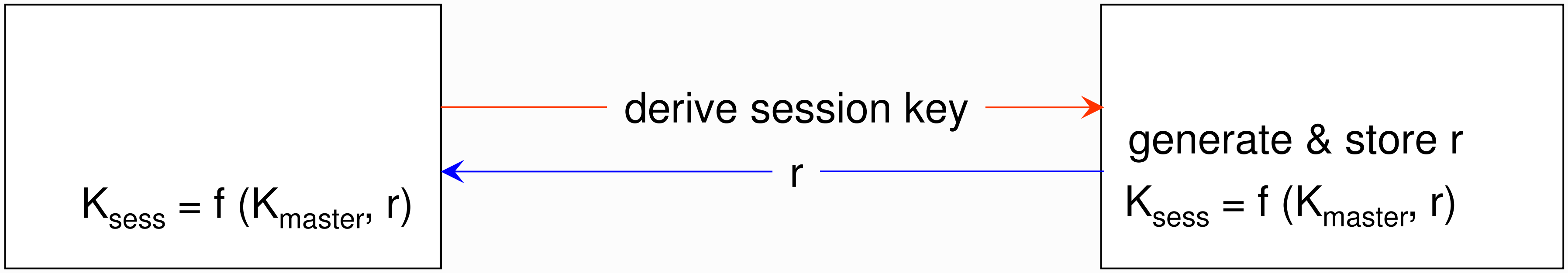

give random r
store r
read protected (file, off, len)
MAC =? f (data, K_{file}, r)
MAC = f (data, K_{file}, r)
E (K_{file}, data + MAC)

▷ Authenticated and confidential writings

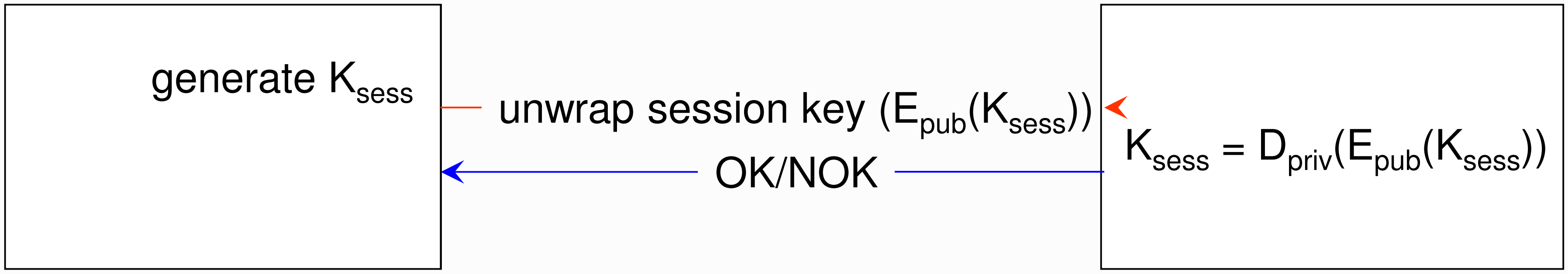

get random
gen. & store r
r
MAC = f (data, K_{file}, r)
write prot. (file, off, E_{file}(data, MAC))
MAC =? f (data, K_{file}, r)
OK / NOK

Smartcard: Cryptographic protocols (6/6)

- Session key derivation



- Session key uploading


generate K_{sess}
unwrap session key $(E_{pub}(K_{sess}))$
$K_{sess} = D_{priv}(E_{pub}(K_{sess}))$
OK/NOK

OpenCard Framework (OCF)

- Goal: facilitate the development of smartcard-based solutions
  - Make the parts of the solution, typically provided by different parties, independent of each other
  - https://www.openscdp.org/ocf

- Parties:
  - Card issuer
    - Card initialization, personalization and issuing
  - Card OS provider
    - Basic, lowest level card behavior
  - Card reader / terminal provider
    - Interfaces that deal with reading from and writing into cards
  - Application / service provider
    - Development of off-card (and possibly on-card) applications

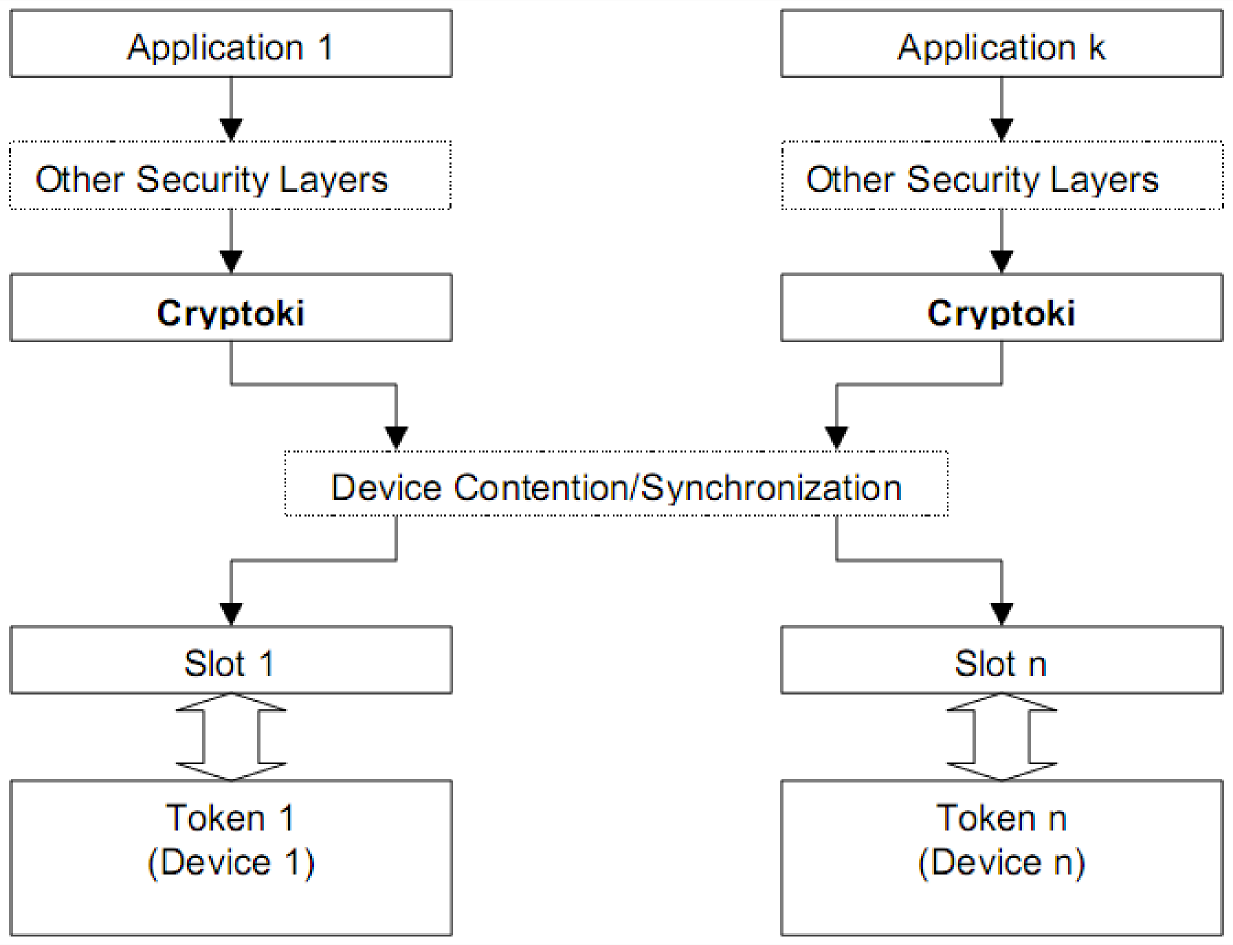
Cryptographic services

- Ciphers
- Digest functions
- Key generation
- Key management
  - Key import
  - Key export
- Digital signatures
  - Generation
  - Verification
- Management of public key certificates
  - Generation
  - Verification

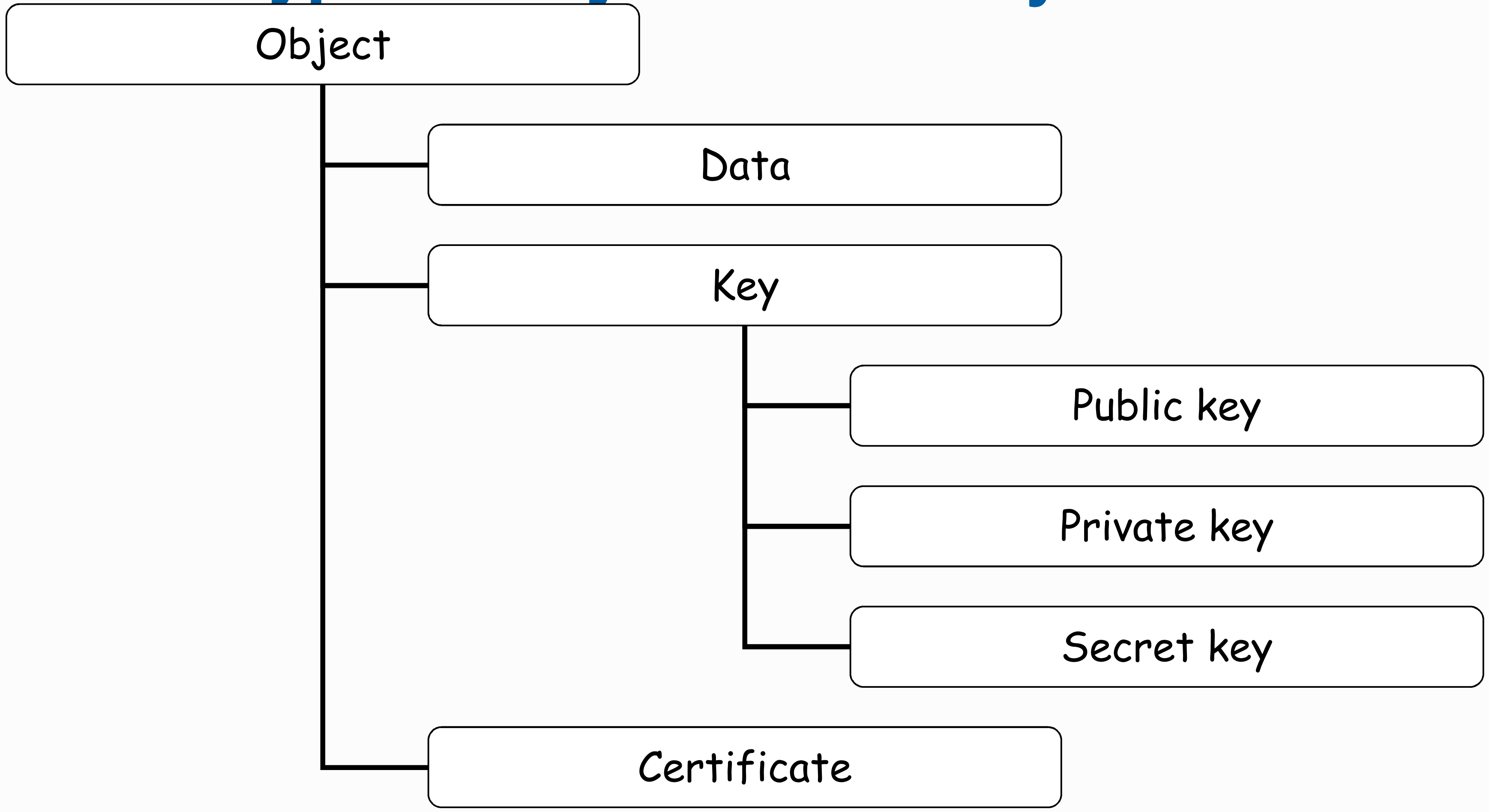
Cryptographic services: Middleware

- Libraries that bridge the gap between functionalities of smartcards and high-level applications
- Some standard approaches:
  - PKCS #11
    - Cryptographic Token Interface Standard (Cryptoki)
    - Defined by RSA Security Inc.
  - PKCS #15
    - Cryptographic Token Information Format Standard
    - Defined by RSA Security Inc.
  - CAPI CSP
    - CryptoAPI Cryptographic Service Provider
    - Defined by Microsoft for Windows systems
  - PC/SC
    - Personal computer/smartcard
    - Standard framework for smartcard access on Windows systems

PKCS #11: Cryptoki middleware integration



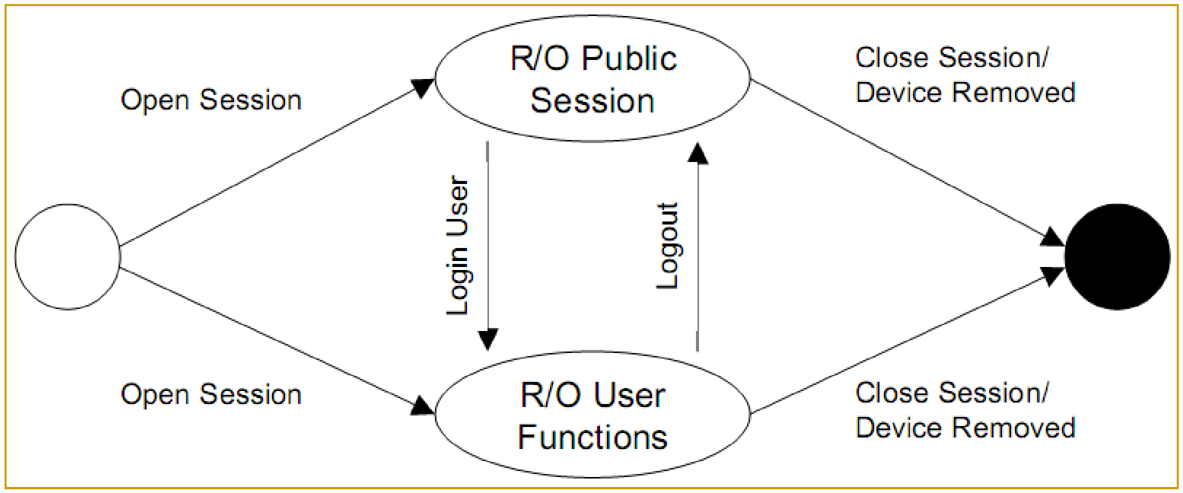
PKCS #11: Cryptoki object hierarchy



PKCS #11: Cryptoki sessions

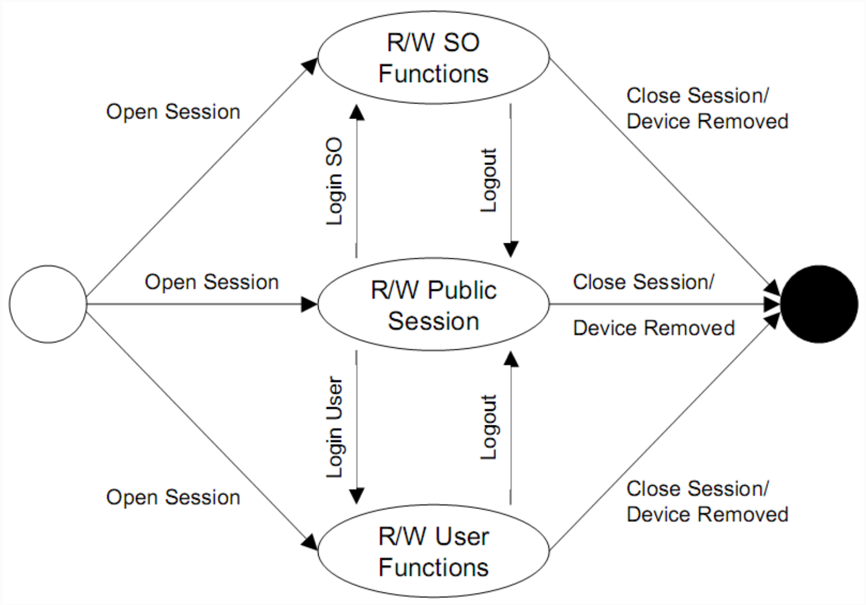
- Logical connections between applications and tokens
  - R/O and R/W sessions
  - Session owners
    - Public
    - User
    - Security Officer (SO)
- Operations on open sessions
  - Administrative
    - Login/logout
  - Object management
    - Create / destroy an object on the token
  - Cryptographic
- Session objects
  - Transient objects created during sessions
- Lifetime of sessions
  - Usually for a single operation on the token

PKCS #11: Cryptoki R/O sessions login/logout



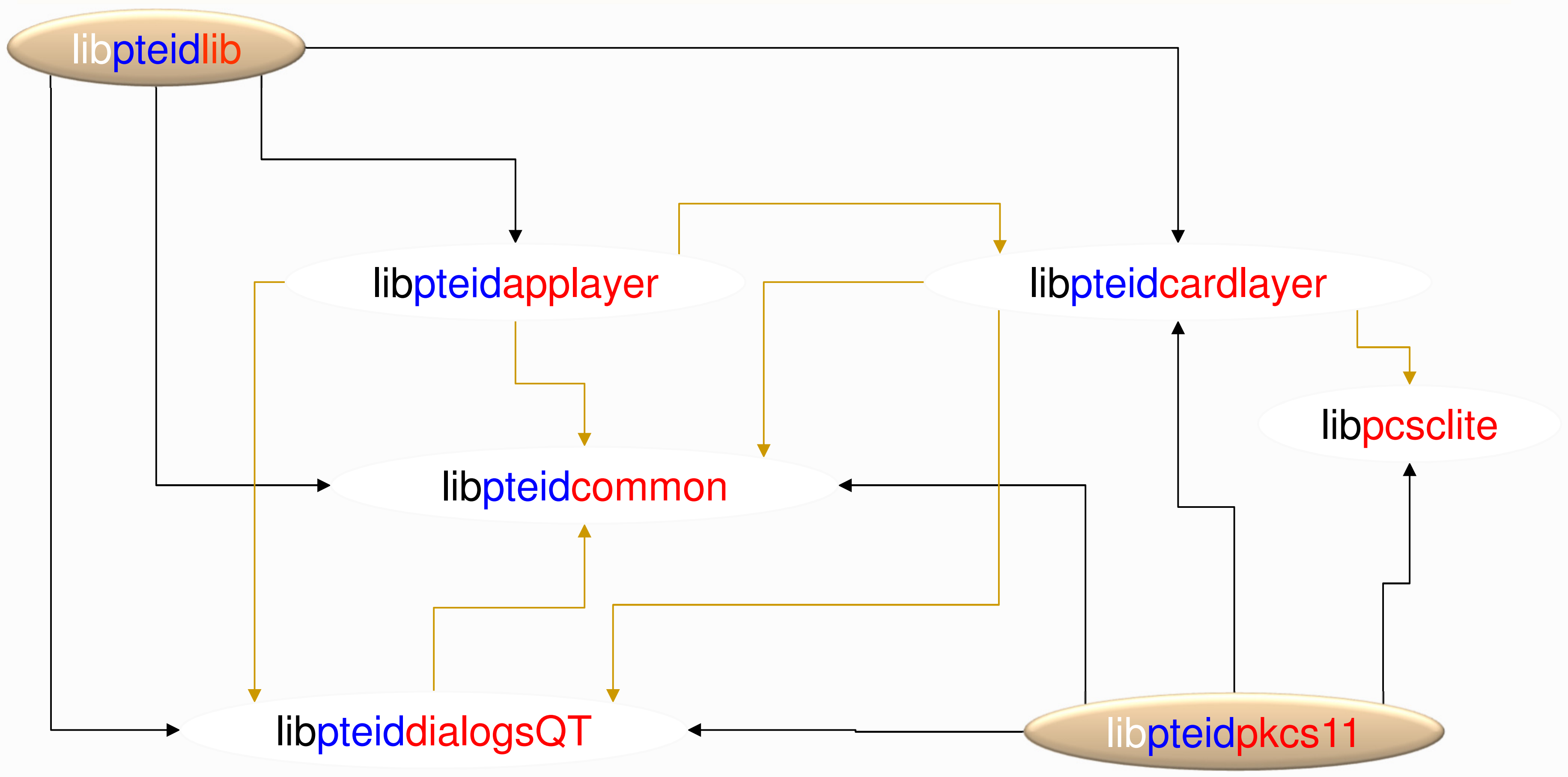
- R/O public session
  - Read-only access to public token objects
  - Read/write access to public session objects
- R/O user functions
  - Read-only access to all token objects (public or private)
  - Read/write access to all session objects (public or private)

PKCS #11: Cryptoki R/W sessions login/logout

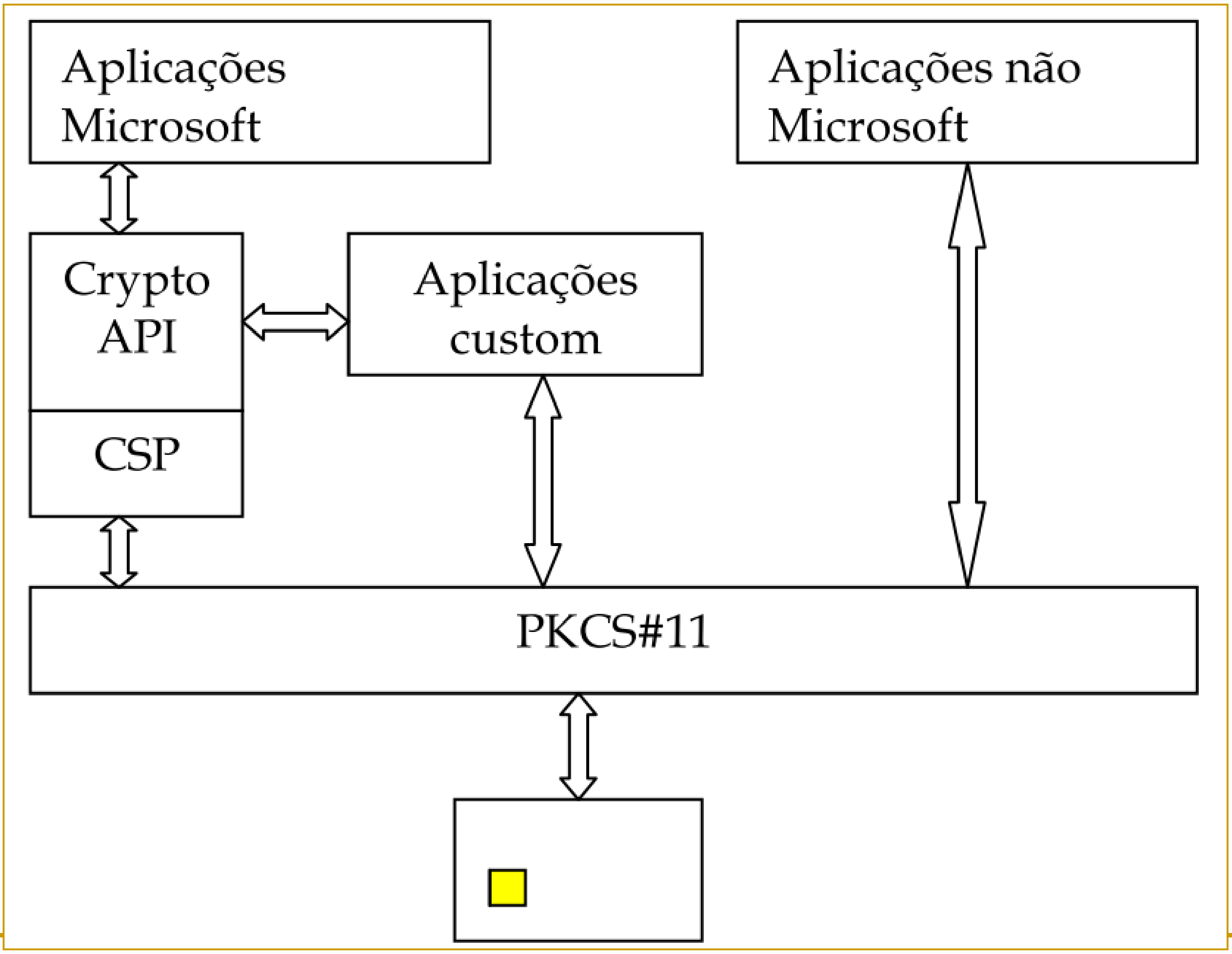


- ▷R/W public session
  - Read/write access to all public objects
- ▷R/W SO functions
  - Read/write access only to public objects on the token
    - Not to private objects
  - The SO can set the normal user's PIN
- ▷R/W user functions
  - Read/write access to all objects

Cartão de Cidadão: Middleware for Unix (Linux/MacOS)



Cartão de Cidadão: Middleware for Windows


Aplicações Microsoft
Aplicações não Microsoft
Crypto API
CSP
Aplicações custom
PKCS#11