“Understanding tools for a more secure internet” 2nd cyber-security week @ CIC-IPN.

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CONACYT

Centro de Investigación
en Computación
Instituto Politécnico Nacional

CIMAT

Public Key Cryptography

- In 1976, Whitfield Diffie, and Martin Hellman published their famous article: “New Directions in Cryptography”

- A bit before, Ralph Merkle invented a public key construction for his lectures: “Secure communication over insecure channels” in 1982

- Originally, the concepts were discovered by James Ellis; however, these were kept secret as the were classified information by the GCHQ from 1969 to 1997.

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RSA

Designed in 1977 by Ron Rivest, Adi Shamir, and Leonar Adleman.

- Let p y q be two different random large prime numbers
- The modulus n is the product of p, and q
- The function $\Phi(n) = (p-1)(q-1)$
- Choose $1 < e < \Phi(n)$, such that $\mathrm{GCD}(e, \Phi(n)) = 1$; $e = 2^{16}+1$ typically
- Compute $d \equiv e^{-1} \bmod \Phi(n)$

The public key is (e, n). The private key is (d, p, q).

RSA enc

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- **Encr**
- **Decr**

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Example

- $p = 1$
- $n = p$
- $\Phi(n)$
- GCD
- $d = e$

- Publi
- Priva

Rivest, Adi Shamir, and

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RSA encryption, and decryption

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Example

- $p = 11, \ q = 13$
- $n = p \cdot q = 11 \cdot 13 = 143$
- $\Phi(n) = (p-1)(q-1) = 10 \cdot 12 = 120$
- GCD$(e, \Phi(n))$ =GCD$(e, 120) = 1$; $e =$
- $d = e^{-1} \bmod \Phi(n) = 17^{-1} \bmod 120 =$

- Public Key $= (e, n) = (17, 143)$
- Private Key $= (d, p, q) = (113, 11, 23)$

RSA encryption, and decryption

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- Message $M = 50$

- **Encryption:**
  $C = M^e \bmod n = 50^{1}$

- **Decryption:**
  $M = C^d \bmod n = 85^{1}$

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DHKE Diagram

Alice

$$a \in_R \mathbb{Z}_p^\star$$
$$A_{\text{priv}} = a$$
$$A_{\text{pub}} \equiv \alpha^a \bmod p$$

$$k_{AB} \equiv (B_{pub})^a \bmod p$$

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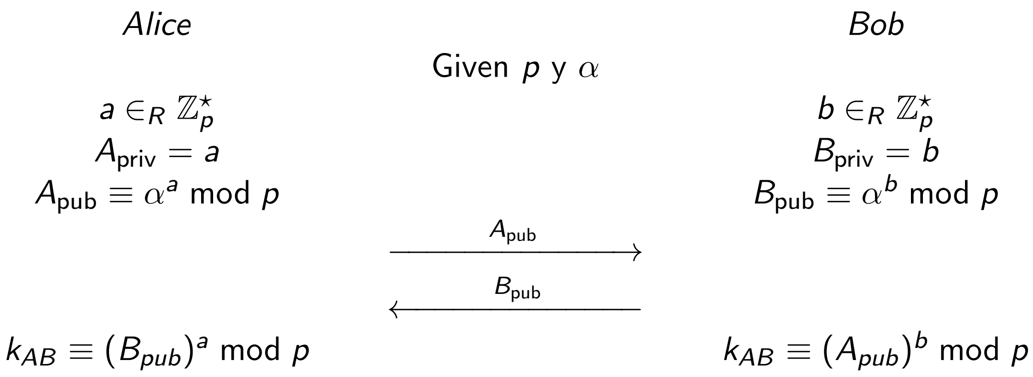

Alice

Given p y α

Bob

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$A_{\text{priv}} = a$

$A_{\text{pub}} \equiv \alpha^a \bmod p$

$b \in_R \mathbb{Z}_p^\star$

$B_{\text{priv}} = b$

$B_{\text{pub}} \equiv \alpha^b \bmod p$

$\xrightarrow{A_{\text{pub}}}$

$\xleftarrow{B_{\text{pub}}}$

$k_{AB} \equiv (B_{pub})^a \bmod p$

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Hellman Key Exchange

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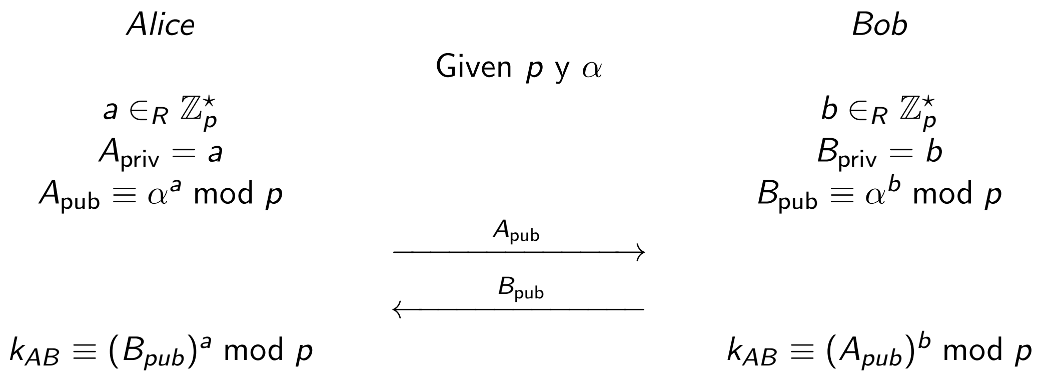

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DHKE Diagram

$$\begin{array}{ccc}
\textit{Alice} & & \textit{Bob} \\
 & \text{Given } p \text{ y } \alpha & \\
a \in_R \mathbb{Z}_p^\star & & b \in_R \mathbb{Z}_p^\star \\
A_{\text{priv}} = a & & B_{\text{priv}} = b \\
A_{\text{pub}} \equiv \alpha^a \bmod p & & B_{\text{pub}} \equiv \alpha^b \bmod p \\
 & \xrightarrow{\qquad A_{\text{pub}} \qquad} & \\
 & \xleftarrow{\qquad B_{\text{pub}} \qquad} & \\
k_{AB} \equiv (B_{pub})^a \bmod p & & k_{AB} \equiv (A_{pub})^b \bmod p
\end{array}$$

Bob

$$b \in_R \mathbb{Z}_p^\star$$
$$B_{\text{priv}} = b$$
$$B_{\text{pub}} \equiv \alpha^b \bmod p$$

$\longrightarrow$

$—$

$$k_{AB} \equiv (A_{pub})^b \bmod p$$

Digital Signatures

- Demonstrating that certain person generated a message is critical so some applications.
- In the "analog" world, we use hand-written signatures (in some countries any way).
- Only the person who created the signature can reproduce it.

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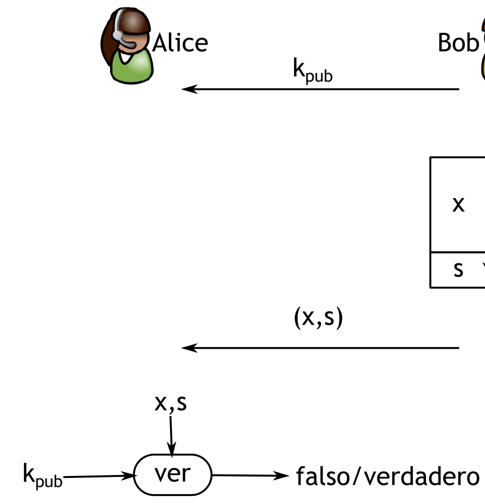

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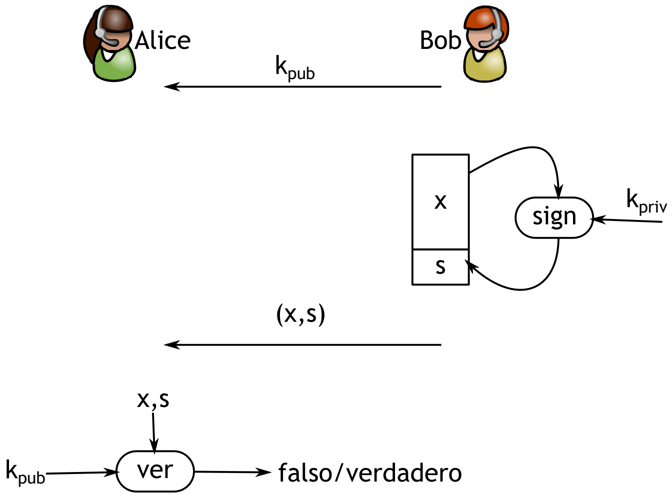
Diagram

In the digital world this is possible by using public key cryptography. The signatory signs with her private key, and addressee uses the corresponding public key to verify.



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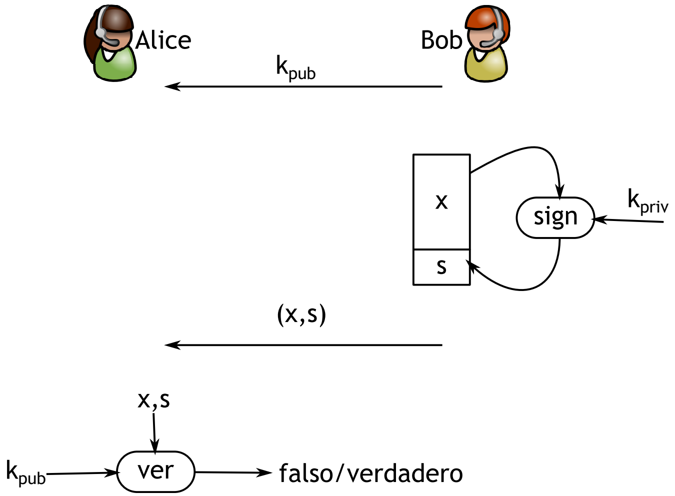

General

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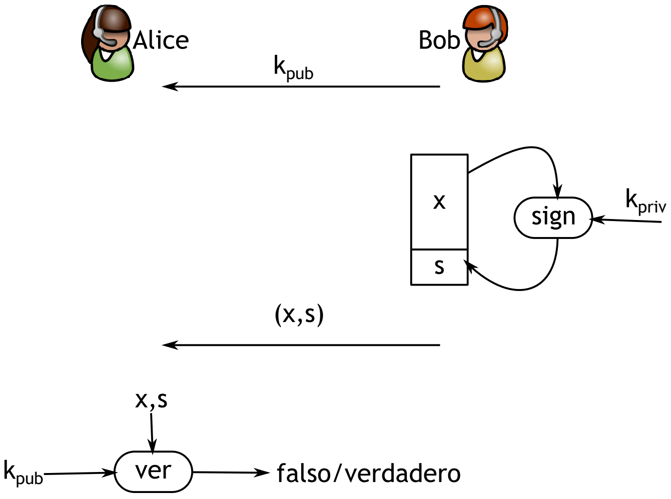
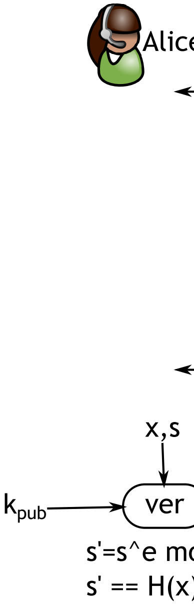


General diagram for R

Basic RSA signature



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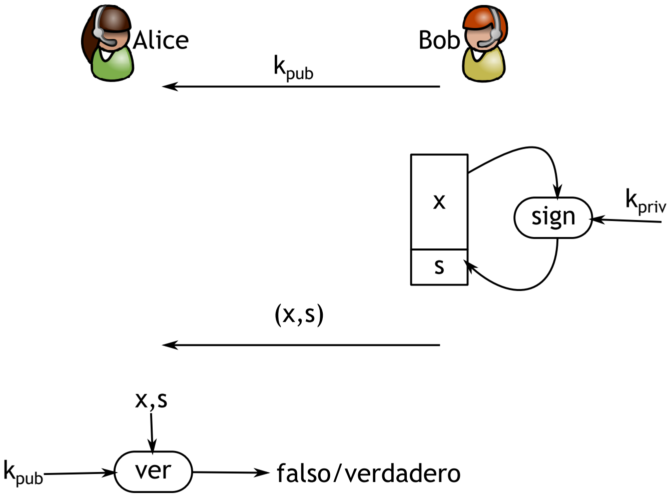
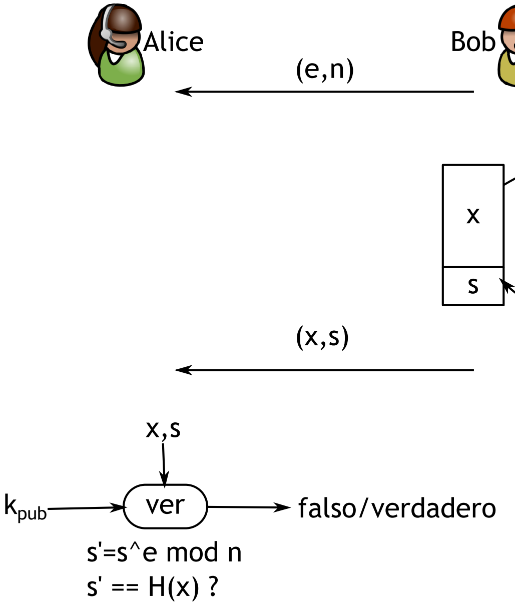


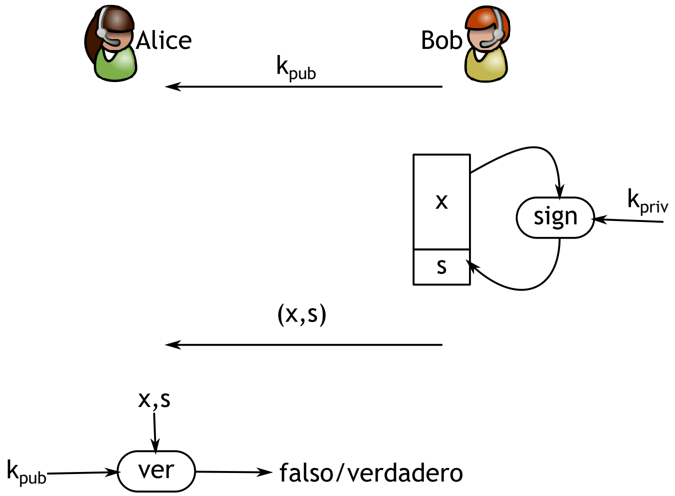
General diagram for RSA signature

Basic RSA signature



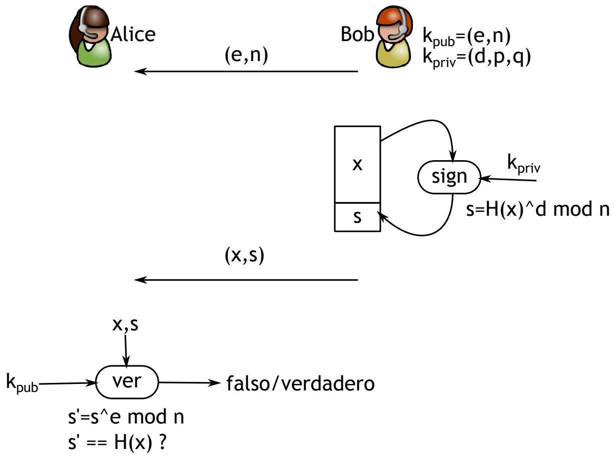
Diagram

In the digital world this is possible by using public key cryptography. The signatory signs with her private key, and addressee uses the corresponding public key to verify.



General diagram for RSA signature

Basic RSA signature



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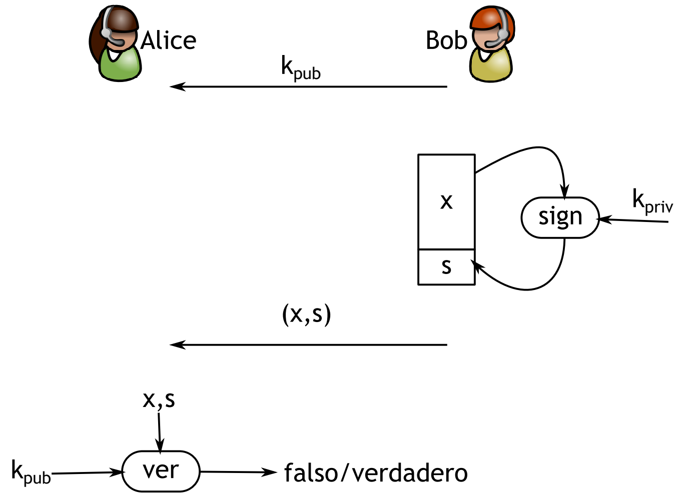

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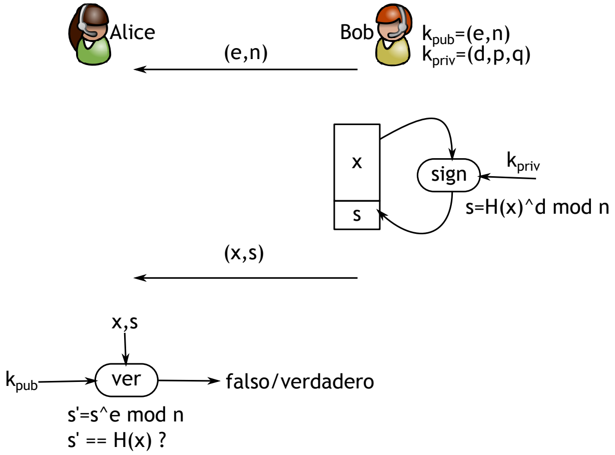
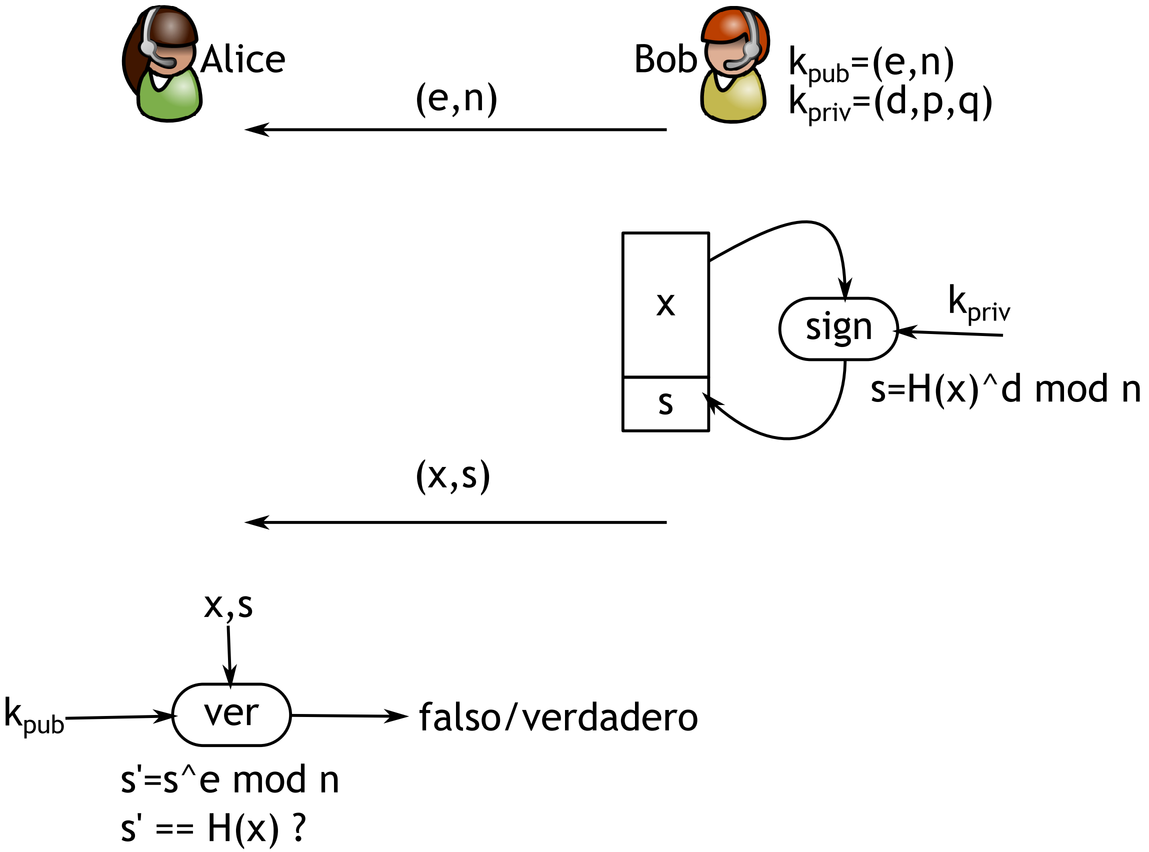
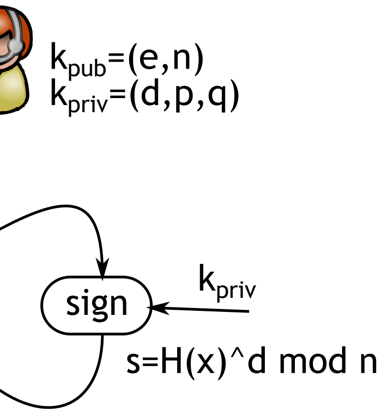


General diagram for RSA signature

Basic RSA signature



e



k_{pub}=(e,n)
k_{priv}=(d,p,q)

sign

k_{priv}

s=H(x)^d mod n

ElGamal

- The Elgamal encryption was proposed by Taher Elgamal in 1985.
- It can be seen as an extension of the Diffie-Hellman Key Exchange (DHKE)

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  - Given a message M
  - Choose an ephemeral key k_E $0 < k_E < p - 2$, with GCD(
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Elgamal Signature Ve

- Signature Verification:
  - Compute $t \equiv \beta^r \cdot r^s$

- If $t \equiv \alpha^x$ mod pq, the

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1

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Example

$t = 7^3 \cdot 3$

$\alpha^x \equiv 2^2$

$t \equiv \alpha^x$

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Example, sign M

$\leftarrow$

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$$t = 7^3 \cdot 3^{26} \equiv 22$$
$$\alpha^x \equiv 2^{26} \equiv 22$$
$$t \equiv \alpha^x \Rightarrow \text{OK}$$

$/ < p - 2$

$= 1$

1

Elgamal Signature Verification

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Example, sign M

$\xleftarrow{k_{\text{pub}}(p,\alpha,\beta)=(29,2,}$

$\xleftarrow{(26,(3,26))}$

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Example, sign M

$$p = 29,\ \alpha = 2$$
$$d = 12$$
$$\beta = \alpha^d \equiv 7$$

$$\xleftarrow{k_{\text{pub}}(p,\alpha,\beta)=(29,2,7)}$$

$$k_E = 5$$
$$(5, 28) = 1$$
$$x = 26$$
$$r = 2^5 \equiv 3$$
$$s = -10 \cdot 7 \equiv 26$$

$$\xleftarrow{(26,(3,26))}$$

$$t = 7^3 \cdot 3^{26} \equiv 22$$
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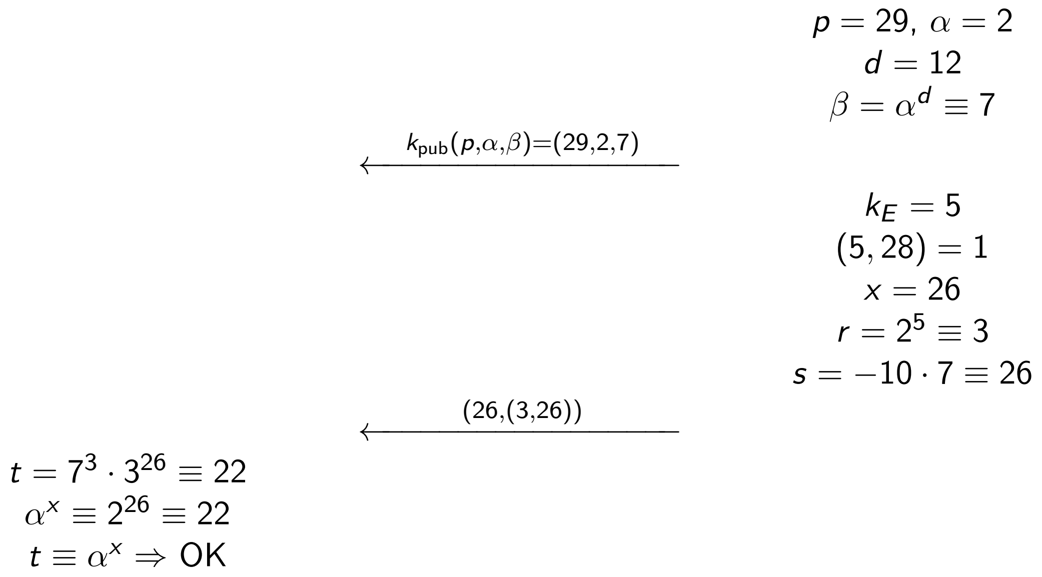

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DSA Signature

The standard signature DSA has the following steps:

- Key Generation:
  - Find Prime number p, with $2^{1023} < p < 2^{1024}$
  - Find a prime number q: $2^{159} < q < 2^{160}$
  - Find an element α, of order q
  - Choose a random number d, with $1 < d < q$
  - Compute $\beta = \alpha^d \bmod p$
- The key are:
  - Public: (p, q, α, β)
  - Private: d

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DSA signature of a messag

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  - Given a message M
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  - Compute $s \equiv (SHA(M) + d$
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DSA sign

- Signa
  - Co
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- If $v \equiv$

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DSA signature verifica

- Signature verification:
  - Compute $w \equiv s^{-1}$ m
  - Compute $u_1 \equiv w \cdot SH$
  - Compute $u_2 \equiv w \cdot r$ r
  - Compute $v \equiv (\alpha^{u_1} \cdot \beta$
- If $v \equiv r \bmod q$, the si

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2^{1024}

0

$d < q$

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  - Compute $u_1 \equiv w \cdot SHA(M) \bmod q$
  - Compute $u_2 \equiv w \cdot r \bmod q$
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- If $v \equiv r \bmod q$, the signature verifies

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- If $v \equiv r \bmod q$, the signature verifies

Example

$$
\begin{aligned}
w &= 5 \\
u_1 &= 6 \cdot \\
u_2 &= 6 \\
v = 20 &\equiv
\end{aligned}
$$

$$v \equiv r$$

essage

key k_E, with $0 < k_E < q$

od p) mod q

$M) + d \cdot r)k_E^{-1}$ mod q

(r, s)

DSA signature verification

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  - Compute $u_2 \equiv w \cdot r$ mod q
  - Compute $v \equiv (\alpha^{u_1} \cdot \beta^{u_2}$ mod $p)$ mod q
- If $v \equiv r$ mod q, the signature verifies

Example, sign messag

$\leftarrow$

$\leftarrow$

$$w = 5^{-1} \equiv 6 \bmod 29$$
$$u_1 = 6 \cdot 26 \equiv 11 \bmod 29$$
$$u_2 = 6 \cdot 20 \equiv 4 \bmod 29$$
$$v = 20 \equiv (3^{11} \cdot 4^4 \bmod 59$$
$$\bmod 29$$
$$v \equiv r \bmod 29 \Rightarrow \text{OK}$$

$k_E < q$

d q

DSA signature verification

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- If $v \equiv r \bmod q$, the signature verifies

Example, sign message M

$\xleftarrow{k_{\text{pub}}(p,q,\alpha,\beta)=(59,29}$

$\xleftarrow{(M,(r,s))}$

$$w = 5^{-1} \equiv 6 \bmod 29$$
$$u_1 = 6 \cdot 26 \equiv 11 \bmod 29$$
$$u_2 = 6 \cdot 20 \equiv 4 \bmod 29$$
$$v = 20 \equiv (3^{11} \cdot 4^4 \bmod 59)$$
$$\bmod 29$$
$$v \equiv r \bmod 29 \Rightarrow \text{OK}$$

DSA signature verification

- Signature verification:
  - Compute $w \equiv s^{-1} \bmod q$
  - Compute $u_1 \equiv w \cdot SHA(M) \bmod q$
  - Compute $u_2 \equiv w \cdot r \bmod q$
  - Compute $v \equiv (\alpha^{u_1} \cdot \beta^{u_2} \bmod p) \bmod q$

- If $v \equiv r \bmod q$, the signature verifies

Example, sign message M

$$p = 59,\ q = 29$$
$$\alpha = 3,\ d = 7$$
$$\beta = \alpha^d \equiv 4$$

$$\xleftarrow{k_{\text{pub}}(p,q,\alpha,\beta)=(59,29,3,4)}$$

$$k_E = 10$$
$$r = (3^{10} \bmod 59)$$
$$\equiv 20 \bmod 29$$
$$s = (26 + 7 \cdot 20) \cdot 3$$
$$\equiv 5 \bmod 29$$

$$\xleftarrow{(M,(r,s))}$$

$$w = 5^{-1} \equiv 6 \bmod 29$$
$$u_1 = 6 \cdot 26 \equiv 11 \bmod 29$$
$$u_2 = 6 \cdot 20 \equiv 4 \bmod 29$$
$$v = 20 \equiv (3^{11} \cdot 4^4 \bmod 59)$$
$$\bmod 29$$
$$v \equiv r \bmod 29 \Rightarrow \text{OK}$$

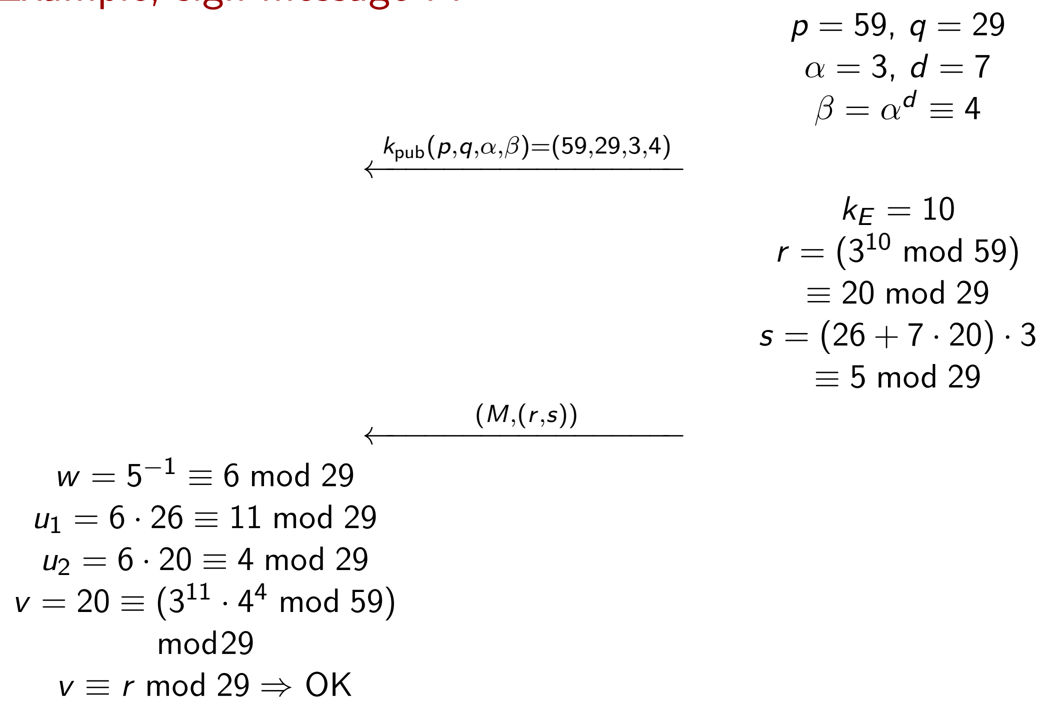
signature verification

ignature verification:

- Compute $w \equiv s^{-1} \bmod q$
- Compute $u_1 \equiv w \cdot SHA(M) \bmod q$
- Compute $u_2 \equiv w \cdot r \bmod q$
- Compute $v \equiv (\alpha^{u_1} \cdot \beta^{u_2} \bmod p) \bmod q$

f $v \equiv r \bmod q$, the signature verifies

Example, sign message M



$p = 59,\ q = 29$

$\alpha = 3,\ d = 7$

$\beta = \alpha^d \equiv 4$

$\xleftarrow{k_{\text{pub}}(p,q,\alpha,\beta)=(59,29,3,4)}$

$k_E = 10$

$r = (3^{10} \bmod 59)$

$\equiv 20 \bmod 29$

$s = (26 + 7 \cdot 20) \cdot 3$

$\equiv 5 \bmod 29$

$\xleftarrow{(M,(r,s))}$

$w = 5^{-1} \equiv 6 \bmod 29$

$u_1 = 6 \cdot 26 \equiv 11 \bmod 29$

$u_2 = 6 \cdot 20 \equiv 4 \bmod 29$

$v = 20 \equiv (3^{11} \cdot 4^4 \bmod 59)$

$\bmod 29$

$v \equiv r \bmod 29 \Rightarrow$ OK

Example, sign message M

$$p = 59,\ q = 29$$
$$\alpha = 3,\ d = 7$$
$$\beta = \alpha^d \equiv 4$$

$$\xleftarrow{k_{\text{pub}}(p,q,\alpha,\beta)=(59,29,3,4)}$$

$$k_E = 10$$
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$$\equiv 20 \bmod 29$$
$$s = (26 + 7 \cdot 20) \cdot 3$$
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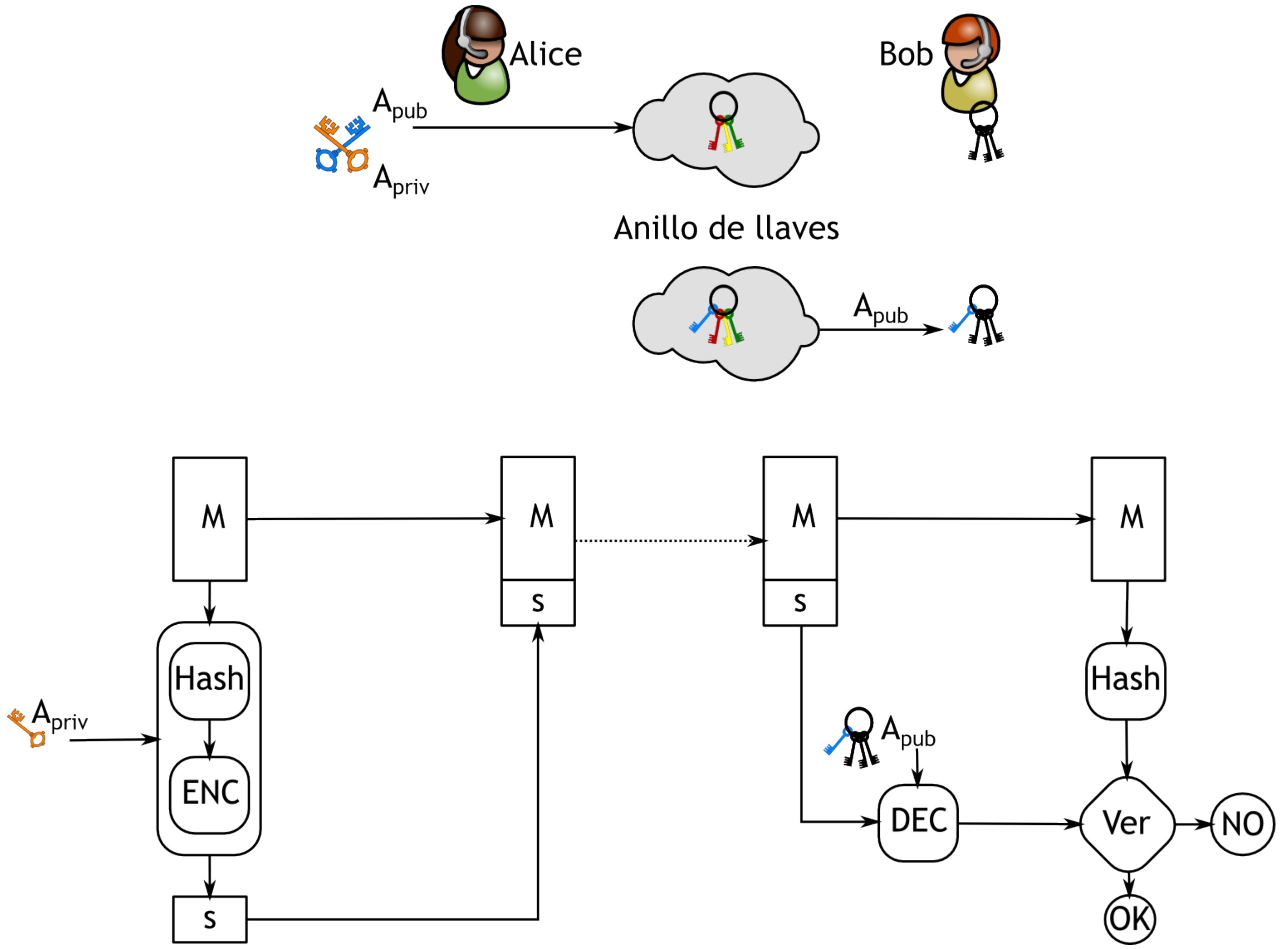
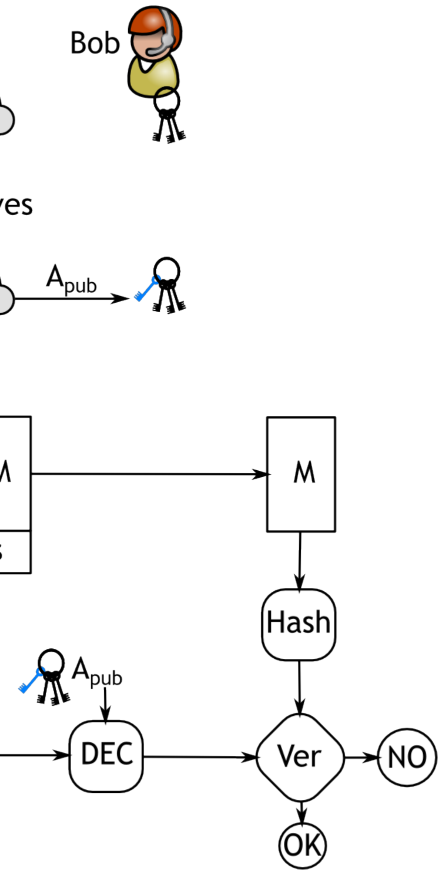
$$\xleftarrow{(M,(r,s))}$$

$$w = 5^{-1} \equiv 6 \bmod 29$$
$$u_1 = 6 \cdot 26 \equiv 11 \bmod 29$$
$$u_2 = 6 \cdot 20 \equiv 4 \bmod 29$$
$$v = 20 \equiv (3^{11} \cdot 4^4 \bmod 59)$$
$$\bmod 29$$
$$v \equiv r \bmod 29 \Rightarrow \text{OK}$$

Digital Signature



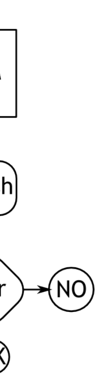


Digital certificate

Is a document in which the digital signature of a trustworthy entity, whose public key is previously stored, associates the public key to a given entity: name, organization, address, email, RFC, CURP, etc.

The certificate serves to warranty that a given public key belongs to the owner of its corresponding private key.

These certificate are granted by a trustworhty entity, a Certificate Authority.. perhaps, in practice, we delegate who to trust to Mozilla, Microsoft, Apple, BlackBerry.



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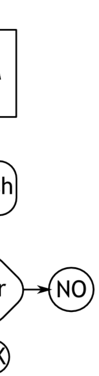

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- Key generation (Secur
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- CRL publication

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- Certificate Emission
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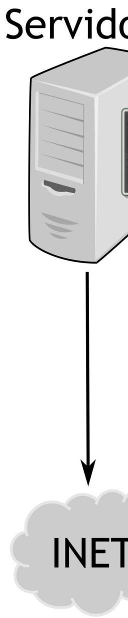

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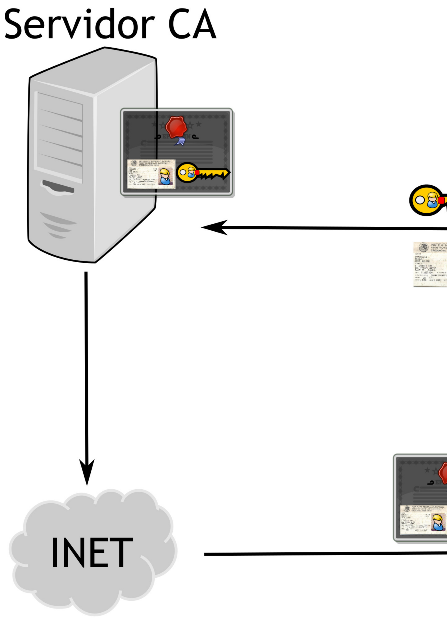

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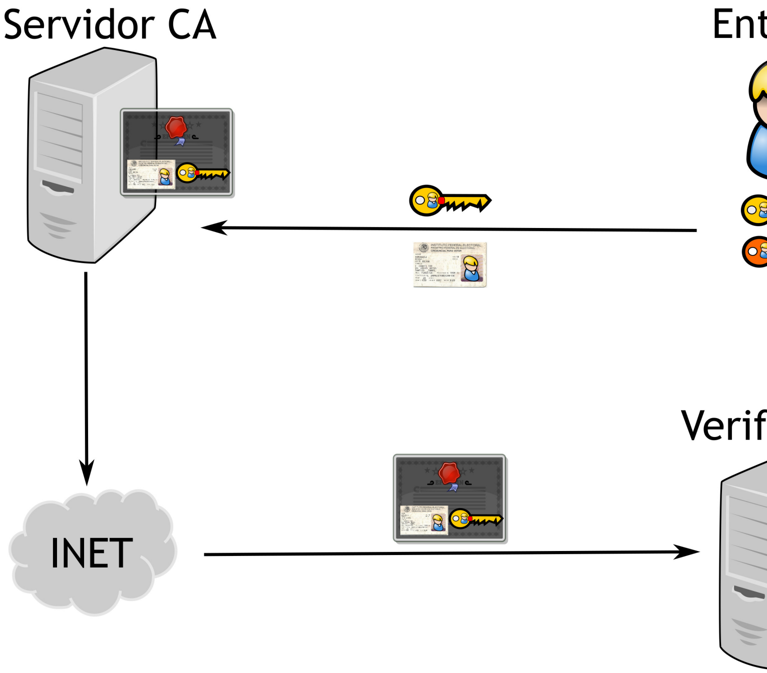

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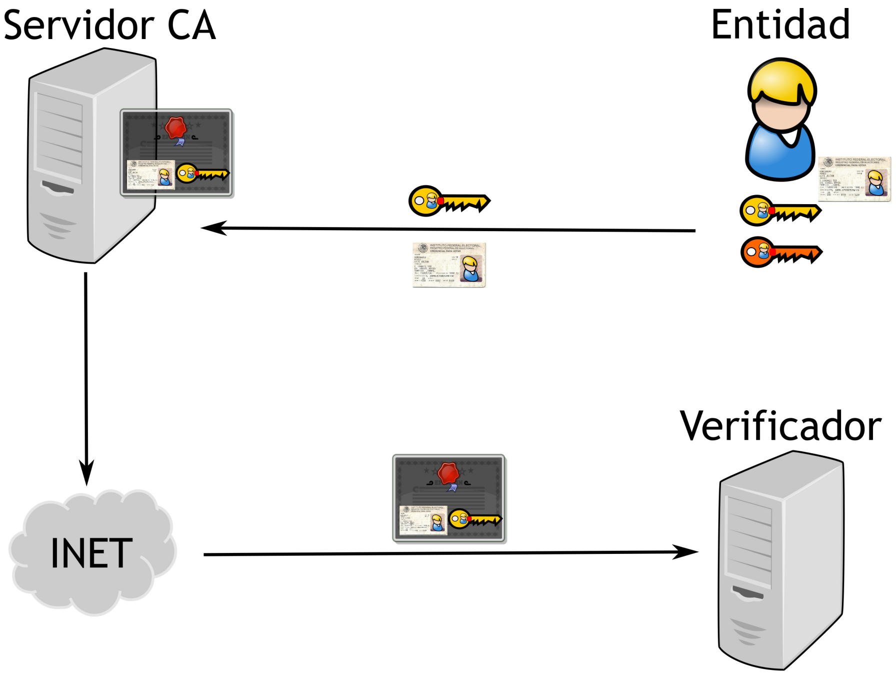

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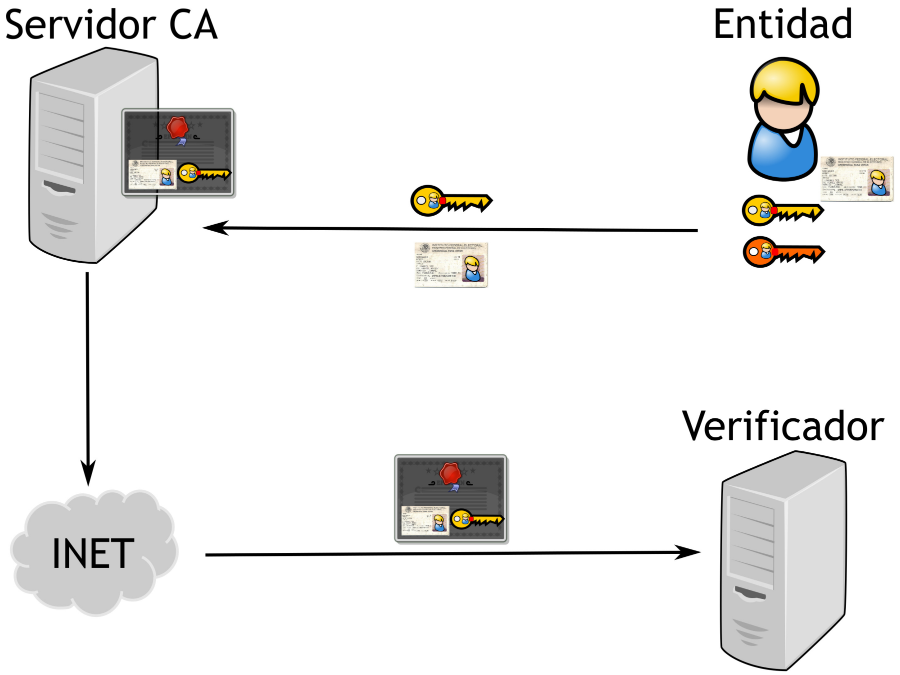

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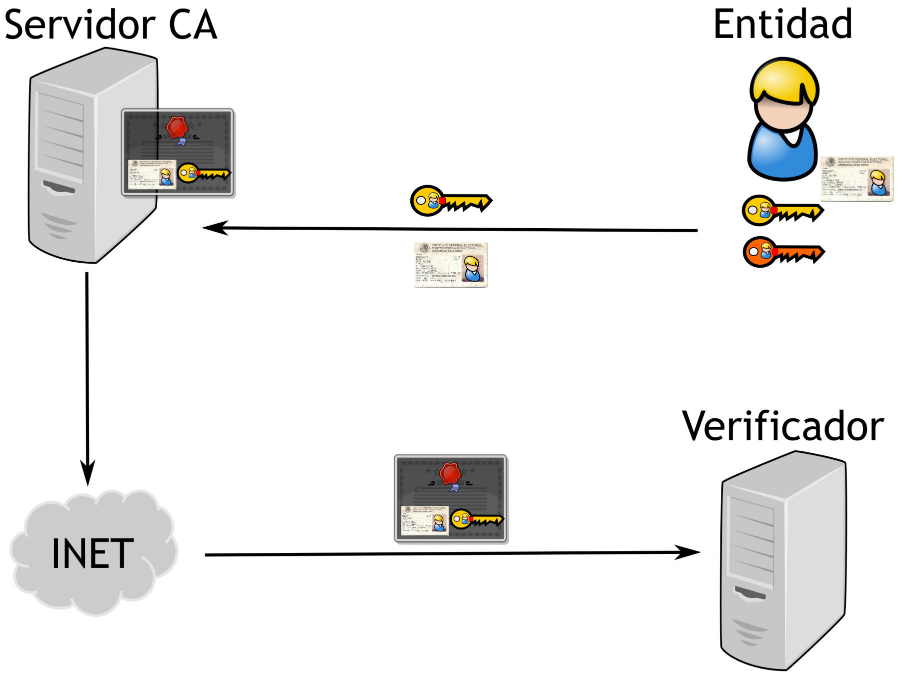

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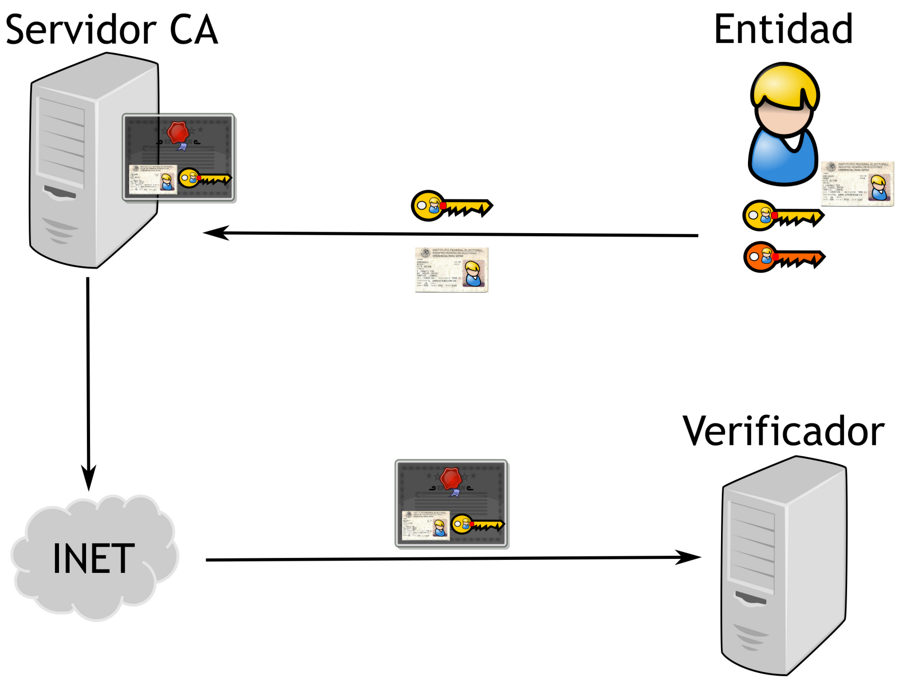

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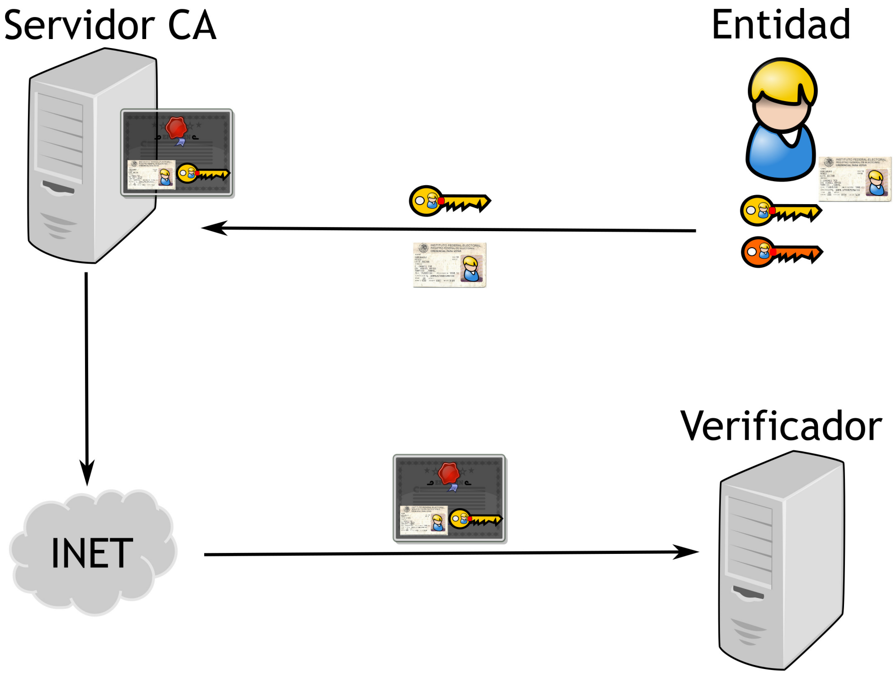

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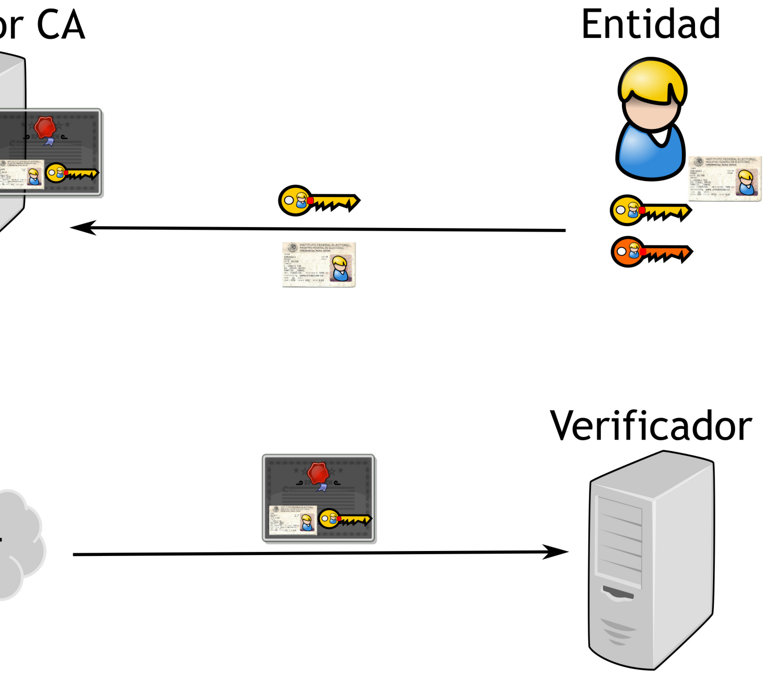

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Example

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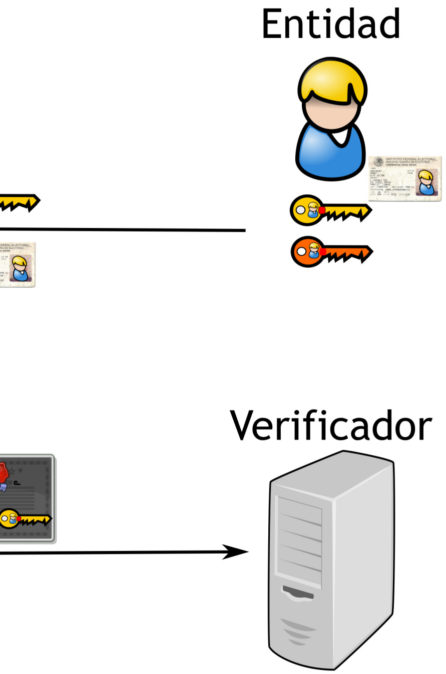

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Example

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:
    Signature Algorithm: sha1WithRSA
        Issuer: C=US, O=DigiCert Inc
        Validity
            Not Before: Oct  8 00:00
            Not After : Dec 16 12:00
        Subject: C=MX, ST=Distrito F
        Subject Public Key Info:
            Public Key Algorithm: rs
                Public-Key: (2048 bi
                Modulus:
                    00:d8:dc:9d:1a:7
                    05:8a:c1:0b:3f:b
                    c1:59:ec:13:68:5
                    84:4a:e7:97:55:8
                    be:5c:23:2d:ab:3
                    46:23:39:20:78:d
                    8d:7d:33:98:b3:f
                    55:87:13:a5:54:b
                    1f:e6:29:01:1e:a
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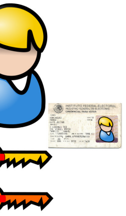

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Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, C
        Validity
            Not Before: Oct  8 00:00:00 2012 GMT
            Not After : Dec 16 12:00:00 2015 GMT
        Subject: C=MX, ST=Distrito Federal, L=Mexico, O=Cent
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:5
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:b
                    c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:8
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                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:9
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6
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```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
        Validity
            Not Before: Oct  8 00:00:00 2012 GMT
            Not After : Dec 16 12:00:00 2015 GMT
        Subject: C=MX, ST=Distrito Federal, L=Mexico, O=Centro de Investigacion
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
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                    be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
                    46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
                    8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
                    55:87:13:a5:54:b5:e7:be:15:dc:da:9d:61:8c:06:
                    1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
                    88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
                    c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
                    0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
                    65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
                    90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
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                    b6:a7
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    Data:
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        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
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            Not Before: Oct  8 00:00:00 2012 GMT
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        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
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                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
                    c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:82:d9:
                    84:4a:e7:97:55:84:f2:cf:71:ad:e4:e5:a6:73:5c:
                    be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
                    46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
                    8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
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                    1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
                    88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
                    c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
                    0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
                    65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
                    90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
                    2b:a5:22:06:22:46:c2:90:a6:8b:dd:95:61:7b:89:
                    b6:a7
```

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Example

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
        Validity
            Not Before: Oct  8 00:00:00 2012 GMT
            Not After : Dec 16 12:00:00 2015 GMT
        Subject: C=MX, ST=Distrito Federal, L=Mexico, O=Centro de Investigacion
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
                    c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:82:d9:
                    84:4a:e7:97:55:84:f2:cf:71:ad:e4:e5:a6:73:5c:
                    be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
                    46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
                    8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
                    55:87:13:a5:54:b5:e7:be:15:dc:da:9d:61:8c:06:
                    1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
                    88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
                    c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
                    0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
                    65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
                    90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
                    2b:a5:22:06:22:46:c2:90:a6:8b:dd:95:61:7b:89:
                    b6:a7
```

```
                Exponent: 65537 (0x1
        X509v3 extensions:
            X509v3 Authority Key Ide
                keyid:50:EA:73:89:DB

            X509v3 Subject Key Ident
                37:92:15:14:C3:5C:87
            X509v3 Subject Alternati
                DNS:*.cinvestav.mx,
                 DNS:webmail.tamps.c
            X509v3 Key Usage: critic
                Digital Signature, K
            X509v3 Extended Key Usag
                TLS Web Server Authe
            X509v3 CRL Distribution

                Full Name:
                  URI:http://crl3.di

                Full Name:
                  URI:http://crl4.di

            X509v3 Certificate Polic
                Policy: 2.16.840.1.1
                  CPS: http://www.di
                  User Notice:
                    Explicit Text:

            Authority Information Ac
                OCSP - URI:http://oc
                CA Issuers - URI:htt

            X509v3 Basic Constraints
                CA:FALSE
```

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ecutive)

Example

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
        Validity
            Not Before: Oct  8 00:00:00 2012 GMT
            Not After : Dec 16 12:00:00 2015 GMT
        Subject: C=MX, ST=Distrito Federal, L=Mexico, O=Centro de Investigacion
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
                    c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:82:d9:
                    84:4a:e7:97:55:84:f2:cf:71:ad:e4:e5:a6:73:5c:
                    be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
                    46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
                    8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
                    55:87:13:a5:54:b5:e7:be:15:dc:da:9d:61:8c:06:
                    1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
                    88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
                    c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
                    0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
                    65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
                    90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
                    2b:a5:22:06:22:46:c2:90:a6:8b:dd:95:61:7b:89:
                    b6:a7
```

```
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Authority Key Identifier:
                keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20

            X509v3 Subject Key Identifier:
                37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F
            X509v3 Subject Alternative Name:
                DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:ww
                 DNS:webmail.tamps.cinvestav.mx, DNS:noc.tam
            X509v3 Key Usage: critical
                Digital Signature, Key Encipherment
            X509v3 Extended Key Usage:
                TLS Web Server Authentication, TLS Web Clien
            X509v3 CRL Distribution Points:

                Full Name:
                  URI:http://crl3.digicert.com/ca3-g15.crl

                Full Name:
                  URI:http://crl4.digicert.com/ca3-g15.crl

            X509v3 Certificate Policies:
                Policy: 2.16.840.1.114412.1.1
                  CPS: http://www.digicert.com/ssl-cps-repos
                  User Notice:
                    Explicit Text:

            Authority Information Access:
                OCSP - URI:http://ocsp.digicert.com
                CA Issuers - URI:http://cacerts.digicert.com

            X509v3 Basic Constraints: critical
                CA:FALSE
```

Example

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
        Validity
            Not Before: Oct  8 00:00:00 2012 GMT
            Not After : Dec 16 12:00:00 2015 GMT
        Subject: C=MX, ST=Distrito Federal, L=Mexico, O=Centro de Investigacion
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
                    05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
                    c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:82:d9:
                    84:4a:e7:97:55:84:f2:cf:71:ad:e4:e5:a6:73:5c:
                    be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
                    46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
                    8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
                    55:87:13:a5:54:b5:e7:be:15:dc:da:9d:61:8c:06:
                    1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
                    88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
                    c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
                    0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
                    65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
                    90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
                    d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
                    2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
                    2b:a5:22:06:22:46:c2:90:a6:8b:dd:95:61:7b:89:
                    b6:a7
```

```
        Exponent: 65537 (0x10001)
X509v3 extensions:
    X509v3 Authority Key Identifier:
        keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

    X509v3 Subject Key Identifier:
        37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
    X509v3 Subject Alternative Name:
        DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
         DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
    X509v3 Key Usage: critical
        Digital Signature, Key Encipherment
    X509v3 Extended Key Usage:
        TLS Web Server Authentication, TLS Web Client Authentication
    X509v3 CRL Distribution Points:

        Full Name:
          URI:http://crl3.digicert.com/ca3-g15.crl

        Full Name:
          URI:http://crl4.digicert.com/ca3-g15.crl

    X509v3 Certificate Policies:
        Policy: 2.16.840.1.114412.1.1
          CPS: http://www.digicert.com/ssl-cps-repository.htm
          User Notice:
            Explicit Text:

    Authority Information Access:
        OCSP - URI:http://ocsp.digicert.com
        CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

    X509v3 Basic Constraints: critical
        CA:FALSE
```

```
sion: 3 (0x2)
al Number:
07:23:53:8d:87:6d:b6:27:fc:1e:08:aa:49:96:d9:60
re Algorithm: sha1WithRSAEncryption
uer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert High Ass
dity
Not Before: Oct  8 00:00:00 2012 GMT
Not After : Dec 16 12:00:00 2015 GMT
ect: C=MX, ST=Distrito Federal, L=Mexico, O=Centro de Investigacion
ect Public Key Info:
Public Key Algorithm: rsaEncryption
    Public-Key: (2048 bit)
    Modulus:
        00:d8:dc:9d:1a:7e:d4:6f:49:5b:7a:95:6a:57:6c:
        05:8a:c1:0b:3f:b1:03:e0:1a:53:e5:22:8f:bd:6c:
        c1:59:ec:13:68:5e:f2:6f:44:55:21:36:8c:82:d9:
        84:4a:e7:97:55:84:f2:cf:71:ad:e4:e5:a6:73:5c:
        be:5c:23:2d:ab:3b:5d:b7:c3:de:2f:0a:35:74:84:
        46:23:39:20:78:d4:8b:47:eb:e1:d4:b4:c2:ab:59:
        8d:7d:33:98:b3:f7:bf:3a:07:c0:64:8a:4f:a6:78:
        55:87:13:a5:54:b5:e7:be:15:dc:da:9d:61:8c:06:
        1f:e6:29:01:1e:ab:61:5d:bf:06:cb:ec:48:89:b0:
        88:6f:e5:b0:4b:bf:83:bd:a0:58:bf:ff:33:0d:f8:
        c7:73:ff:00:0b:64:f2:2b:9a:69:3f:d5:74:d3:12:
        0f:e9:15:70:f8:7c:f1:2b:5c:70:d4:49:ce:01:c9:
        65:47:5f:a2:8f:8f:fa:af:2a:00:c9:ec:20:fd:33:
        90:12:5c:1c:46:2b:44:24:04:77:44:82:98:26:93:
        d3:f3:53:a1:5e:a0:f5:f0:1f:f5:6b:22:27:94:a9:
        2a:45:7d:73:6d:68:39:cf:d2:d2:60:3a:fd:6a:89:
        2b:a5:22:06:22:46:c2:90:a6:8b:dd:95:61:7b:89:
        b6:a7
```

```
        Exponent: 65537 (0x10001)
X509v3 extensions:
    X509v3 Authority Key Identifier:
        keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

    X509v3 Subject Key Identifier:
        37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
    X509v3 Subject Alternative Name:
        DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
         DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
    X509v3 Key Usage: critical
        Digital Signature, Key Encipherment
    X509v3 Extended Key Usage:
        TLS Web Server Authentication, TLS Web Client Authentication
    X509v3 CRL Distribution Points:

        Full Name:
          URI:http://crl3.digicert.com/ca3-g15.crl

        Full Name:
          URI:http://crl4.digicert.com/ca3-g15.crl

    X509v3 Certificate Policies:
        Policy: 2.16.840.1.114412.1.1
          CPS: http://www.digicert.com/ssl-cps-repository.htm
          User Notice:
            Explicit Text:

    Authority Information Access:
        OCSP - URI:http://ocsp.digicert.com
        CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

    X509v3 Basic Constraints: critical
        CA:FALSE
```

```
Signatu
     89:
     a7:
     58:
     57:
     0d:
     d2:
     e8:
     af:
     75:
     f9:
     0a:
     cd:
     bb:
     43:
     d7:
```

```
fc:1e:08:aa:49:96:d9:60
Encryption
, OU=www.digicert.com, CN=DigiCert High Ass

:00 2012 GMT
:00 2015 GMT
ederal, L=Mexico, O=Centro de Investigacion

aEncryption
t)

e:d4:6f:49:5b:7a:95:6a:57:6c:
1:03:e0:1a:53:e5:22:8f:bd:6c:
e:f2:6f:44:55:21:36:8c:82:d9:
4:f2:cf:71:ad:e4:e5:a6:73:5c:
b:5d:b7:c3:de:2f:0a:35:74:84:
4:8b:47:eb:e1:d4:b4:c2:ab:59:
7:bf:3a:07:c0:64:8a:4f:a6:78:
5:e7:be:15:dc:da:9d:61:8c:06:
b:61:5d:bf:06:cb:ec:48:89:b0:
f:83:bd:a0:58:bf:ff:33:0d:f8:
4:f2:2b:9a:69:3f:d5:74:d3:12:
c:f1:2b:5c:70:d4:49:ce:01:c9:
f:fa:af:2a:00:c9:ec:20:fd:33:
b:44:24:04:77:44:82:98:26:93:
0:f5:f0:1f:f5:6b:22:27:94:a9:
8:39:cf:d2:d2:60:3a:fd:6a:89:
6:c2:90:a6:8b:dd:95:61:7b:89:
```

```
        Exponent: 65537 (0x10001)
X509v3 extensions:
    X509v3 Authority Key Identifier:
        keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

    X509v3 Subject Key Identifier:
        37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
    X509v3 Subject Alternative Name:
        DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
         DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
    X509v3 Key Usage: critical
        Digital Signature, Key Encipherment
    X509v3 Extended Key Usage:
        TLS Web Server Authentication, TLS Web Client Authentication
    X509v3 CRL Distribution Points:

        Full Name:
          URI:http://crl3.digicert.com/ca3-g15.crl

        Full Name:
          URI:http://crl4.digicert.com/ca3-g15.crl

    X509v3 Certificate Policies:
        Policy: 2.16.840.1.114412.1.1
          CPS: http://www.digicert.com/ssl-cps-repository.htm
          User Notice:
            Explicit Text:

    Authority Information Access:
        OCSP - URI:http://ocsp.digicert.com
        CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

    X509v3 Basic Constraints: critical
        CA:FALSE
```

```
Signature Algorithm: sha1WithRSA
     89:72:14:45:fc:52:d2:46:12:
     a7:d9:a1:6d:d4:4e:09:aa:c0:
     58:26:59:bc:95:d7:73:28:36:
     57:3d:2e:c2:9e:86:9f:08:47:
     0d:e4:f3:11:aa:69:9d:c1:6b:
     d2:b5:5e:60:ef:35:d2:bb:19:
     e8:0a:d0:d4:b0:b7:13:4f:43:
     af:3c:d7:61:89:24:6b:8a:88:
     75:ca:18:e9:11:8f:7a:c4:0a:
     f9:f5:fc:48:96:bf:e3:87:2c:
     0a:08:56:a2:be:28:ea:47:d2:
     cd:c4:14:5d:2c:13:21:6a:d0:
     bb:7c:ac:56:41:c0:64:3e:2a:
     43:02:27:eb:a5:87:71:e6:79:
     d7:3d:5f:c6
```

```
N=DigiCert High Ass

ro de Investigacion

7:6c:
d:6c:
2:d9:
3:5c:
4:84:
b:59:
6:78:
c:06:
9:b0:
d:f8:
3:12:
1:c9:
d:33:
6:93:
4:a9:
a:89:
b:89:
```

```
        Exponent: 65537 (0x10001)
X509v3 extensions:
    X509v3 Authority Key Identifier:
        keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

    X509v3 Subject Key Identifier:
        37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
    X509v3 Subject Alternative Name:
        DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
         DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
    X509v3 Key Usage: critical
        Digital Signature, Key Encipherment
    X509v3 Extended Key Usage:
        TLS Web Server Authentication, TLS Web Client Authentication
    X509v3 CRL Distribution Points:

        Full Name:
          URI:http://crl3.digicert.com/ca3-g15.crl

        Full Name:
          URI:http://crl4.digicert.com/ca3-g15.crl

    X509v3 Certificate Policies:
        Policy: 2.16.840.1.114412.1.1
          CPS: http://www.digicert.com/ssl-cps-repository.htm
          User Notice:
            Explicit Text:

    Authority Information Access:
        OCSP - URI:http://ocsp.digicert.com
        CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

    X509v3 Basic Constraints: critical
        CA:FALSE
```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:
     d7:3d:5f:c6
```

```
        Exponent: 65537 (0x10001)
X509v3 extensions:
    X509v3 Authority Key Identifier:
        keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

    X509v3 Subject Key Identifier:
        37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
    X509v3 Subject Alternative Name:
        DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
         DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
    X509v3 Key Usage: critical
        Digital Signature, Key Encipherment
    X509v3 Extended Key Usage:
        TLS Web Server Authentication, TLS Web Client Authentication
    X509v3 CRL Distribution Points:

        Full Name:
          URI:http://crl3.digicert.com/ca3-g15.crl

        Full Name:
          URI:http://crl4.digicert.com/ca3-g15.crl

    X509v3 Certificate Policies:
        Policy: 2.16.840.1.114412.1.1
          CPS: http://www.digicert.com/ssl-cps-repository.htm
          User Notice:
            Explicit Text:

    Authority Information Access:
        OCSP - URI:http://ocsp.digicert.com
        CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

    X509v3 Basic Constraints: critical
        CA:FALSE
```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
     d7:3d:5f:c6
```

```
    Exponent: 65537 (0x10001)
v3 extensions:
X509v3 Authority Key Identifier:
    keyid:50:EA:73:89:DB:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

X509v3 Subject Key Identifier:
    37:92:15:14:C3:5C:87:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
X509v3 Subject Alternative Name:
    DNS:*.cinvestav.mx, DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
     DNS:webmail.tamps.cinvestav.mx, DNS:noc.tamps.cinvestav.mx
X509v3 Key Usage: critical
    Digital Signature, Key Encipherment
X509v3 Extended Key Usage:
    TLS Web Server Authentication, TLS Web Client Authentication
X509v3 CRL Distribution Points:

    Full Name:
      URI:http://crl3.digicert.com/ca3-g15.crl

    Full Name:
      URI:http://crl4.digicert.com/ca3-g15.crl

X509v3 Certificate Policies:
    Policy: 2.16.840.1.114412.1.1
      CPS: http://www.digicert.com/ssl-cps-repository.htm
      User Notice:
        Explicit Text:

Authority Information Access:
    OCSP - URI:http://ocsp.digicert.com
    CA Issuers - URI:http://cacerts.digicert.com/DigiCertHighAssura

X509v3 Basic Constraints: critical
    CA:FALSE
```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
     d7:3d:5f:c6
```

Hands-o

Certificate

- DSA pa

  `openss`

- Key ger

  `openss`

- Self-sig

  ```
  openss
    dsar
    root
  ```

- Review

  ```
  openss
  openss
  ```

```
0001)

ntifier:
:29:FB:10:8F:9E:E5:01:20:D4:DE:79:99:48:83:

ifier:
:5F:C4:63:E2:F3:20:C1:8F:0C:92:B7:BC:7D
ve Name:
DNS:cinvestav.mx, DNS:www.tamps.cinvestav.m
investav.mx, DNS:noc.tamps.cinvestav.mx
al
ey Encipherment
e:
ntication, TLS Web Client Authentication
Points:


gicert.com/ca3-g15.crl


gicert.com/ca3-g15.crl

ies:
14412.1.1
gicert.com/ssl-cps-repository.htm




cess:
sp.digicert.com
p://cacerts.digicert.com/DigiCertHighAssura

: critical
```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
     d7:3d:5f:c6
```

Hands-on

Certificate creation

- DSA parameter generati

  `openssl dsaparam 204`

- Key generation

  `openssl gendsa -out`

- Self-signed certificate ge

  ```
  openssl req -newkey
    dsarootkey.pem -ne
    rootcert.pem
  ```

- Review the certificate

  ```
  openssl x509 -text -
  openssl asn1parse -i
  ```

```
:D4:DE:79:99:48:83:

:0C:92:B7:BC:7D

v.tamps.cinvestav.m
os.cinvestav.mx

t Authentication

itory.htm

/DigiCertHighAssura
```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
     d7:3d:5f:c6
```

Hands-on

Certificate creation

- DSA parameter generation

  ```
  openssl dsaparam 2048 -out dsapar
  ```

- Key generation

  ```
  openssl gendsa -out dsarootkey.pe
  ```

- Self-signed certificate generation

  ```
  openssl req -newkey dsa:dsaparams
    dsarootkey.pem -new -x509 -days
    rootcert.pem
  ```

- Review the certificate

  ```
  openssl x509 -text -in rootcert.p
  openssl asn1parse -in rootcert.pe
  ```

```
Signature Algorithm: sha1WithRSAEncryption
     89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
     a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
     58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
     57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
     0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
     d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
     e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
     af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
     75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
     f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
     0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
     cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
     bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
     43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
     d7:3d:5f:c6
```

Hands-on

Certificate creation

- DSA parameter generation

  ```
  openssl dsaparam 2048 -out dsaparams.pem
  ```

- Key generation

  ```
  openssl gendsa -out dsarootkey.pem dsaparams.pem
  ```

- Self-signed certificate generation

  ```
  openssl req -newkey dsa:dsaparams.pem -keyout
    dsarootkey.pem -new -x509 -days 365 -out
    rootcert.pem
  ```

- Review the certificate

  ```
  openssl x509 -text -in rootcert.pem | more
  openssl asn1parse -in rootcert.pem | more
  ```

```
ignature Algorithm: sha1WithRSAEncryption
    89:72:14:45:fc:52:d2:46:12:ff:fa:f4:c5:4f:fd:7b:0e:e4:
    a7:d9:a1:6d:d4:4e:09:aa:c0:30:2f:1a:92:eb:0c:5b:6a:8f:
    58:26:59:bc:95:d7:73:28:36:47:d1:14:6e:e5:95:d1:ae:35:
    57:3d:2e:c2:9e:86:9f:08:47:a4:31:61:5d:4b:d6:3f:0a:60:
    0d:e4:f3:11:aa:69:9d:c1:6b:ed:ea:53:82:e0:b3:f7:cd:c4:
    d2:b5:5e:60:ef:35:d2:bb:19:68:84:c9:c0:82:8d:e1:80:e8:
    e8:0a:d0:d4:b0:b7:13:4f:43:24:e6:6f:37:4d:8b:f0:b9:0e:
    af:3c:d7:61:89:24:6b:8a:88:88:82:7e:de:4c:12:8a:64:2b:
    75:ca:18:e9:11:8f:7a:c4:0a:55:2a:d6:6a:a8:84:2e:6d:d9:
    f9:f5:fc:48:96:bf:e3:87:2c:02:41:ab:1a:6b:ce:e3:16:65:
    0a:08:56:a2:be:28:ea:47:d2:03:bb:28:ab:f1:b4:ec:62:44:
    cd:c4:14:5d:2c:13:21:6a:d0:6e:6c:29:ba:80:9c:08:a2:50:
    bb:7c:ac:56:41:c0:64:3e:2a:c3:e1:44:38:a0:31:2a:68:4b:
    43:02:27:eb:a5:87:71:e6:79:09:51:a6:82:83:28:30:0f:9a:
    d7:3d:5f:c6
```

Hands-on

Certificate creation

- DSA parameter generation

  `openssl dsaparam 2048 -out dsaparams.pem`

- Key generation

  `openssl gendsa -out dsarootkey.pem dsaparams.pem`

- Self-signed certificate generation

  ```
  openssl req -newkey dsa:dsaparams.pem -keyout
    dsarootkey.pem -new -x509 -days 365 -out
    rootcert.pem
  ```

- Review the certificate

  ```
  openssl x509 -text -in rootcert.pem | more
  openssl asn1parse -in rootcert.pem | more
  ```

Hands-on

Certificate creation

- DSA parameter generation

```
openssl dsaparam 2048 -out dsaparams.pem
```

- Key generation

```
openssl gendsa -out dsarootkey.pem dsaparams.pem
```

- Self-signed certificate generation

```
openssl req -newkey dsa:dsaparams.pem -keyout
  dsarootkey.pem -new -x509 -days 365 -out
  rootcert.pem
```

- Review the certificate

```
openssl x509 -text -in rootcert.pem | more
openssl asn1parse -in rootcert.pem | more
```

Cliente side hands-on

- Generate a certificate for the client

```
openssl req -newkey dsa:dsaparams.pem -keyout
  dsakey.pem -new -days 365 -out dsareq.pem
```

- Certificate emission

```
openssl x509 -days 180 -CA rootcert.pem -CAkey
  dsarootkey.pem -req -CAcreateserial -CAserial
  ca.srl -in dsareq.pem -out newcert.pem
```

- Revieweing the certificate

```
openssl x509 -text -in newcert.pem | more
openssl asn1parse -in newcert.pem | more
```

- Certificate Verification

```
openssl verify -CAfile rootcert.pem newcert.pem
```

Apache configuration

- Copy the certificates files to the server
- Find the apache config file
- Identify the “VirtuaHost” block to configure

```
<VirtualHost 192.168.0.1:443>
DocumentRoot /var/www/html2
ServerName www.yourdomain.com
SSLEngine on
SSLCertificateFile /path/to/your_domain_name.crt
SSLCertificateKeyFile /path/to/your_private.key
SSLCertificateChainFile /path/to/DigiCertCA.crt
</VirtualHost>
```

Apache configuration

- Test your apache configuration
  - apachectl configtest
- Restart your apache server
  - apachectl stop
  - apachectl start

ngix configuration

- You need the CA's certificate
- Copy the certificates files to the server
- Concatenate the primary certificate and intermediate certificate
    - cat your_domain_name.crt rootcert.pem ¿¿ bundle.crt
- Edit ngix configuration file:

ngix configuration

```
server {
listen   443;
ssl    on;
ssl_certificate    /etc/ssl/your_domain_name.pem; (or bundle.c
ssl_certificate_key    /etc/ssl/your_domain_name.key;
server_name your.domain.com;
access_log /var/log/nginx/nginx.vhost.access.log;
error_log /var/log/nginx/nginx.vhost.error.log;
location / {
root   /home/www/public_html/your.domain.com/public/;
index  index.html;
}
}
```

- Restart the ngix server
  - /etc/init.d/nginx restart

```
nain_name.pem; (or bundle.c
r_domain_name.key;

st.access.log;
t.error.log;

omain.com/public/;
```

IIS configuration

```
pem; (or bundle.
ame.key;

og;
;

ublic/;
```

IIS configuration

SSL - Definiti

- SSL (Secure
standard to
a web server
the protocol

- This links en
server, and t
privacy, and

- This is the s

```
pem; (or bundle.c
ame.key;

log;
g;

public/;
```

IIS configuration

SSL - Definiti

- SSL (Secure
  standard to
  a web server
  the protocol

- This links en
  server, and t
  privacy, and

- This is the s

IIS configuration

e.

SSL - Definition

- SSL (Secure Sockets Layer) i
standard to establish an encry
a web server, and an internet
the protocol could be used fo

- This links ensures the data tr
server, and the client, and th
privacy, and integrity

- This is the standard for onlin

IIS configuration

SSL - Definition

- SSL (Secure Sockets Layer) is the security standard to establish an encrypted link between a web server, and an internet browser (perhaps, the protocol could be used for something else).
- This links ensures the data travels between the server, and the client, and that it mantains its privacy, and integrity
- This is the standard for online transactions.

guration

SSL - Definition

- SSL (Secure Sockets Layer) is the security standard to establish an encrypted link between a web server, and an internet browser (perhaps, the protocol could be used for something else).
- This links ensures the data travels between the server, and the client, and that it mantains its privacy, and integrity
- This is the standard for online transactions.

SSL - R

Ver

Generate 4

MS = (PM

Symmet

SSL - Definition

- SSL (Secure Sockets Layer) is the security standard to establish an encrypted link between a web server, and an internet browser (perhaps, the protocol could be used for something else).
- This links ensures the data travels between the server, and the client, and that it mantains its privacy, and integrity
- This is the standard for online transactions.

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Verify Certificate
Generate 48-byte random PMS
MS = (PMS, CRnd,SRnd,etc.)

Symmetric key generation

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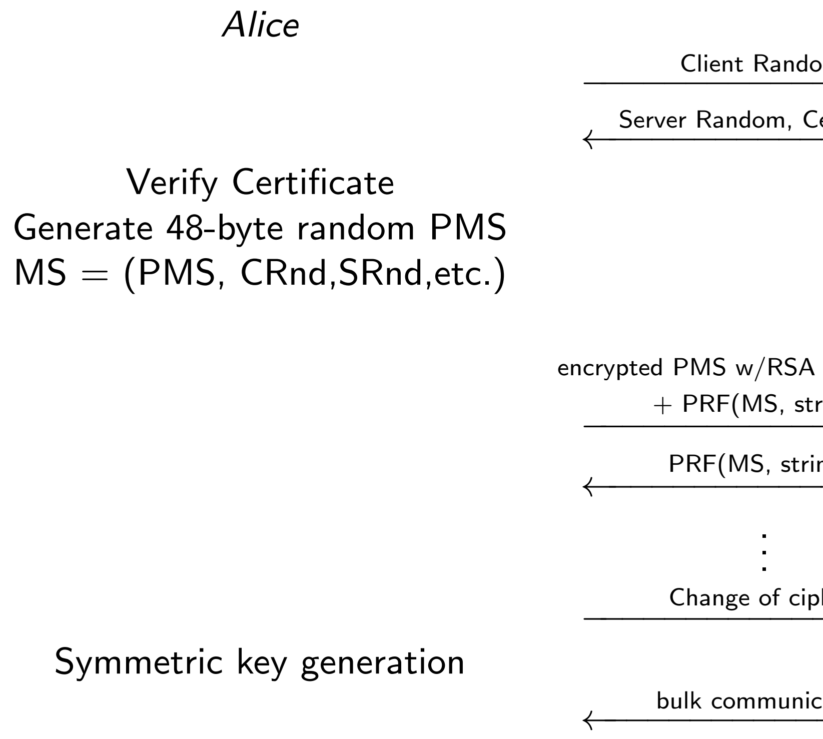

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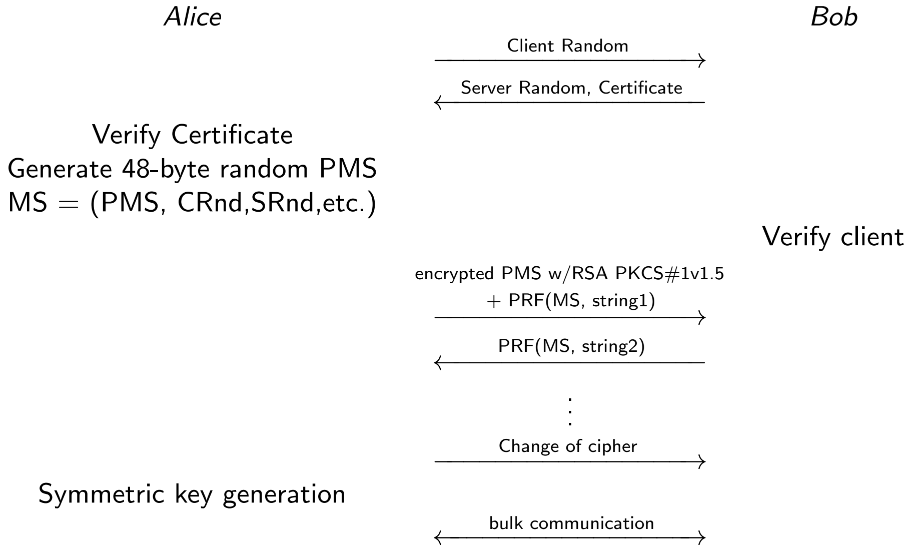

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Server Random, Certificate

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Change of cipher

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bulk communication

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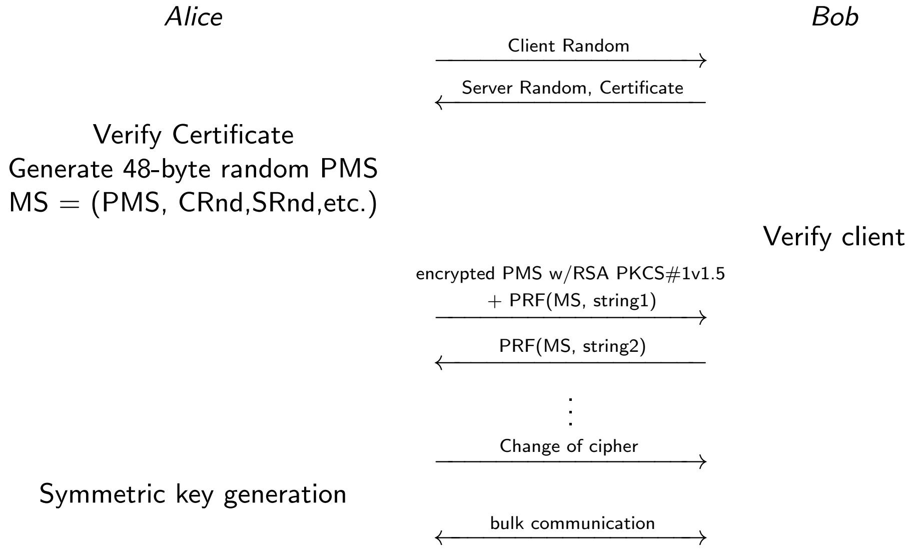

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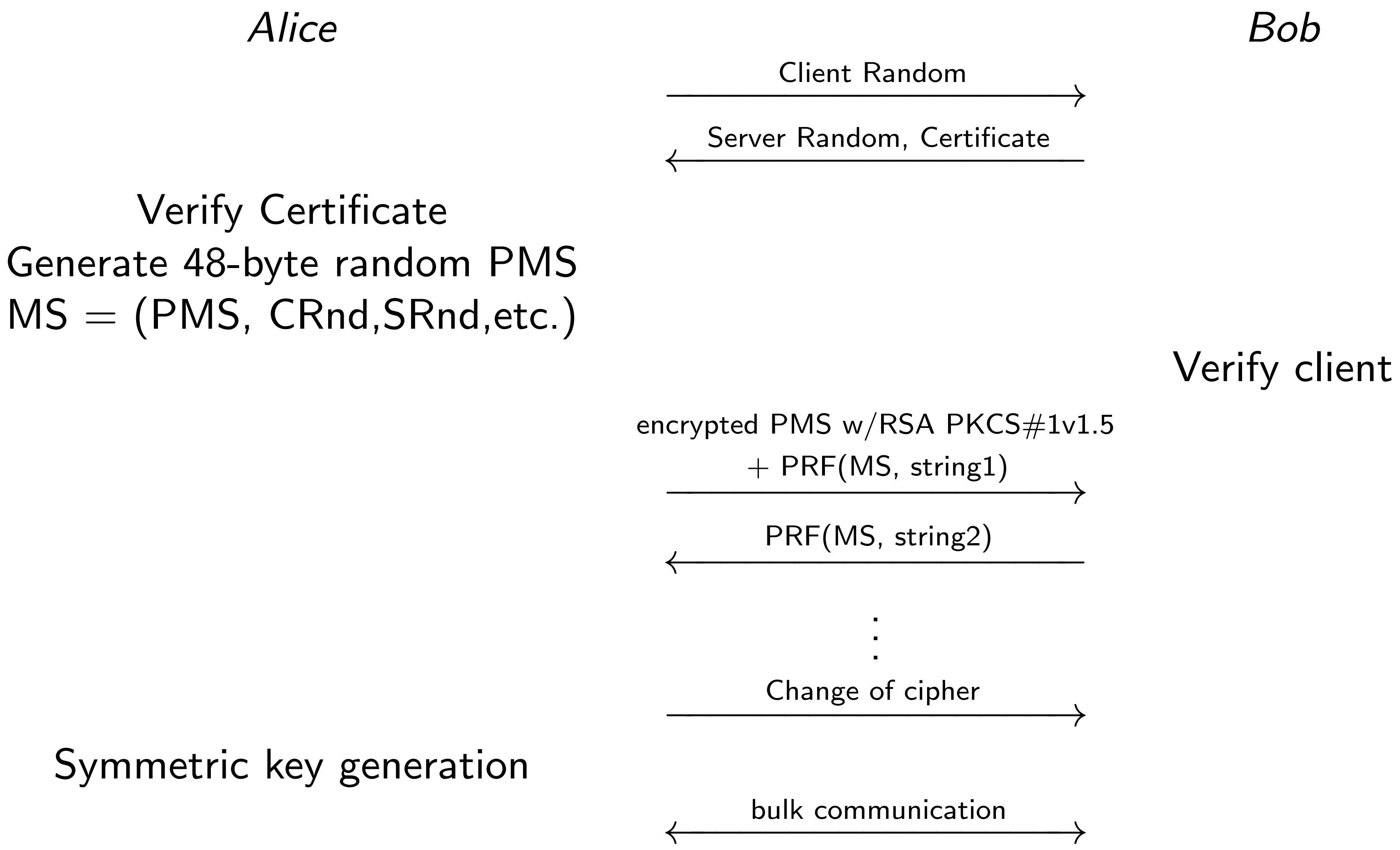

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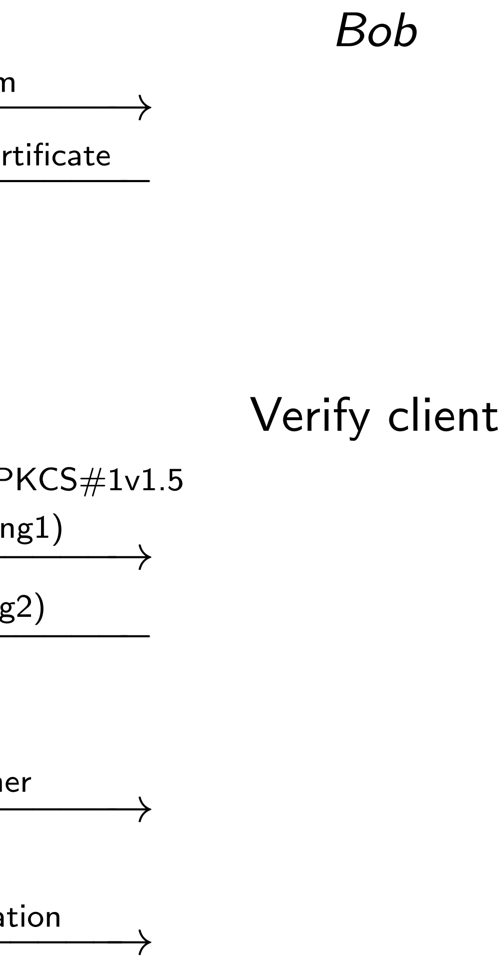

SSL - overview

- We exchange the problem of verifying the public key of Bob (and everybody else), by the one of verifying the public of a Certificate Authority.

- Despite the are a lot of Certificate Authorities, the number of webserver is substantially larger. . .

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PGP

PGP consists of the following services:

- Authentication
- Confidentiality
- E-mail compatibility
- Segmentation

In a nutshell:

- Generates a session key, and encrypt it
- Signs the message
- Compress the message
- Encrypts the message
- (prepend the encrypted key to the message)

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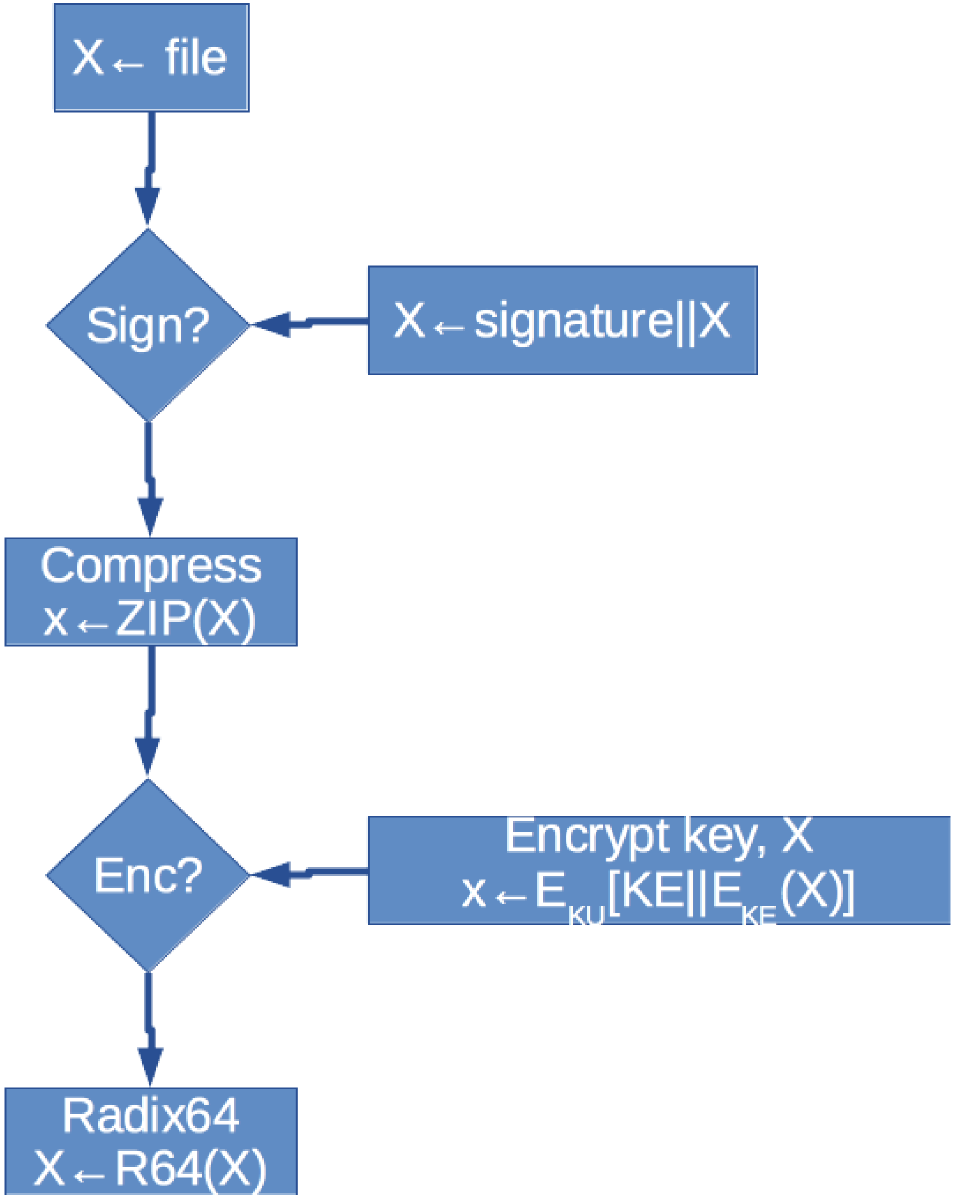
PGP Diagram



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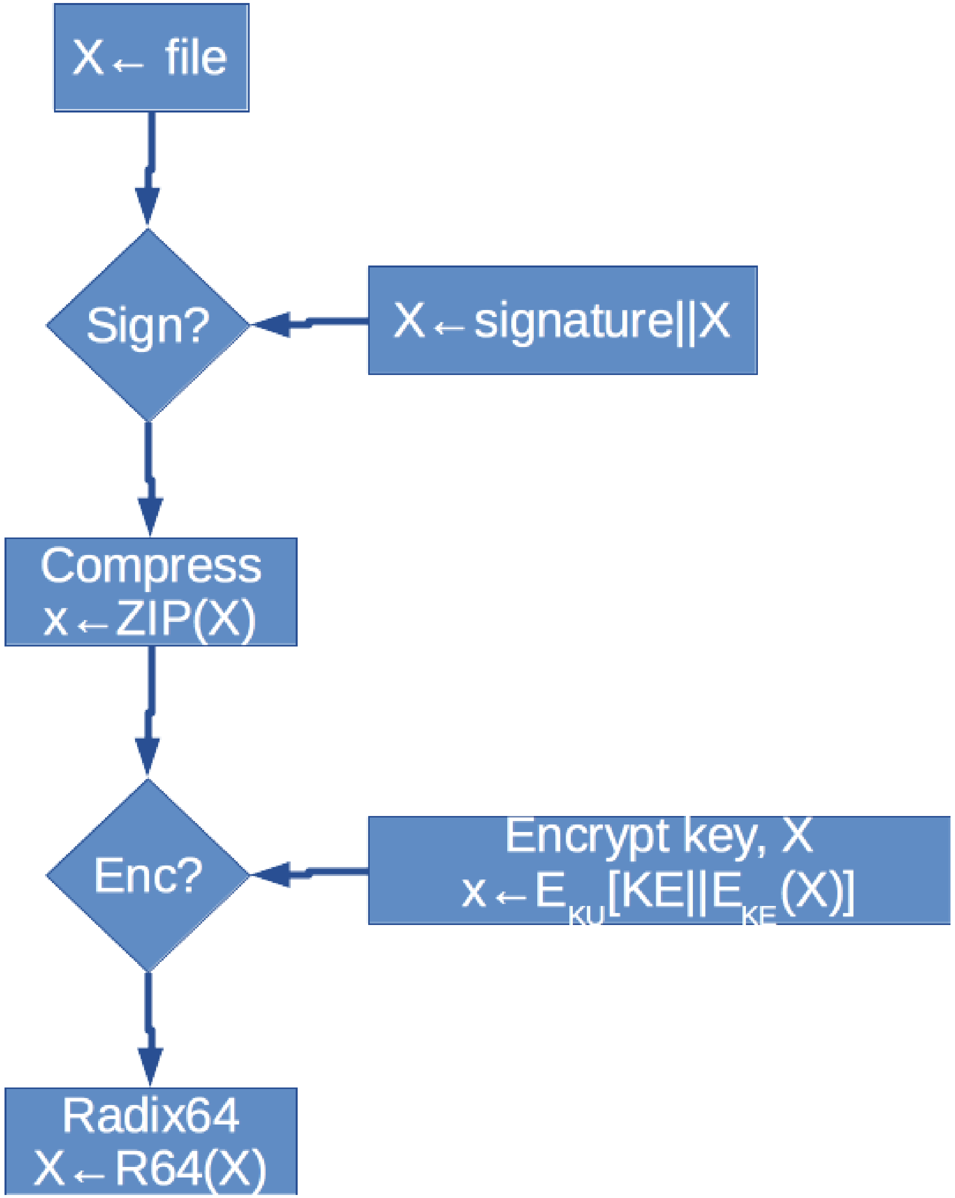

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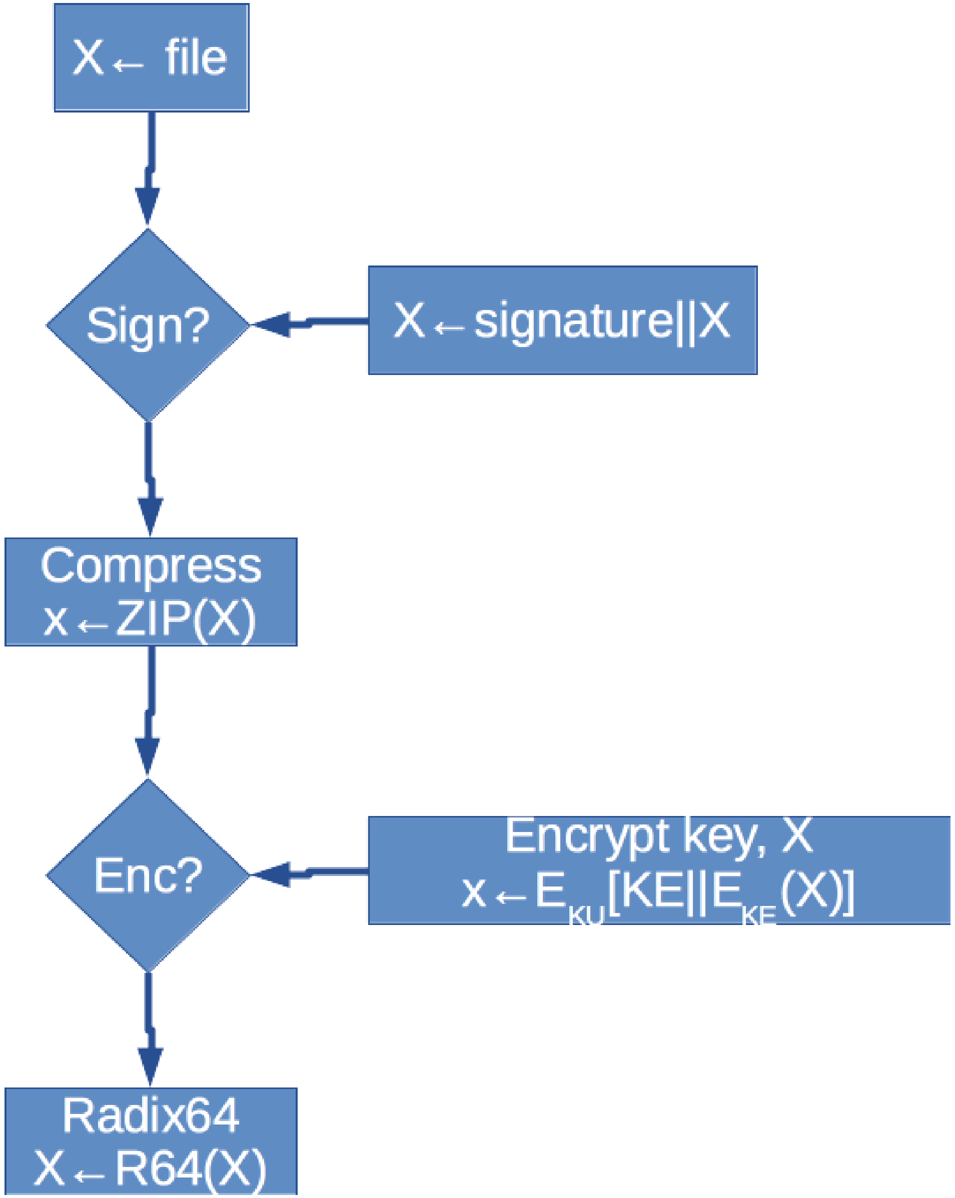

X ← file

Sign?

X ← signature||X

Compress
x ← ZIP(X)

Enc?

Encrypt key, X
$x \leftarrow E_{KU}[KE||E_{KE}(X)]$

Radix64
X ← R64(X)

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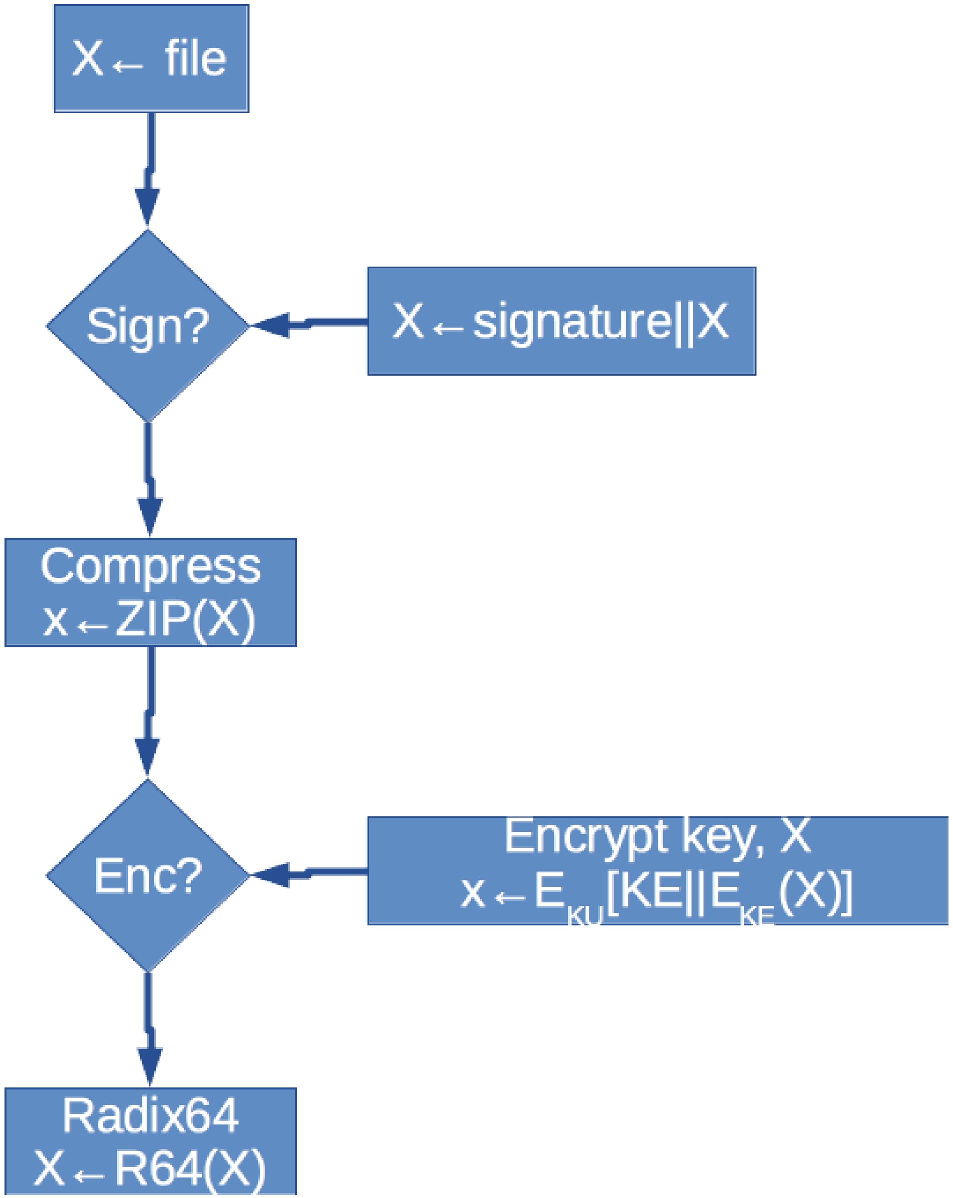

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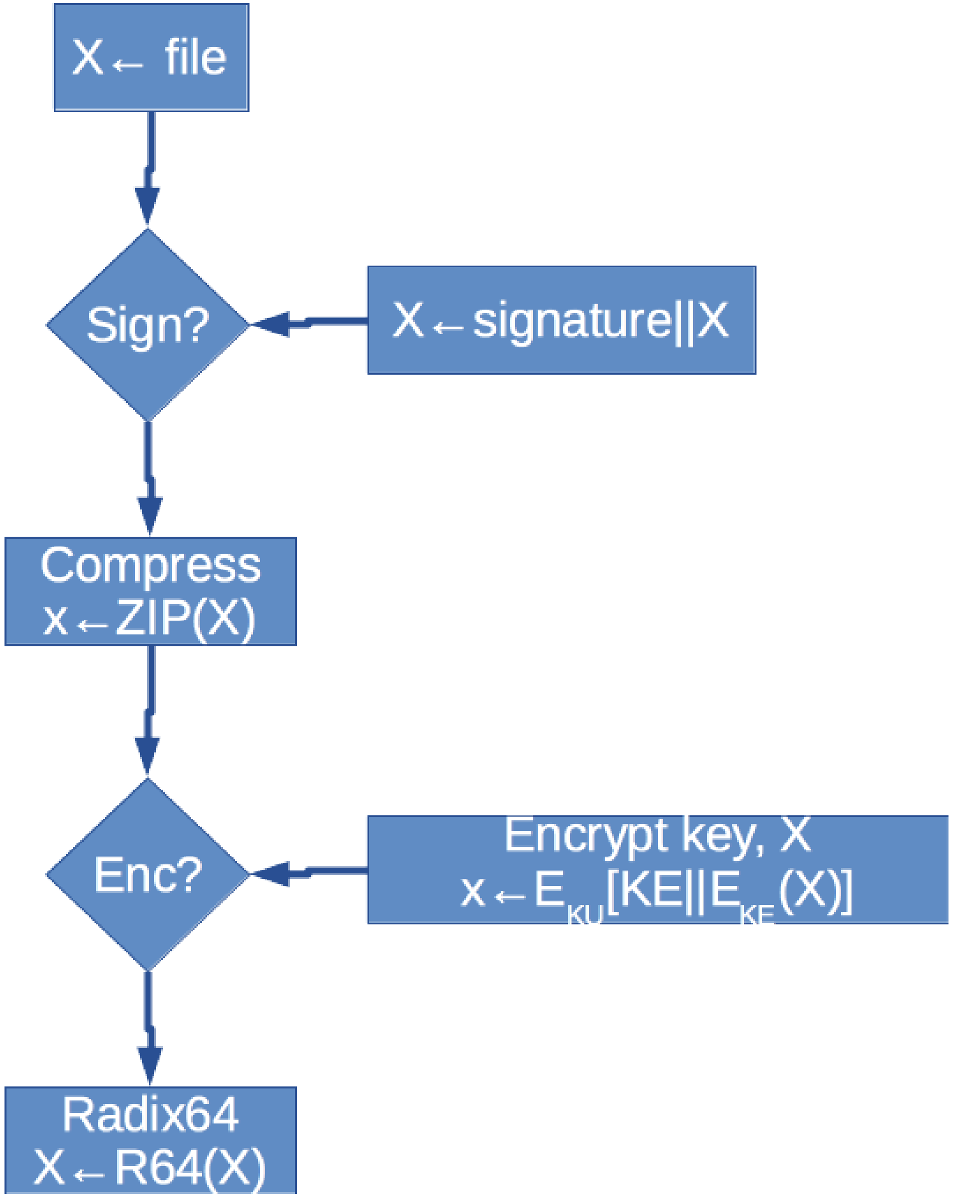

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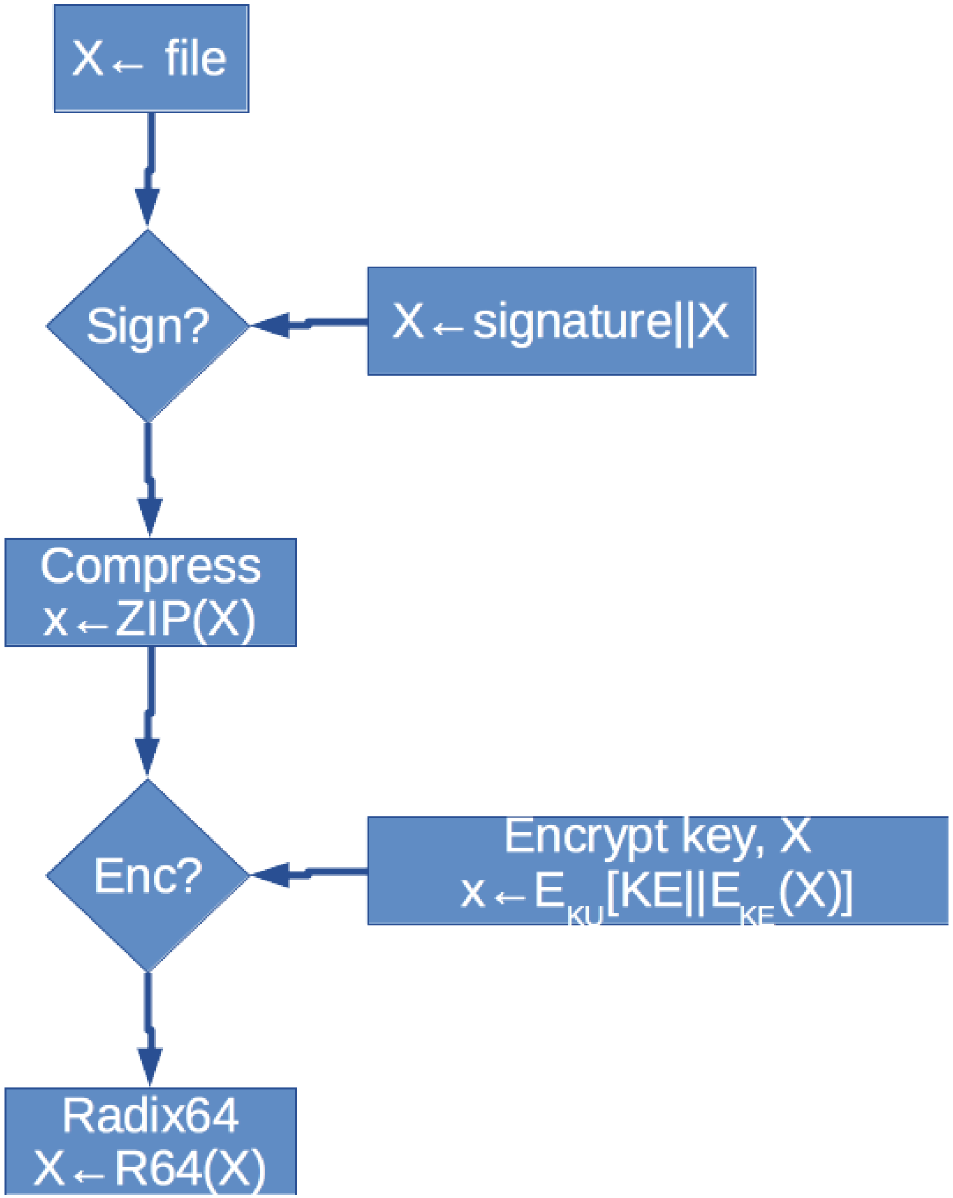

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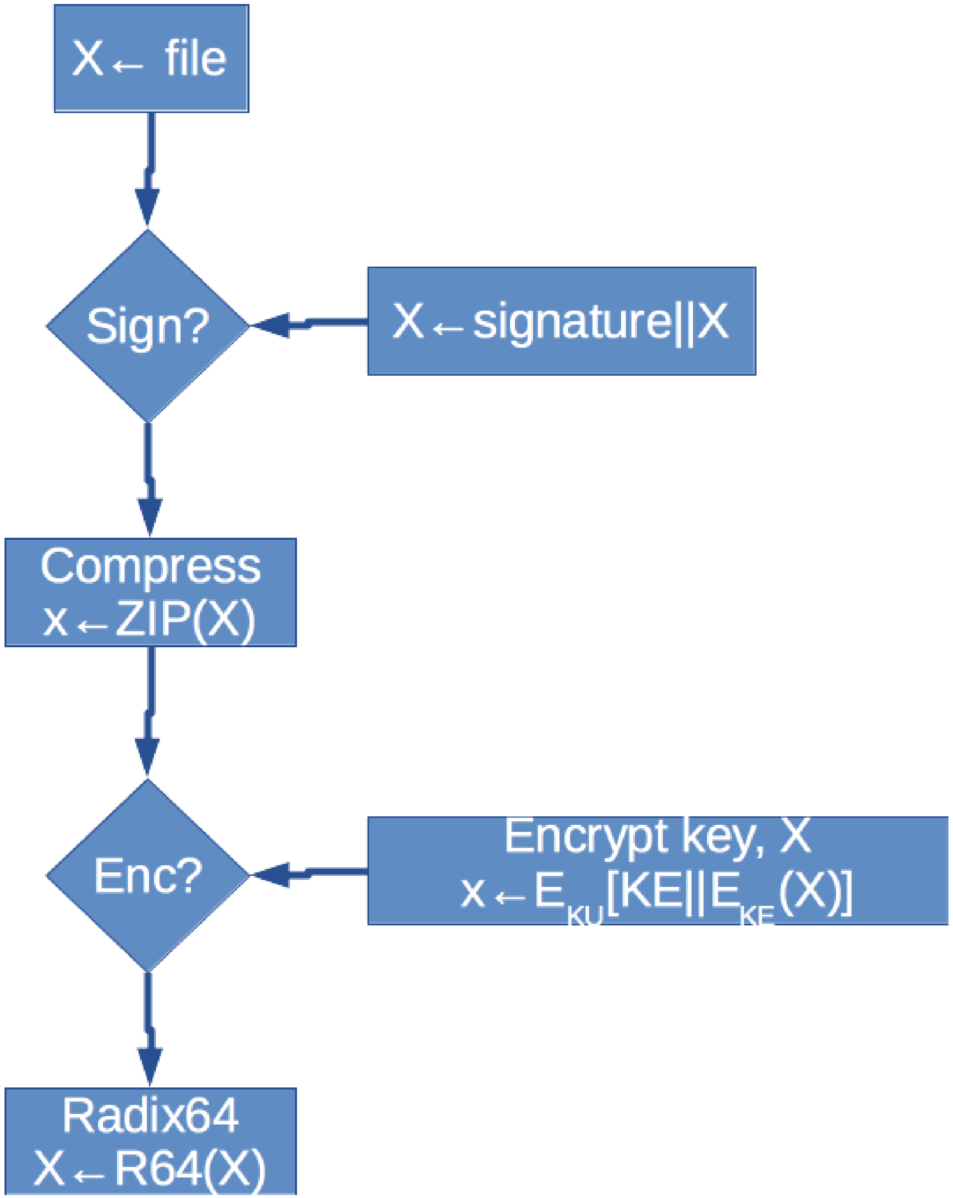

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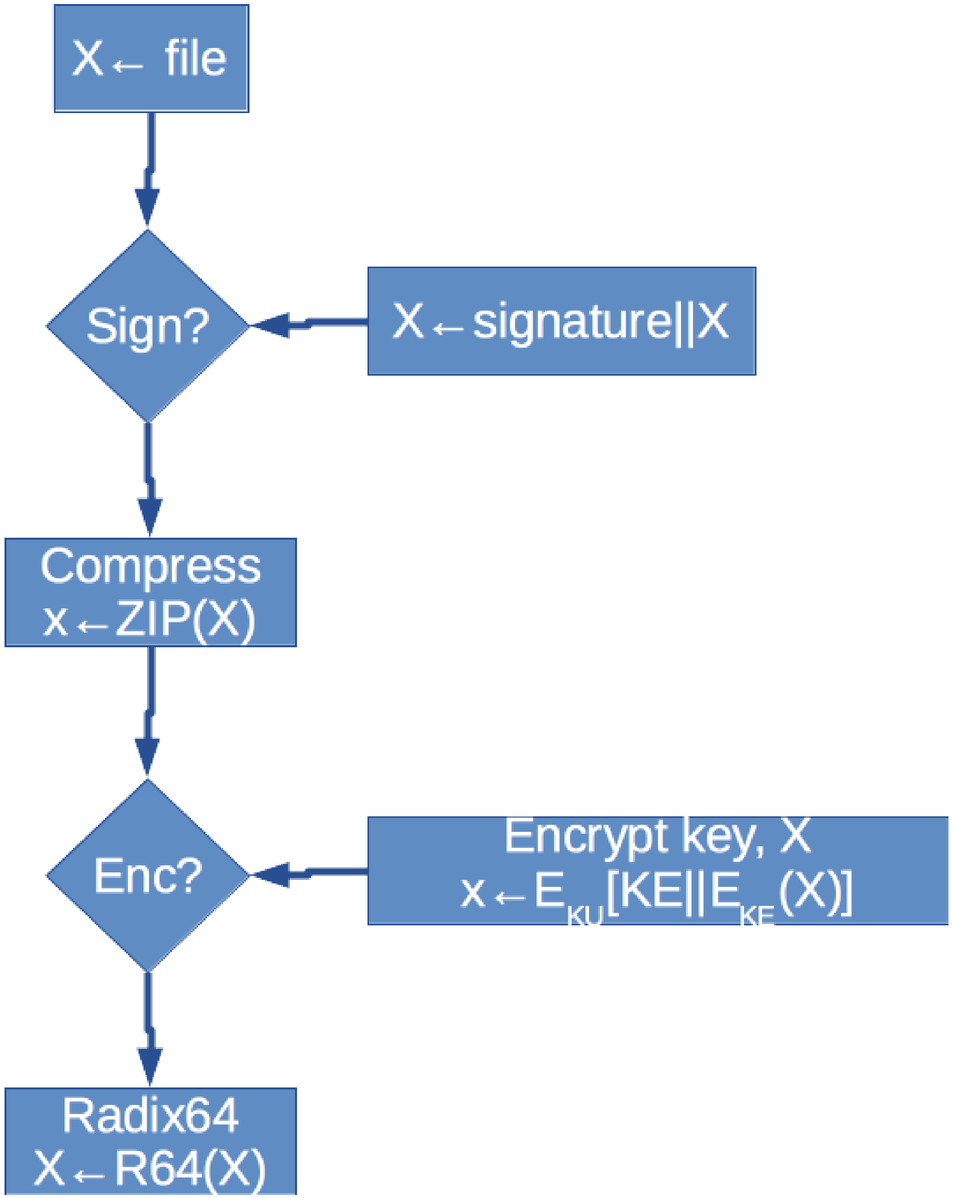

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Usage

- Create Key
  - gpg –gen-key
  - gpg –armor –output pubkey.txt –export ’Your Name’
  - gpg –send-keys ’Your Name’ –keyserver hkp://subkeys.pgp.net
- Encrypting / Decrypting
  - gpg –encrypt –recipient ’Your Name’ foo.txt
  - gpg –output foo.txt –decrypt foo.txt.gpg
- Encrypting for Recipient
  - gpg –search-keys ’user1@example.org’ –keyserver hkp://subkeys.pgp.net
  - gpg –import key.asc
  - gpg –list-keys
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  - gpg –verify crucial.tar.gz.asc crucial.tar.
  - gpg –armor –detach-sign your-file.zip

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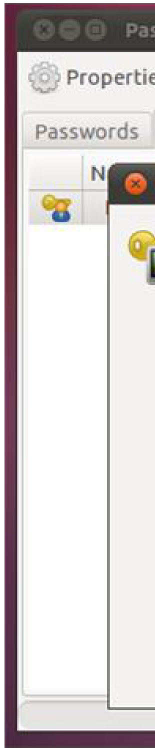

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- We use GPG tools
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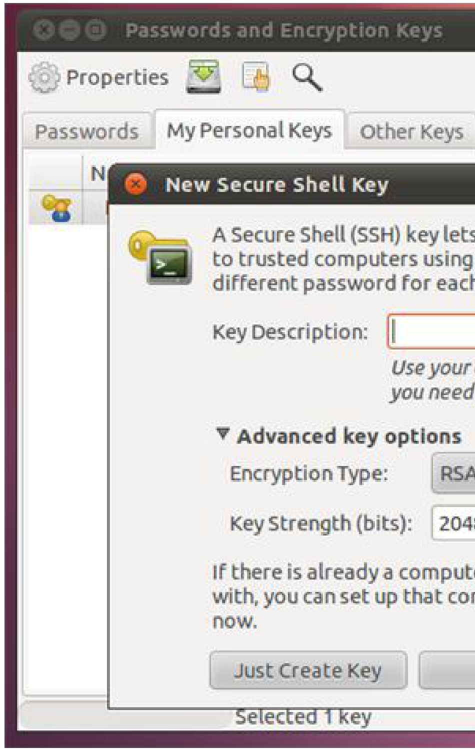

A Secure Shell (SSH) key lets
to trusted computers using
different password for each

Key Description:

Use your
you need

Encryption Type: RSA

Key Strength (bits): 204

If there is already a comput
with, you can set up that co
now.

'Your

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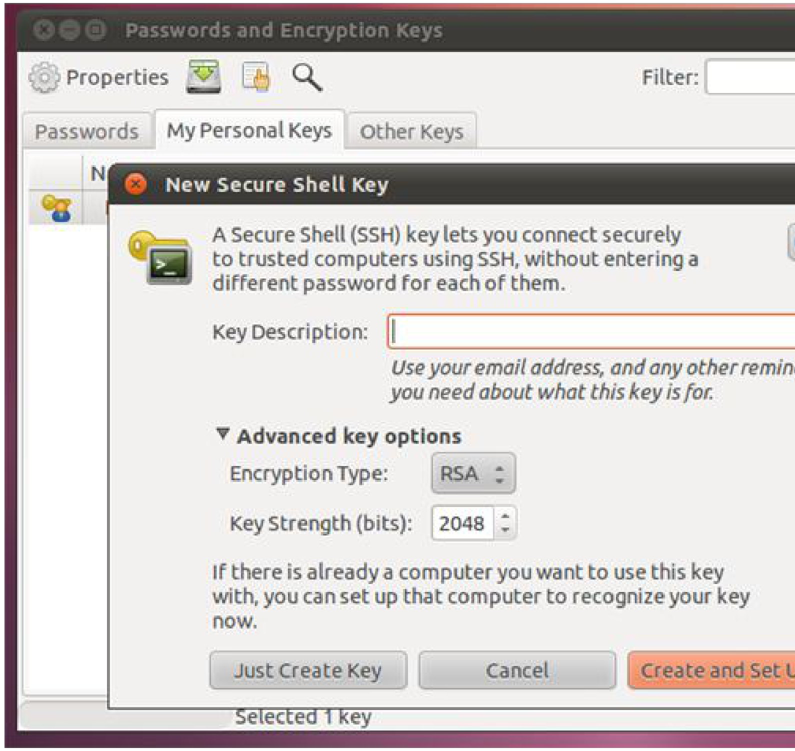

A Secure Shell (SSH) key lets you connect securely to trusted computers using SSH, without entering a different password for each of them.

Key Description:

Use your email address, and any other remin you need about what this key is for.

▼ **Advanced key options**

Encryption Type: RSA

Key Strength (bits): 2048

If there is already a computer you want to use this key with, you can set up that computer to recognize your key now.

Selected 1 key

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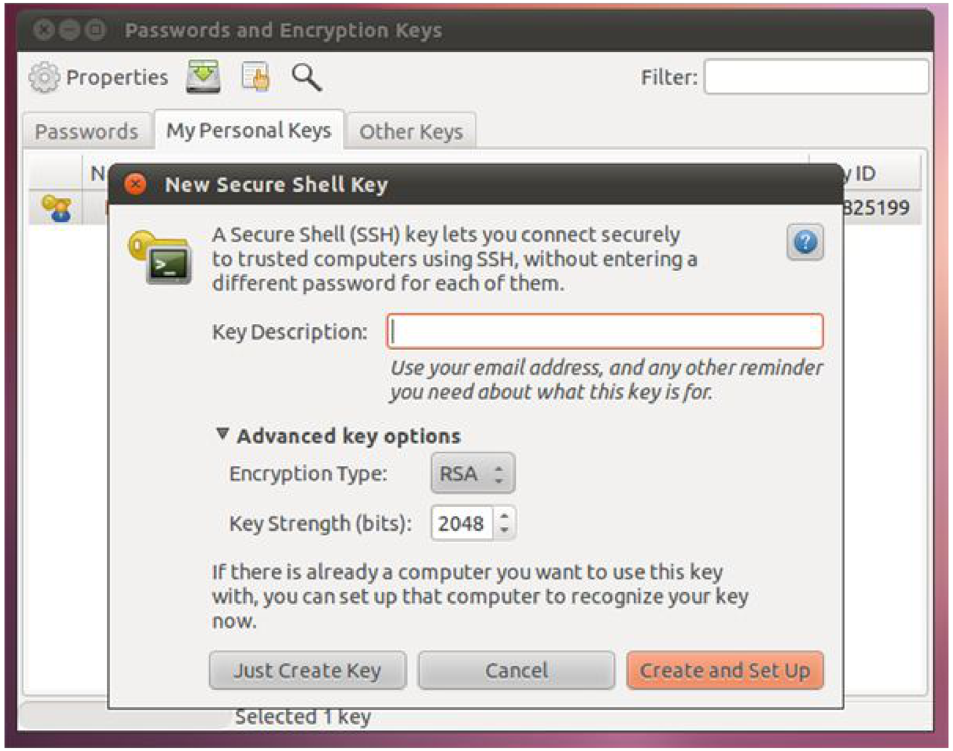

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If there is already a computer you want to use this key with, you can set up that computer to recognize your key now.

ypting

g –output foo.txt –decrypt foo.txt.gpg

tures

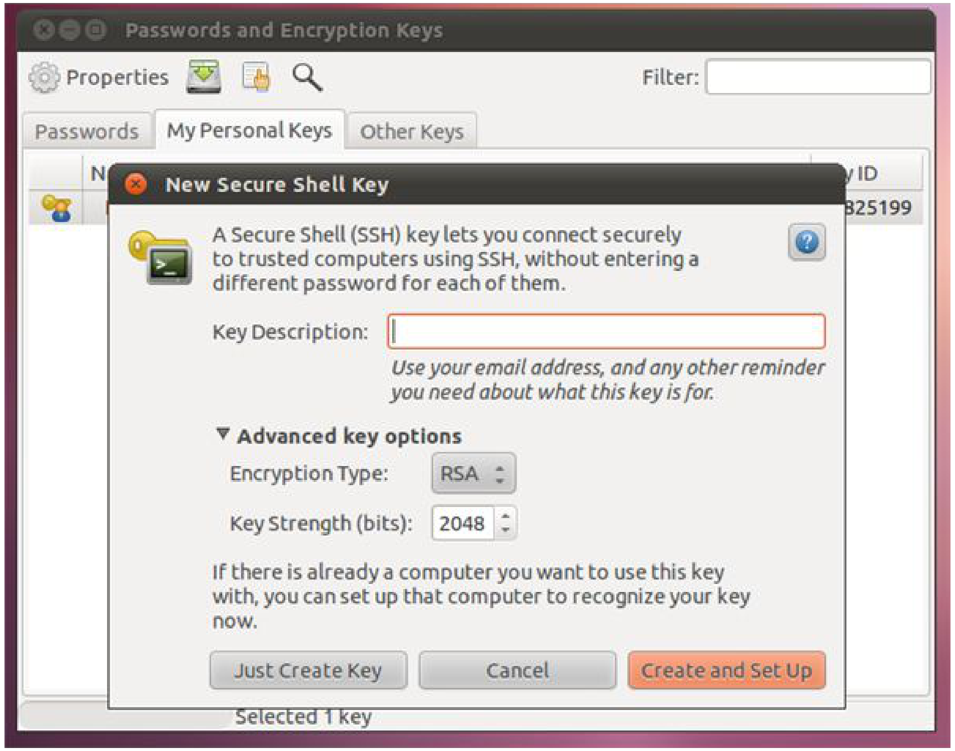
g –verify crucial.tar.gz.asc crucial.tar.gz

g –armor –detach-sign your-file.zip

Linux tools

For Linux

- We use GPG tools
- It has differences between the PGP official implementation
- It provides command line interface
- There are GUI tools, such as Seahorse



A Secure Shell (SSH) key lets you connect securely to trusted computers using SSH, without entering a different password for each of them.

Key Description:

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▼ Advanced key options

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OSX Too

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- Work
- GPG
- GPG
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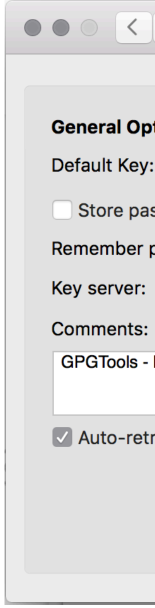
- MacG



General Opt

Default Key:

□ Store pas

Remember p

Key server:

Comments:

GPGTools -

☑ Auto-retr

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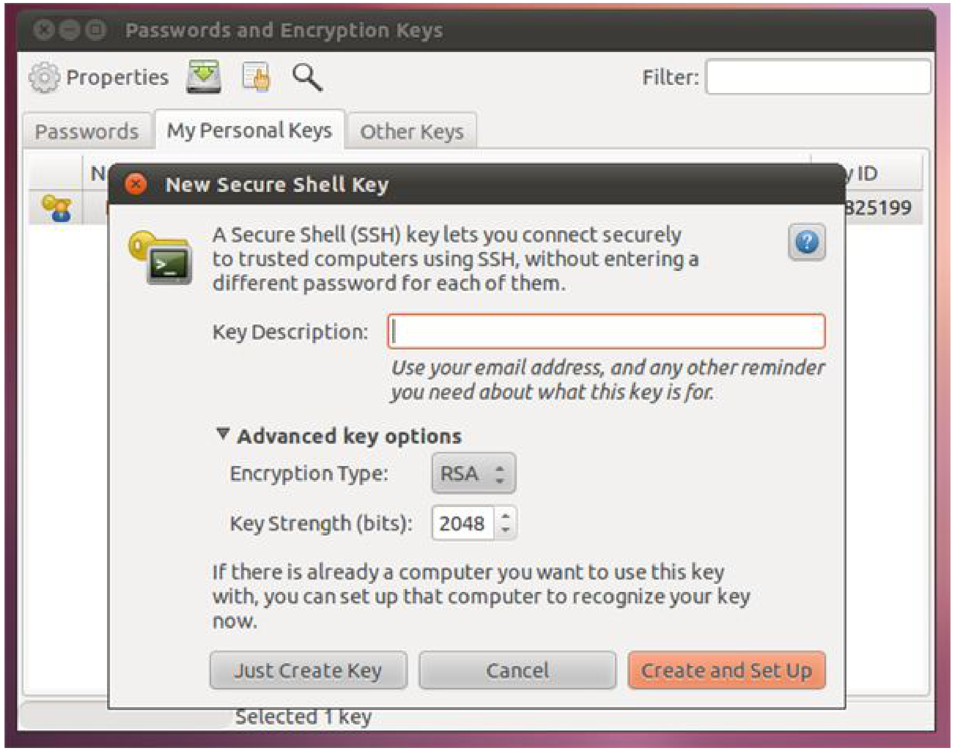
Passwords and Encryption Keys

Properties Filter:

Passwords | My Personal Keys | Other Keys

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New Secure Shell Key

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- GPG keychain
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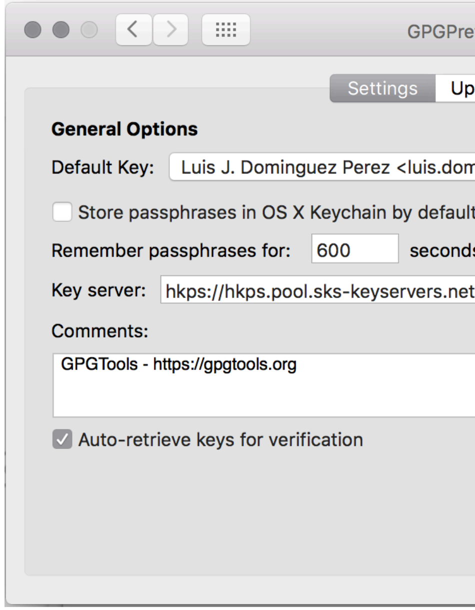
GPGPre

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□ Store passphrases in OS X Keychain by default

Remember passphrases for: 600 seconds

Key server: hkps://hkps.pool.sks-keyservers.net

Comments:

GPGTools - https://gpgtools.org

☑ Auto-retrieve keys for verification

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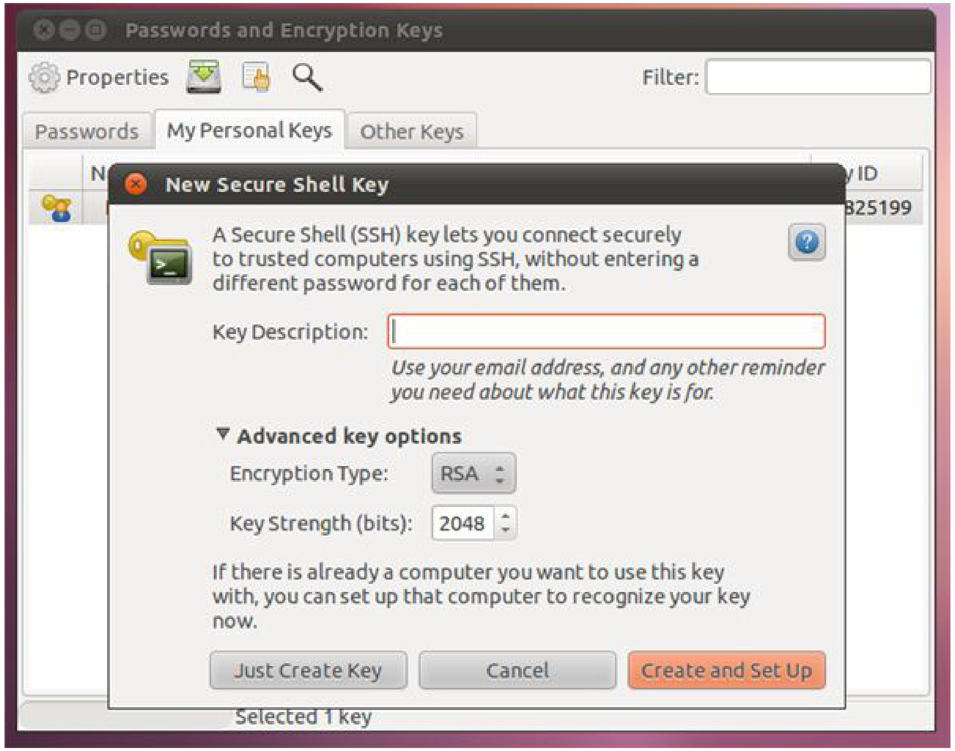

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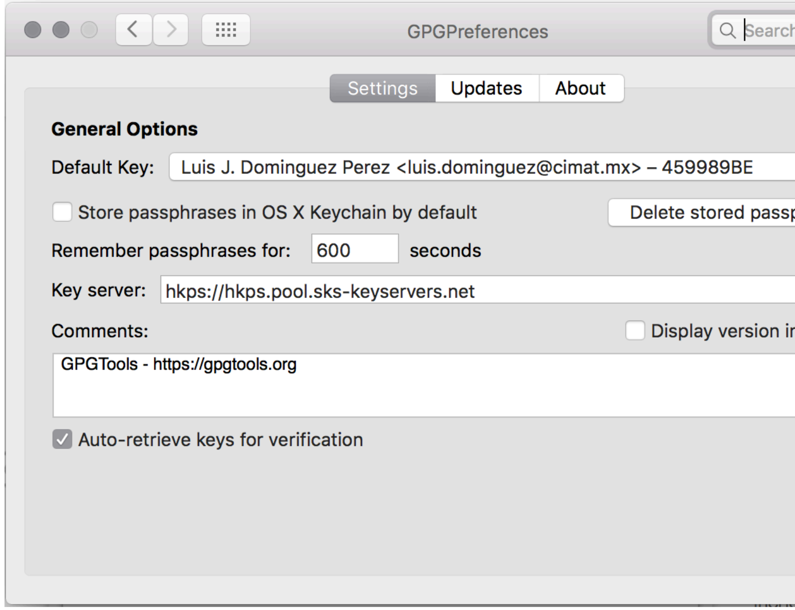

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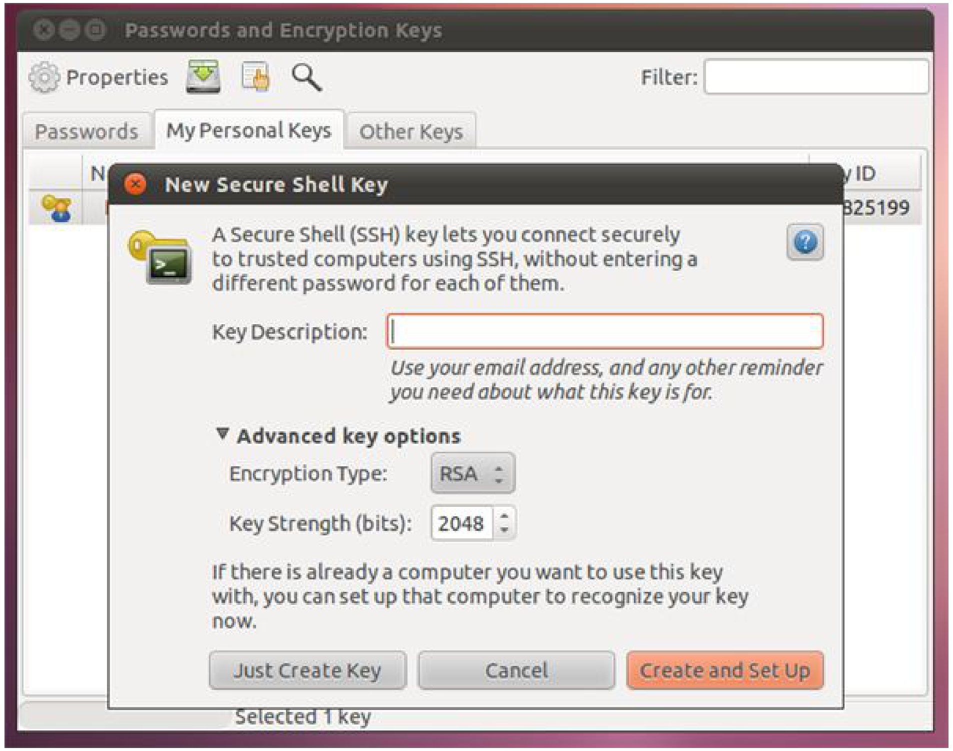

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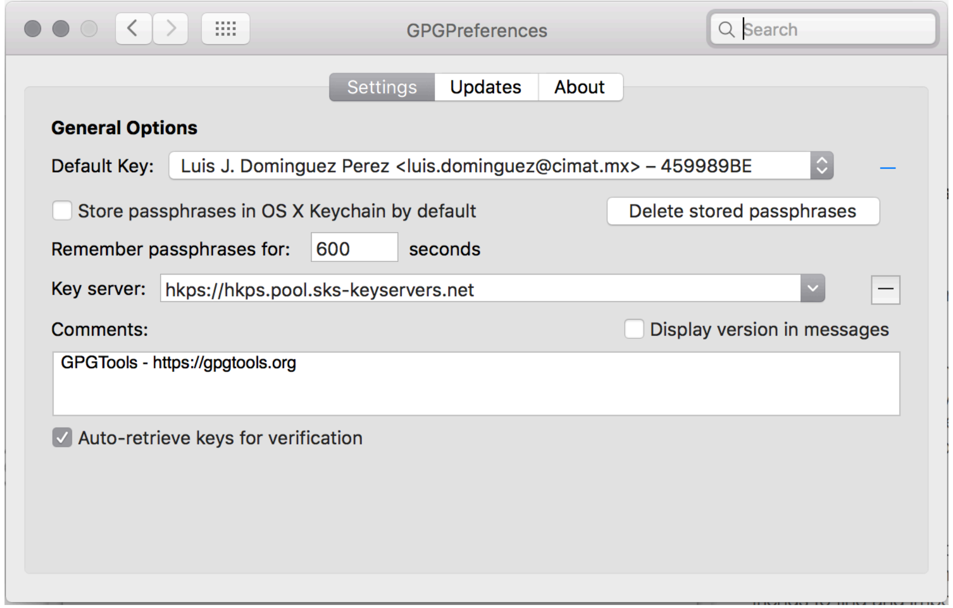

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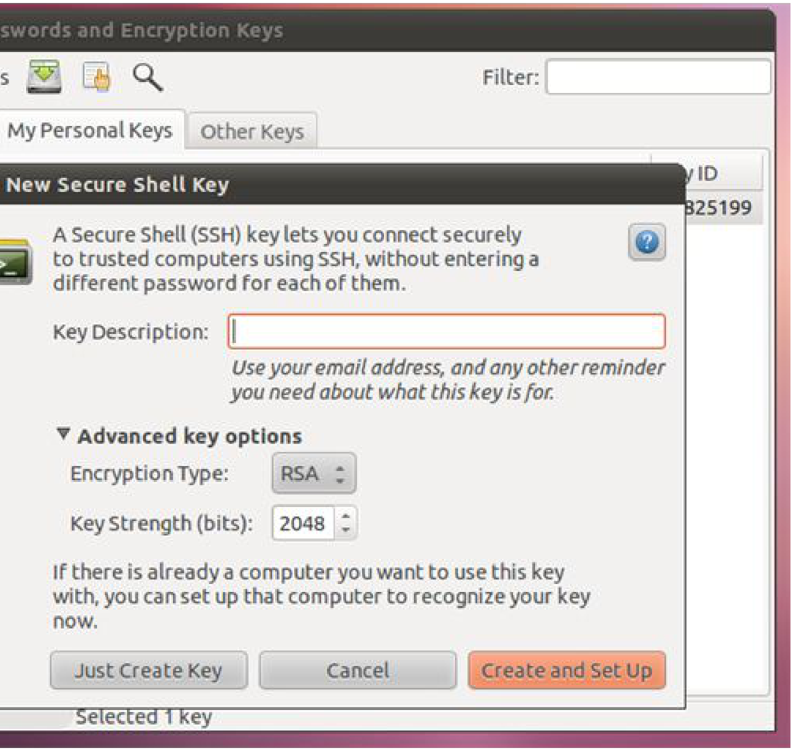

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Just Create Key | Cancel | Create and Set Up

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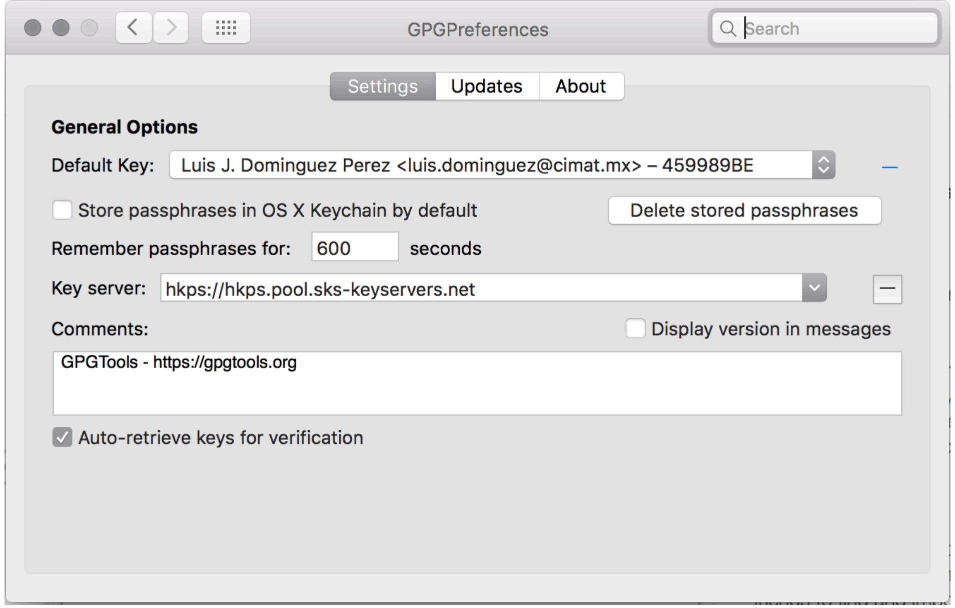

GPGPreferences

Search

Settings | Updates | About

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☑ Auto-retrieve keys for verification

Windows

For Win

- ▶ PGP
- ▶ GPG
- ▶ GNU

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P E8918B35

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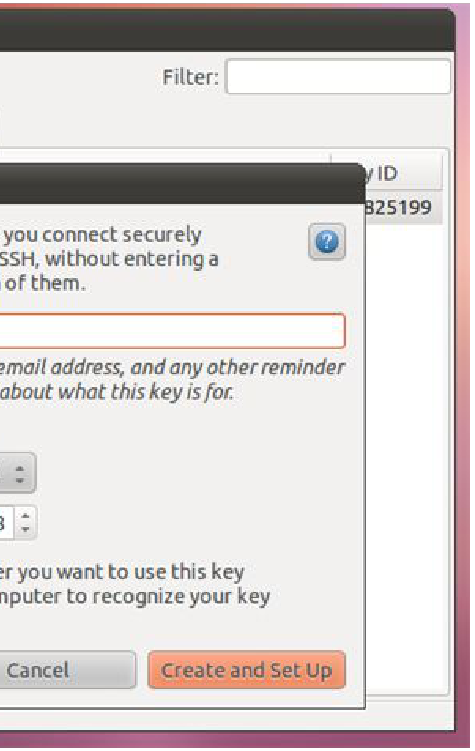

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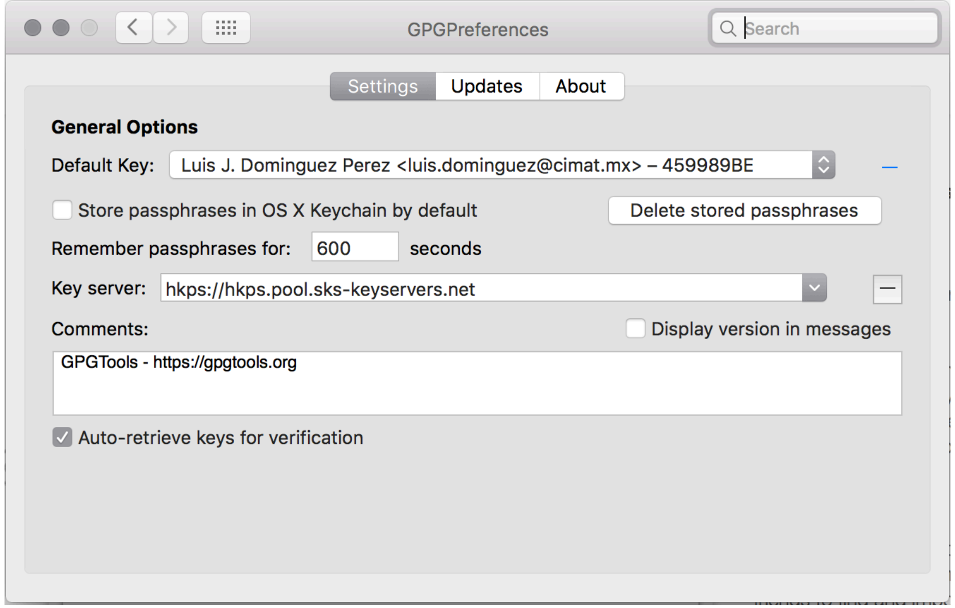

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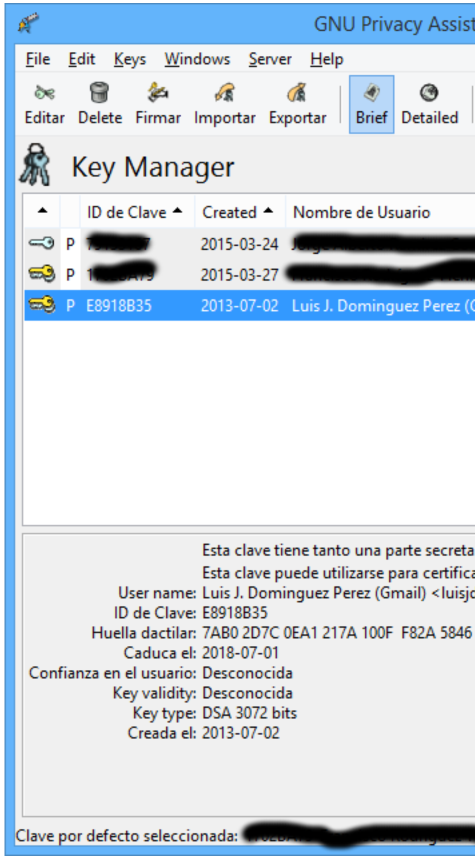

	ID de Clave	Created	Nombre de Usuario
P	[redacted]	2015-03-24	[redacted]
P	[redacted]	2015-03-27	[redacted]
P	E8918B35	2013-07-02	Luis J. Dominguez Perez ((

Esta clave tiene tanto una parte secreta
Esta clave puede utilizarse para certifica
User name: Luis J. Dominguez Perez (Gmail) <luisjo
ID de Clave: E8918B35
Huella dactilar: 7AB0 2D7C 0EA1 217A 100F F82A 5846
Caduca el: 2018-07-01
Confianza en el usuario: Desconocida
Key validity: Desconocida
Key type: DSA 3072 bits
Creada el: 2013-07-02

Clave por defecto seleccionada: [redacted]

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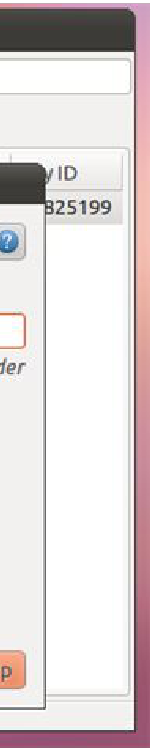

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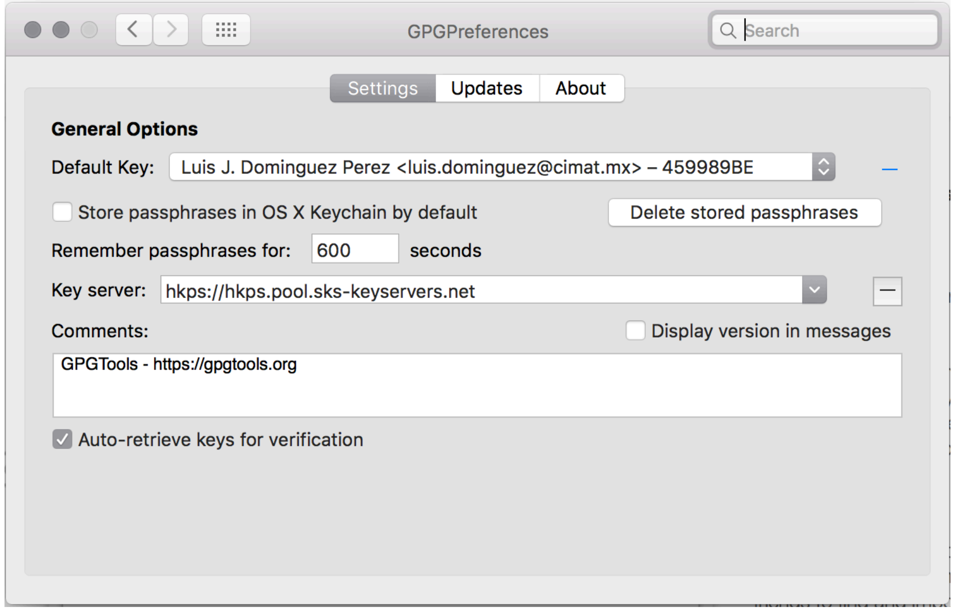

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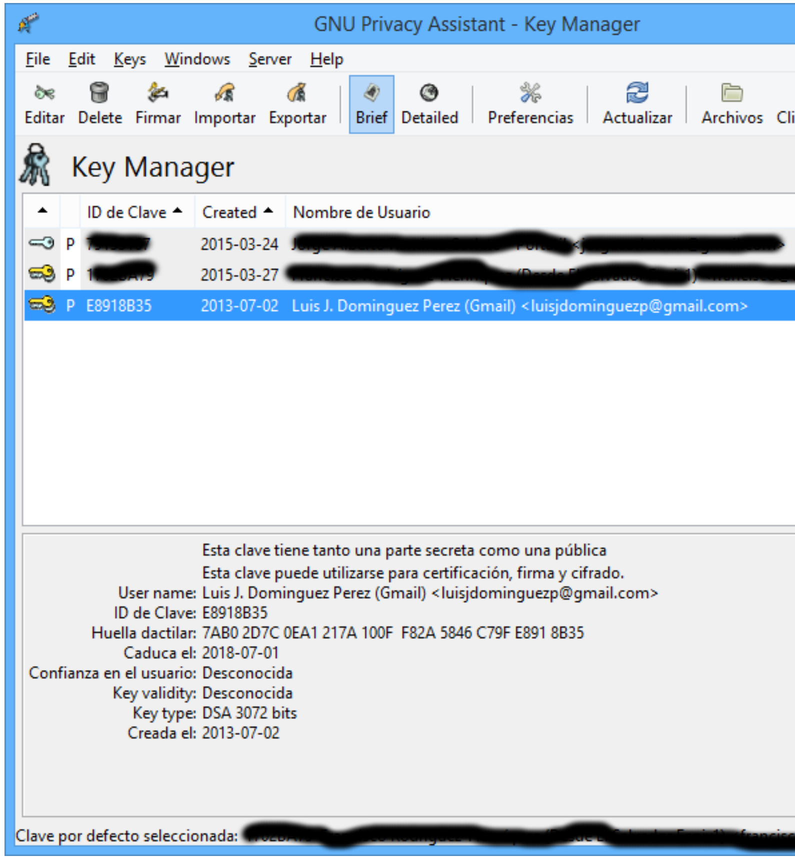

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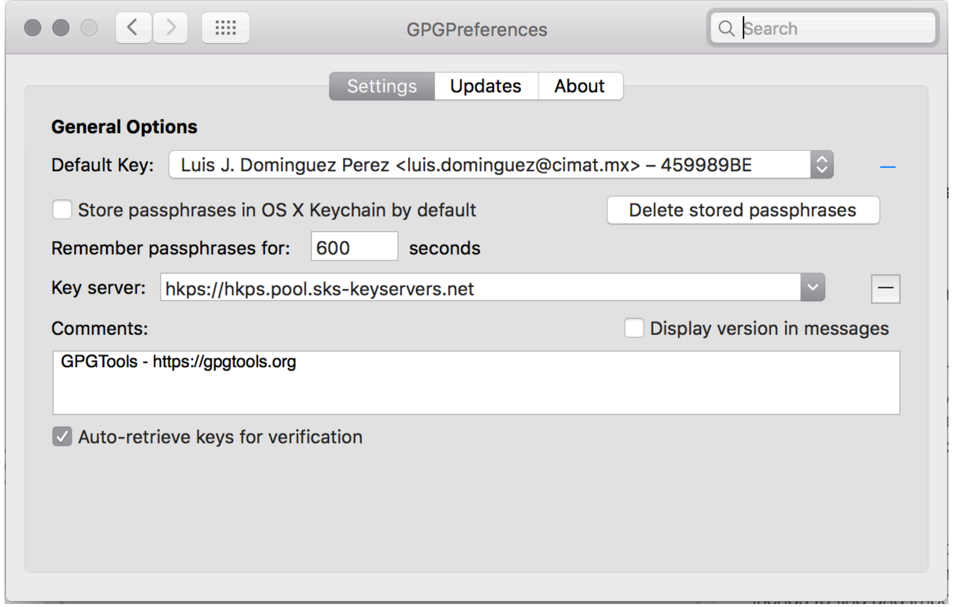

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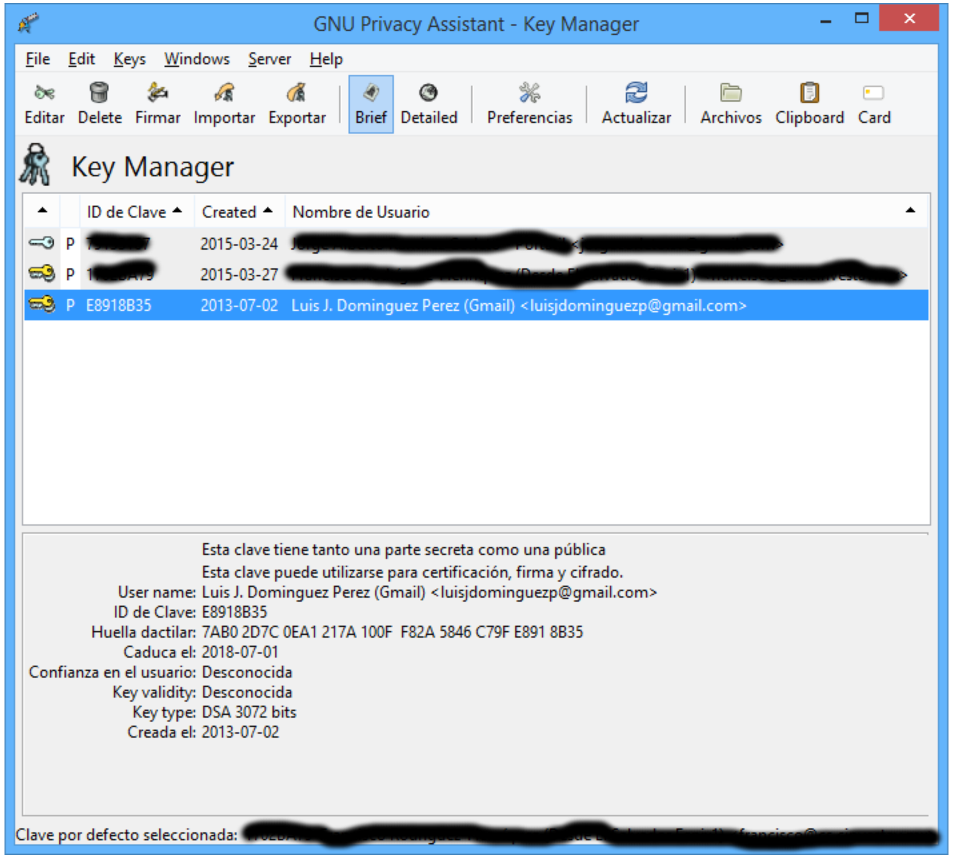

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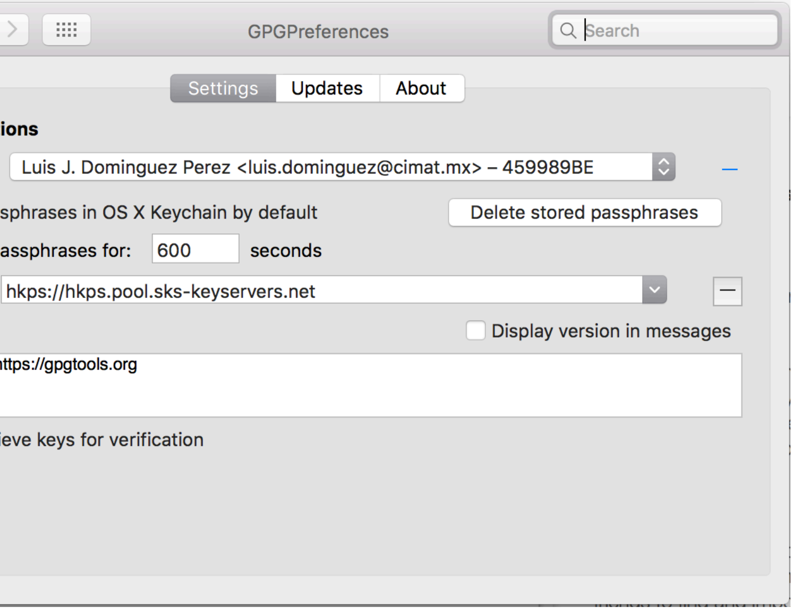
- services
- GPG



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Luis J. Dominguez Perez <luis.dominguez@cimat.mx> – 459989BE

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Delete stored passphrases

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□ Display version in messages

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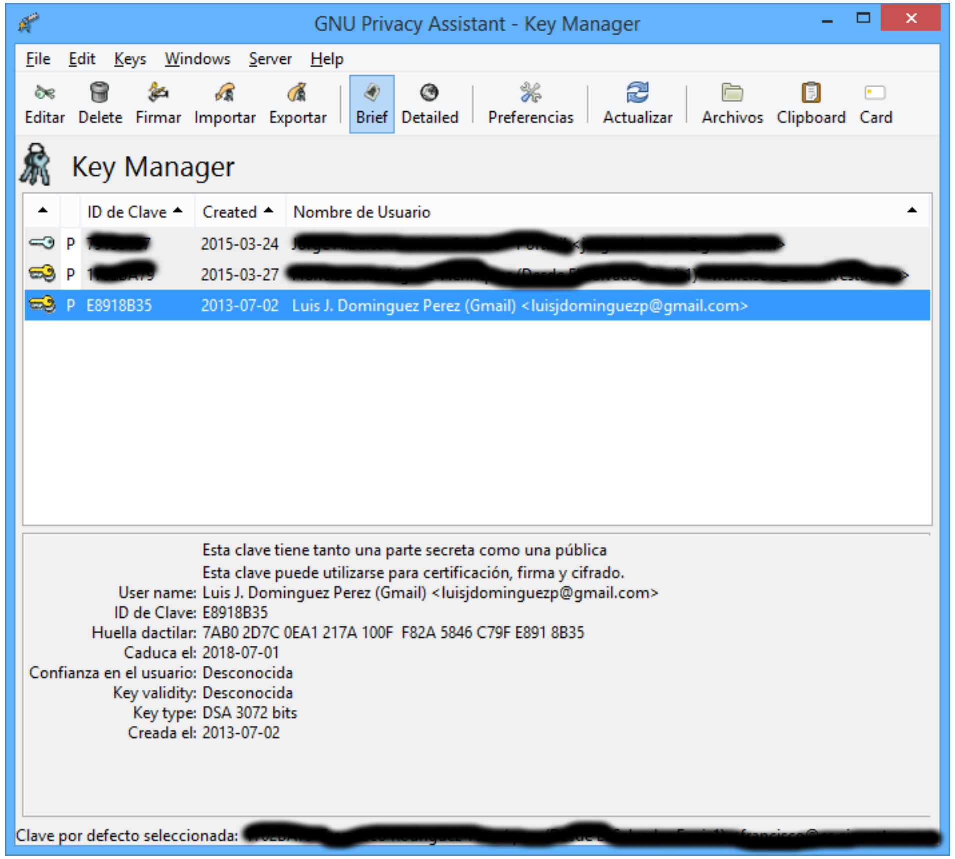

GNU Privacy Assistant - Key Manager
File Edit Keys Windows Server Help
Editar Delete Firmar Importar Exportar Brief Detailed Preferencias Actualizar Archivos Clipboard Card
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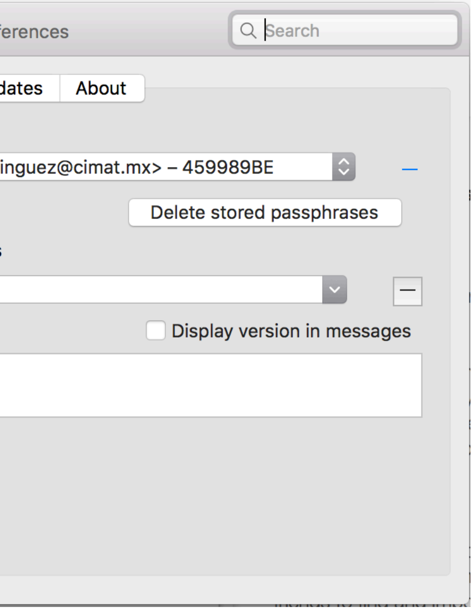

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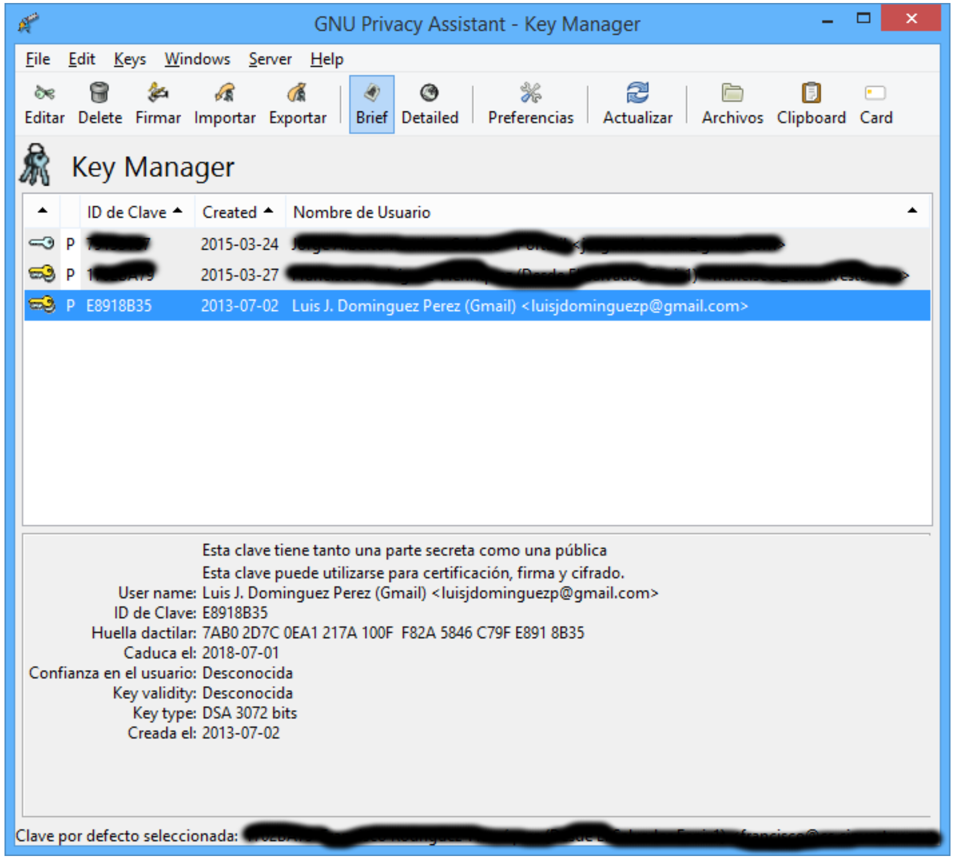
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Mailvelope

- Is a Chrome, and Firef
encryption in your web
- Uses: OpenPGP.js, em
Bootstrap, jQuery, Ox

Supports:

- Key Management
- Key Generation
- Key Import/Export
- Encrypt/Decrypt, and

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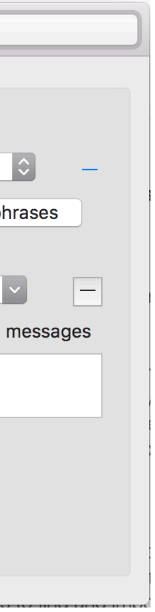

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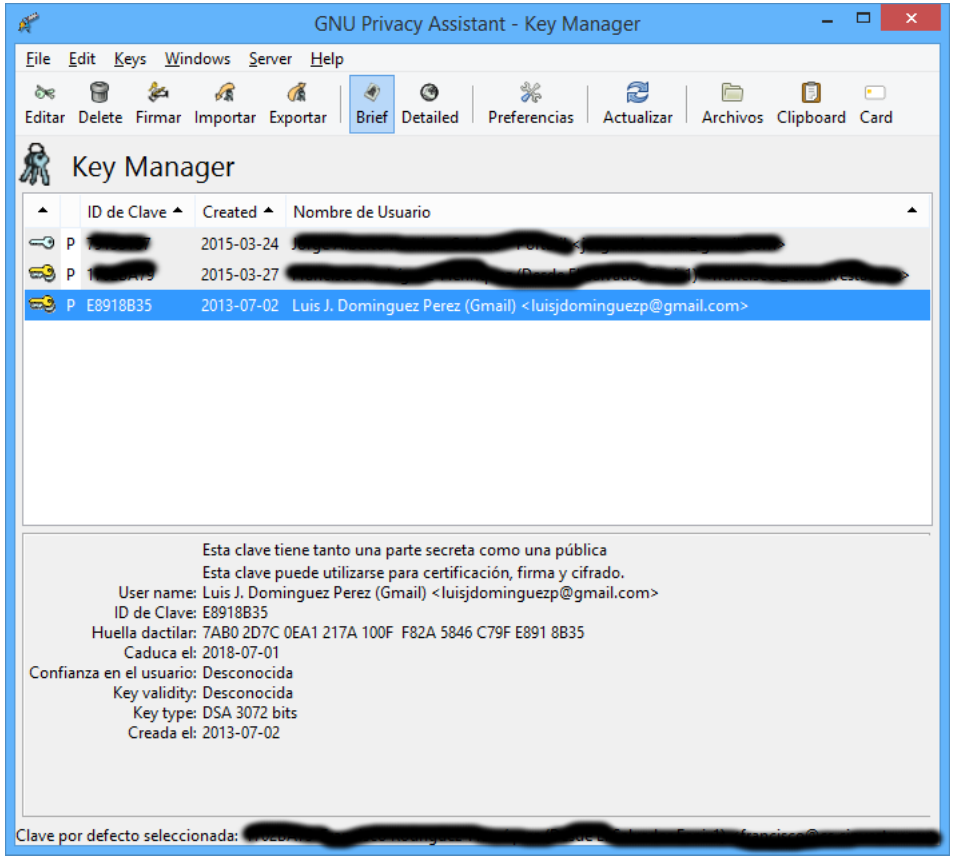
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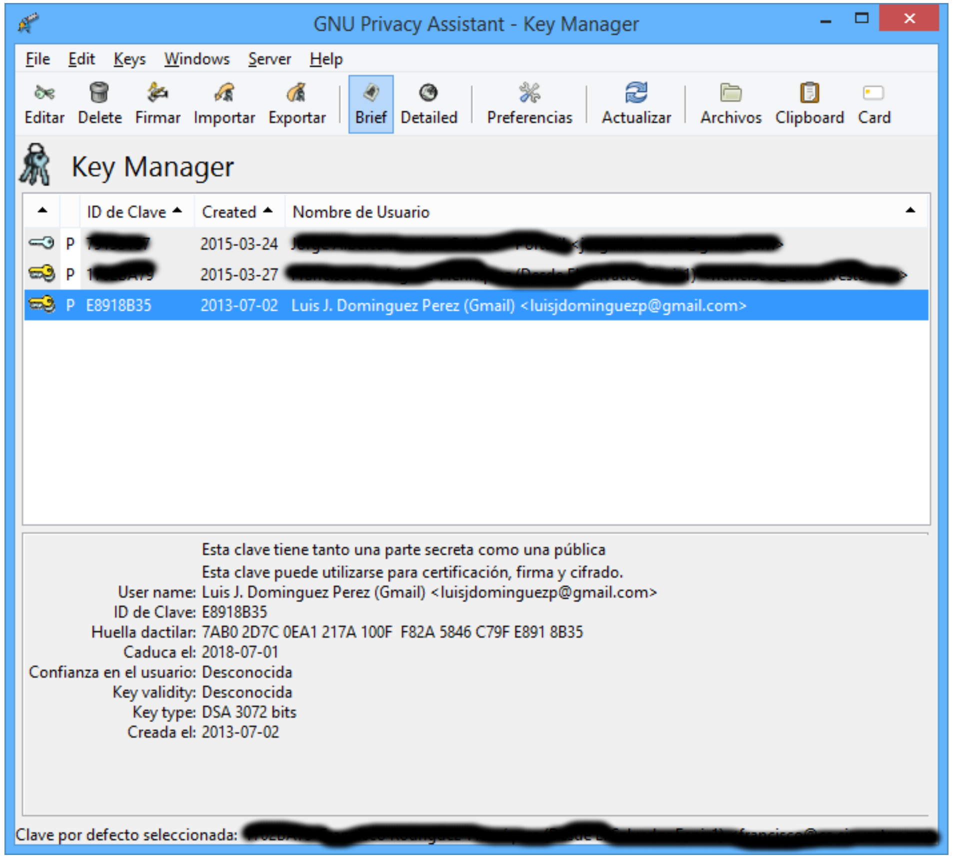
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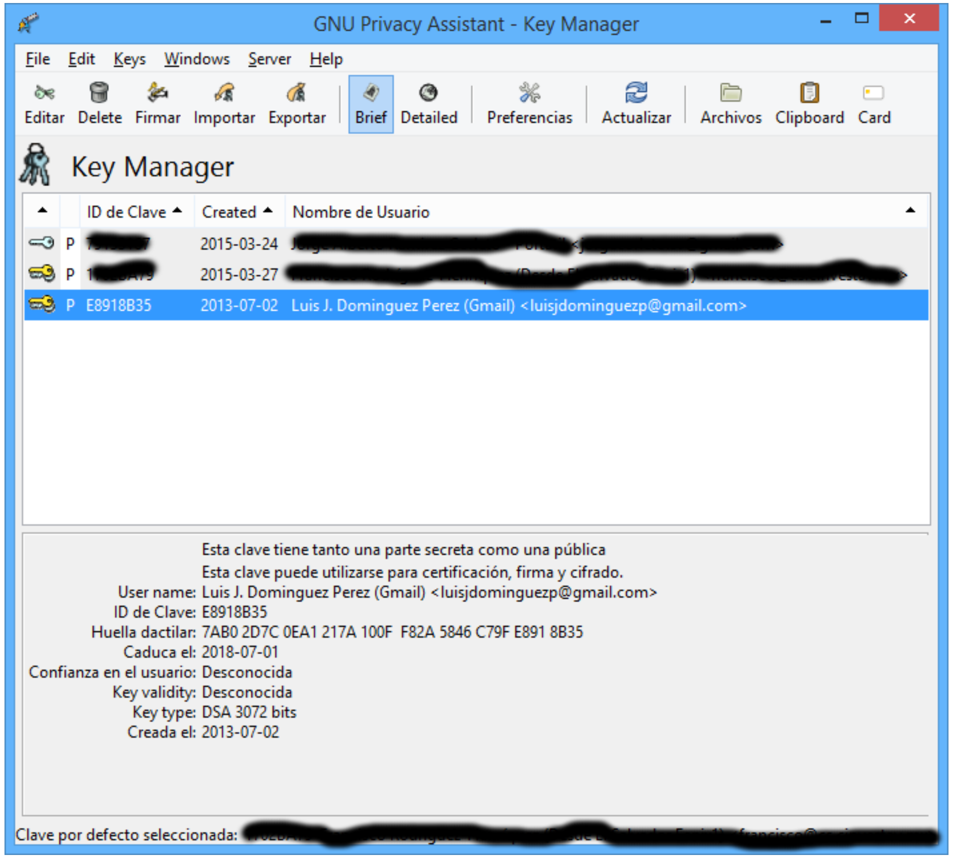
GNU Privacy Assistant - Key Manager
File Edit Keys Windows Server Help
Editar Delete Firmar Importar Exportar Brief Detailed Preferencias Actualizar Archivos Clipboard Card
Key Manager

		ID de Clave	Created	Nombre de Usuario
	P	[redacted]	2015-03-24	[redacted]
	P	[redacted]	2015-03-27	[redacted]
	P	E8918B35	2013-07-02	Luis J. Dominguez Perez (Gmail) <luisjdominguezp@gmail.com>

Esta clave tiene tanto una parte secreta como una pública
Esta clave puede utilizarse para certificación, firma y cifrado.
User name: Luis J. Dominguez Perez (Gmail) <luisjdominguezp@gmail.com>
ID de Clave: E8918B35
Huella dactilar: 7AB0 2D7C 0EA1 217A 100F F82A 5846 C79F E891 8B35
Caduca el: 2018-07-01
Confianza en el usuario: Desconocida
Key validity: Desconocida
Key type: DSA 3072 bits
Creada el: 2013-07-02

Clave por defecto seleccionada: [redacted]

Mailvelope

- Is a Chrome, and Firefox plug-in for using PGP encryption in your webmail clients.
- Uses: OpenPGP.js, email.js, DOMpurify, Bootstrap, jQuery, Oxygen icons

Supports:

- Key Management
- Key Generation
- Key Import/Export
- Encrypt/Decrypt, and signing

The keys are stored in your profile. Only Firefox provides a strong encryption for password, but I am not sure if also for the whole profile.

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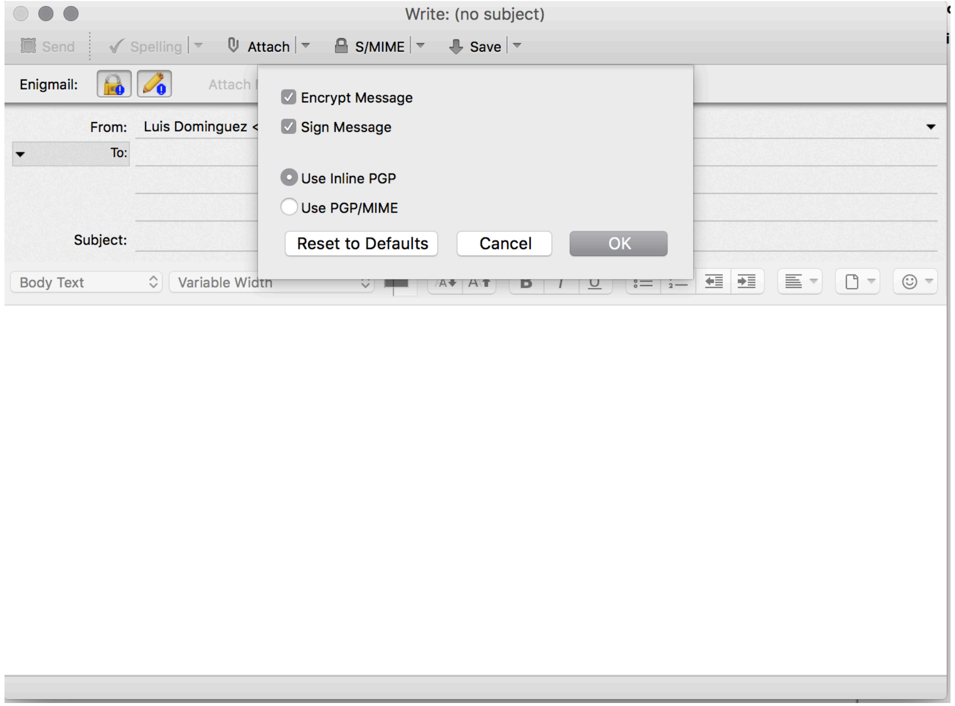
Multiplataform

- A cross platform solution is Enigmail, a plug-in for Thunderbird
- It connects to your GPG installation



Write: (no subject)

From: Luis Dominguez <

To:

Subject:

☑ Encrypt Message

☑ Sign Message

● Use Inline PGP

○ Use PGP/MIME

Reset to Defaults | Cancel | OK

Browsing

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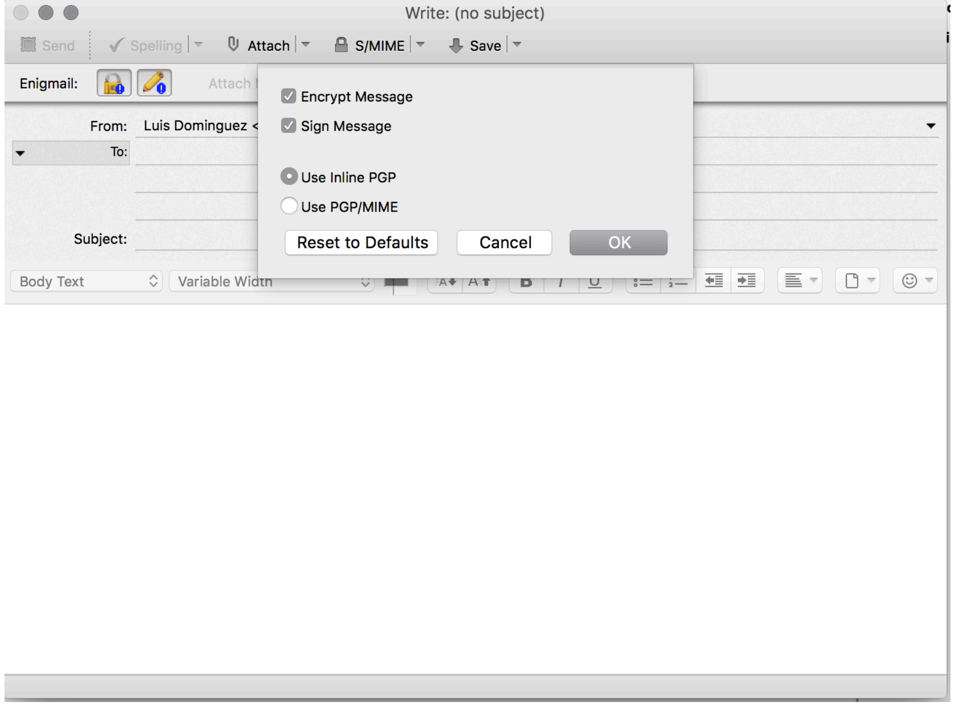

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Browsing

- Private mode browsing on most browsers:
  - No saving cookies
  - No tracking
  - No history
  - No new passwords
  - No cache
  - Yes you can save boo
  - Yes you can undo clo
  - Yes, everybody could browsing
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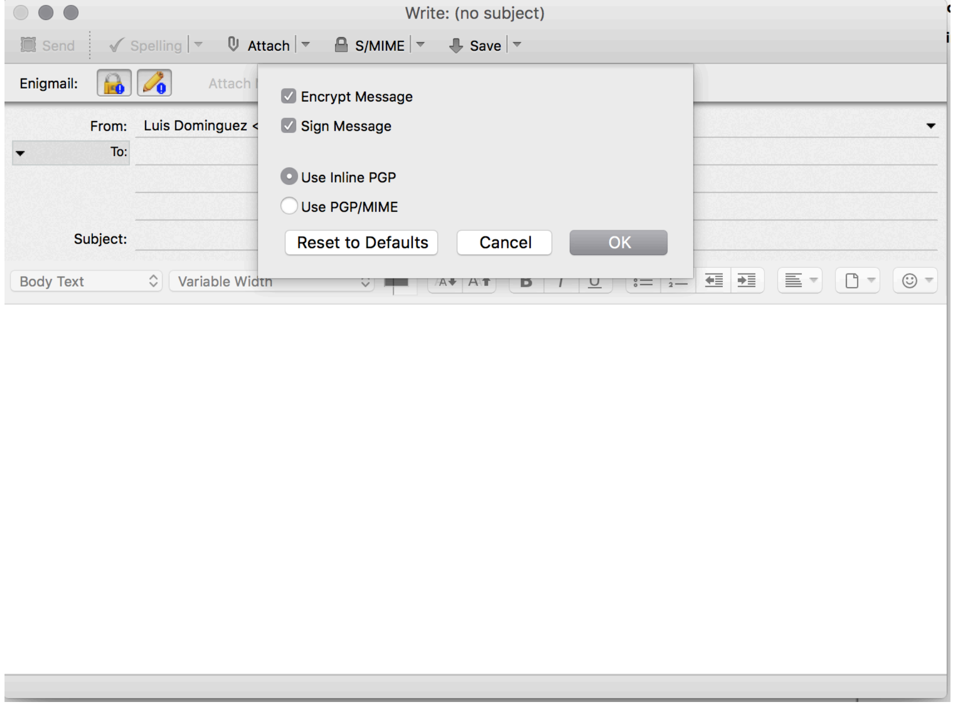
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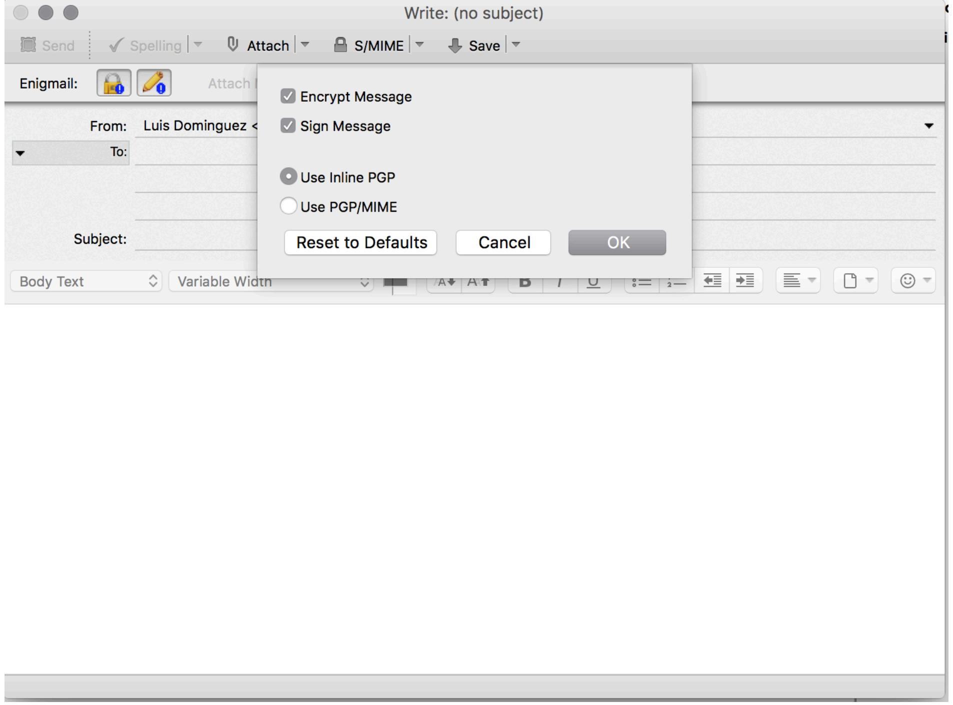

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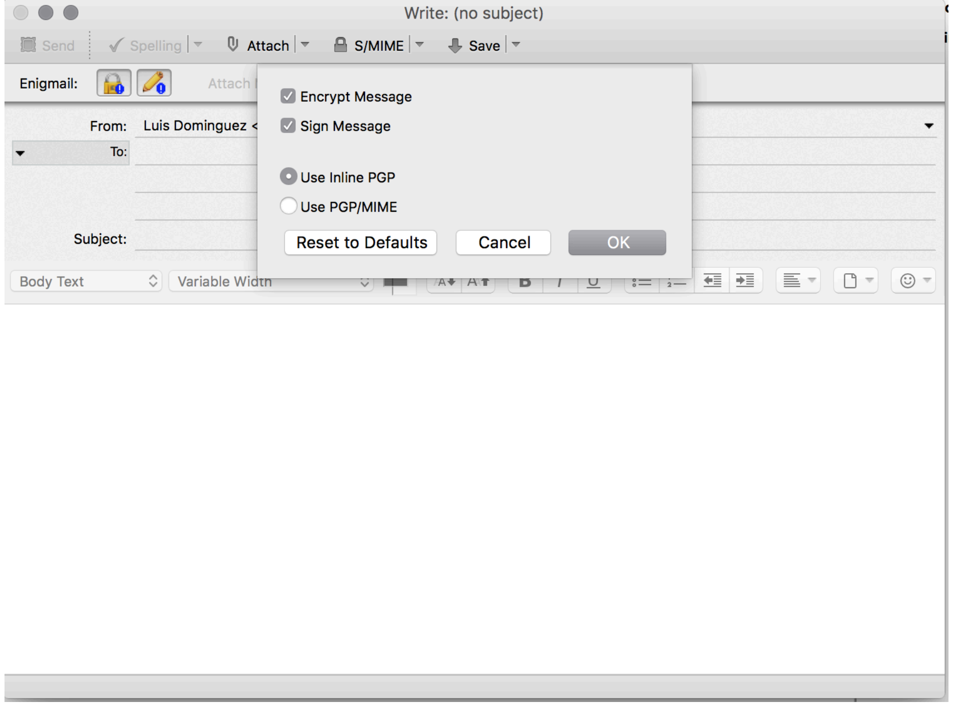

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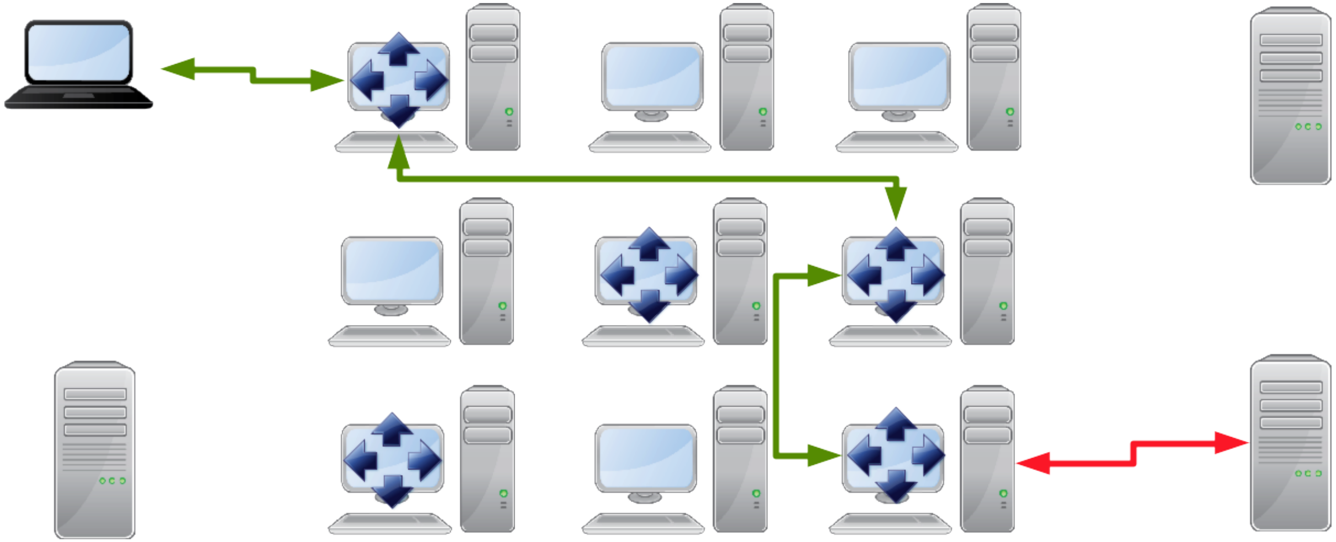
Tor network

"Tor is free software and an open network that helps you defend against traffic analysis, a form of network surveillance that threatens personal freedom and privacy, confidential business activities and relationships, and state security."

- It helps to anonymize your browsing experience from application providers
- Used by journalists, and people in general for free-speech
- Also used for illegal traffic, and terrorists
- Helps on testing network issues
- Military uses it for information gathering

Does not forbids you to leak your information (if you login into facebook, you are no longer anonymous)

Tor diagram



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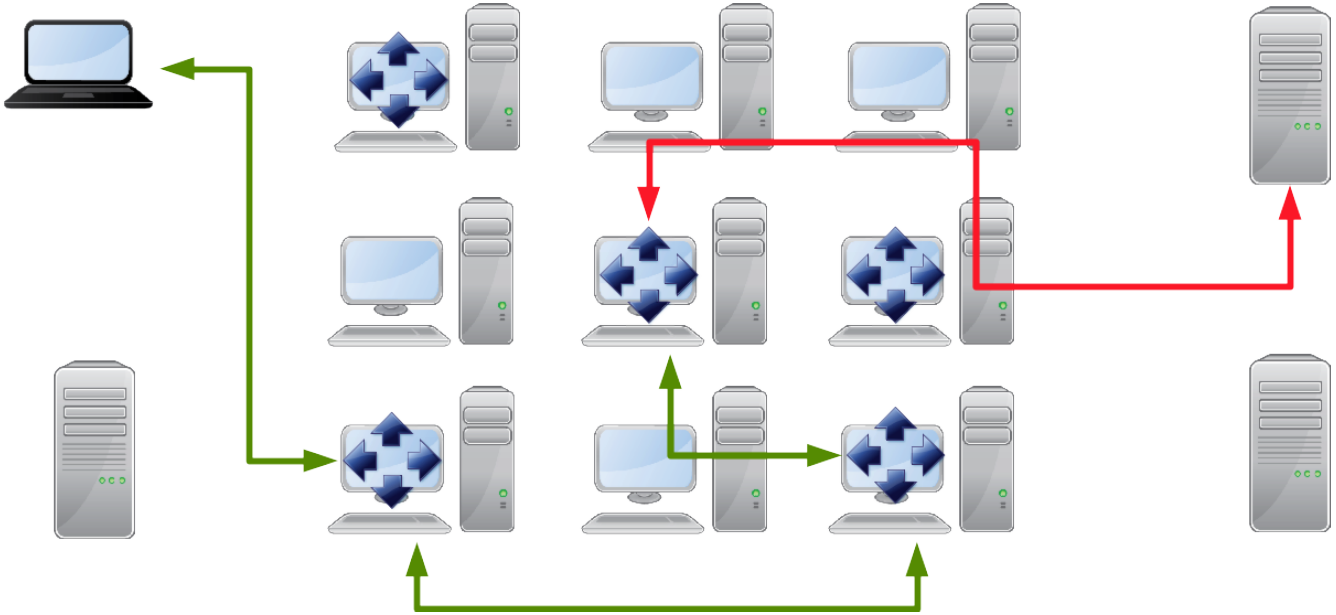

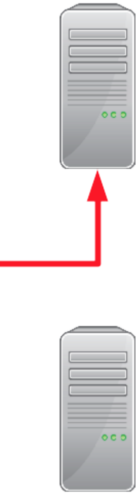

Chat

Instant message conversations are also susceptible to be read on the internet

For mobile, we have very few solutions:

- Telegram - multiplataform, uses “perfect forward secrecy” (100 times, or weekly) for its secure chat mode… but it’s an *in-house* protocol
- BBM using a BES uses Triple DES encryption, as it is the recommended standard in FIPS (they would change it accordingly)
- iMessage uses some sort of encryption, but it has a bad record… perhaps it uses AES-128 until you download your messages
- Another good alternative is Cryptocat, which also works on iPhone… they use OTR, with all the flashes

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“Understanding tools for a more secure internet” 2nd cyber-security week @ CIC-IPN.

Luis J. Dominguez Perez
CONACyT. CIMAT

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CONACYT

Centro de Investigación
en Computación
Instituto Politécnico Nacional

CIMAT