Secured Communication Protocols –Cryptographie et Sécurité des Communications–

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Telecommunications - INSA Lyon

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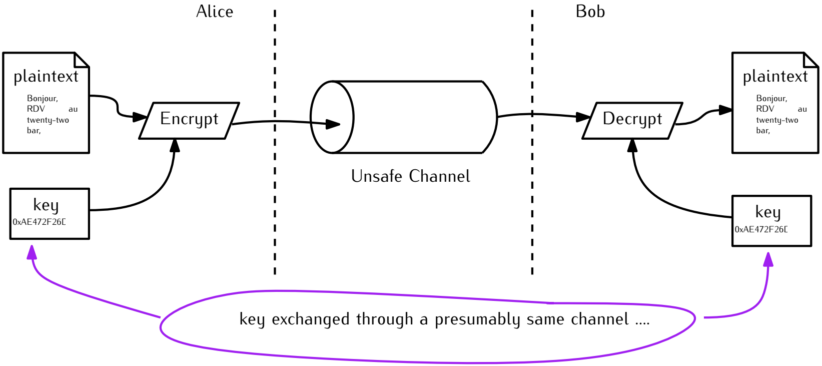
Symmetric Cryptography



- Encryption/Decryption is cheap
- State-of-the-Art: AES
- Limitation: requires a key-sharing mechanism

Diffie-Hellman Key Exchange

Alice

let's agree on :
p = 23 (prime)
and g = 5
(primitive root modulo 23)

Bob

Alice chooses a secret key P_A

Bob chooses a secret key P_B

$g^{P_A} \bmod p$

$g^{P_B} \bmod p$

Alice computes
$(g^{P_B} \bmod p)^{P_A} \bmod p$
$= g^{P_B P_A} \bmod p$

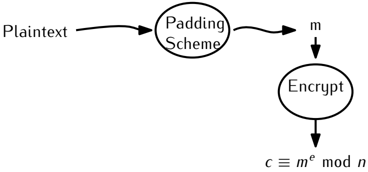
Bob computes
$(g^{P_A} \bmod p)^{P_B} \bmod p$
$= g^{P_A P_B} \bmod p$
$= g^{P_B P_A} \bmod p$

Alice and Bob now share a common key $g^{P_A P_B} \bmod p$

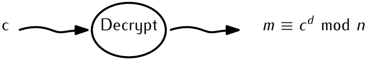
Asymmetric Cryptography

- Each participant builds a $(Pub_k, Priv_k)$ pair of keys

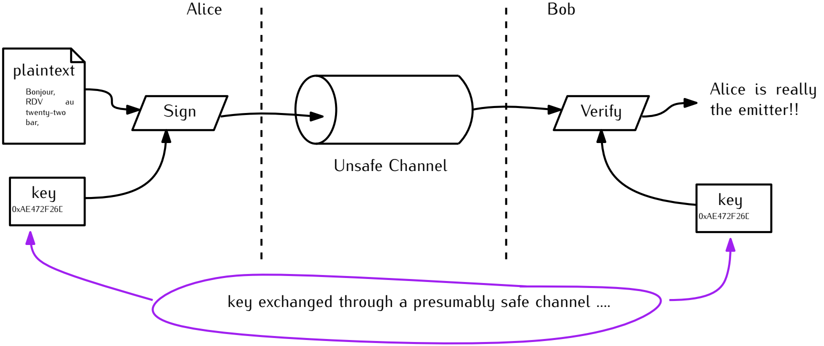
Encryption



Decryption



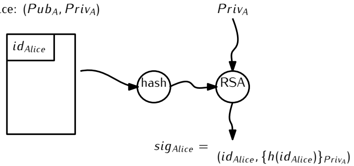
Message-Authentication-Codes (hashes)



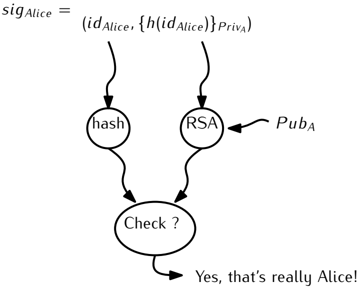
Self-signed Certificates

Sign

Alice: $(Pub_A, Priv_A)$



Verify



- Problem: Man-in-the-Middle

Man-in-the-Middle

- Bob and Alice want to communicate
- Bob $\longrightarrow \boxed{(B, Pub_B)} \longrightarrow$ Alice
- Hypothesis: Charlie can read and modify messages between Bob and Alice.
- Charlie falsifies Key definition of Bob:
  Bob $\longrightarrow \boxed{(B, Pub_B)} \longrightarrow$ Charlie $\longrightarrow \boxed{(B, Pub_C)} \longrightarrow$ Alice
  (he also keeps Pub_B for later)
- Now when Alice writes to Bob, she actually uses Charlie's public key
- Alice $\longrightarrow \boxed{\{m\}_{Pub_C}} \longrightarrow$ Bob
- Charlie can then eavesdrop all messages:
  Alice $\longrightarrow \boxed{\{m\}_{Pub_C}} \longrightarrow$ Charlie $\rightarrow \{\{m\}_{Pub_C}\}_{Priv_C} = m \longrightarrow$
  $\boxed{\{m\}_{Pub_B}} \longrightarrow$ Bob

Public-Key Infrastructure and Certificate Authorities

A PKI consists of:

- A **Certificate Authority** (CA) - stores, issues and signs digital certificates
- A **Registration Authority** (RA) - verifies identity of entities requesting their certificates to be stored at the CA.
- A **Central Directory** - secure location to store keys
- CAs are “Trusted Third Parties”

Certificate Authorities

A
$[Pub_A, Priv_A]$
Pub_C

Init State

- Each participant has its own set of pub/priv keys
- Everybody has C's public key

C (Certificate Authority) $[Pub_C, Priv_C]$

B (insa-lyon.fr)
$[Pub_B, Priv_B]$
Pub_C

Certificate Authorities

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[$Pub_A, Priv_A$]
Pub_C

Init State

- Each participant has its own set of pub/priv keys
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C (Certificate Authority) [$Pub_C, Priv_C$]

1. B registers itself to C:
 - (id_B, Pub_B)

B (insa-lyon.fr)
[$Pub_B, Priv_B$]
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Certificate Authorities

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$[Pub_A, Priv_A]$
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C (Certificate Authority) $[Pub_C, Priv_C]$
2. C computes:
  - $(id_B, Pub_B).\{h((id_B, Pub_B))\}_{Priv_C}$

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  - (id_B, Pub_B)

B (insa-lyon.fr)
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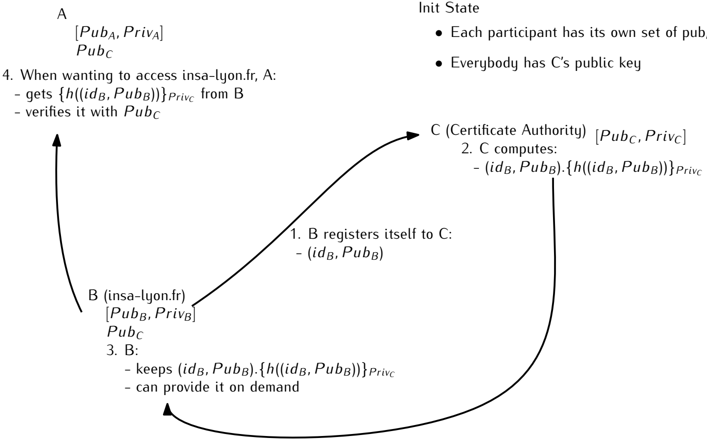
1. B registers itself to C:
   - (id_B, Pub_B)

B (insa-lyon.fr)
$[Pub_B, Priv_B]$
Pub_C
3. B:
   - keeps $(id_B, Pub_B).\{h((id_B, Pub_B))\}_{Priv_C}$
   - can provide it on demand

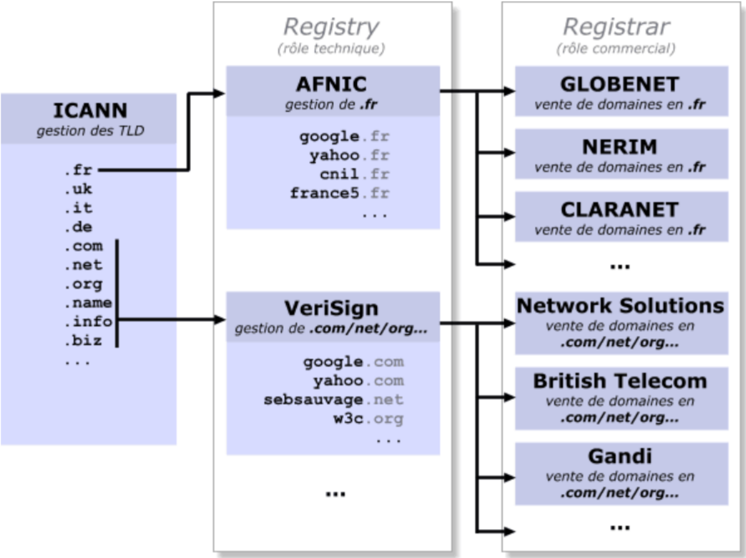
Certificate Authorities

Init State

- Each participant has its own set of pub/priv keys
- Everybody has C's public key



DNS

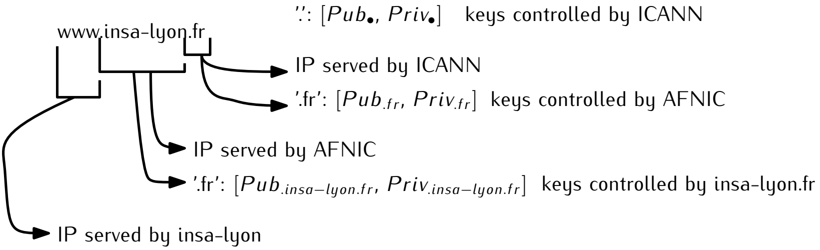


- The **ICANN** (Internet Corporation for Assigned Names and Numbers) manages a list of **Top-Level Domains**

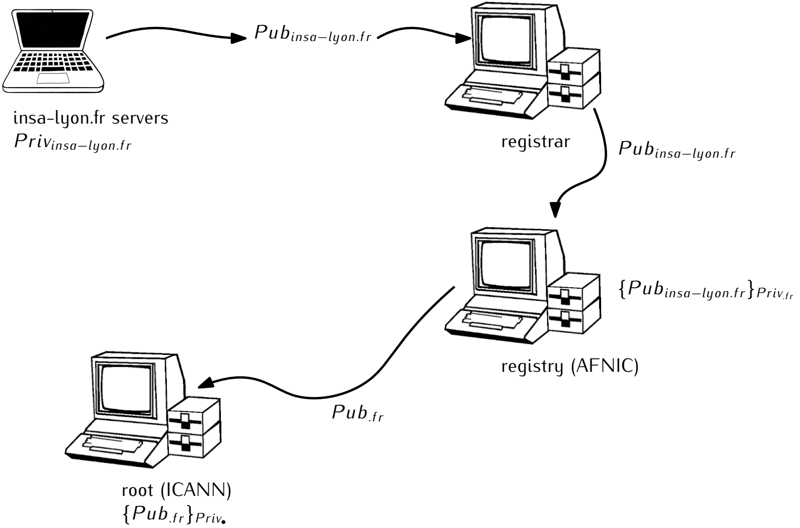
```
whois insa-lyon.fr
%%
%% This is the AFNIC Whois server.
%%
%% complete date format : YYYY-MM-DDThh:mm:ssZ
%% short date format    : DD/MM
%% version              : FRNIC-2.5
%%
%% Rights restricted by copyright.
%% See https://www.afnic.fr/en/products-and-services/services/whois/whois-special-notice/
%%
%% Use '-h' option to obtain more information about this service.
%%
%% [77.134.1.180 REQUEST] >> -V Md5.5.10 insa-lyon.fr
%%
%% RL Net [##########] - RL IP [#########.]
%%

domain:      insa-lyon.fr
status:      ACTIVE
hold:        NO
holder-c:    INSA12-FRNIC
admin-c:     SJ7971-FRNIC
tech-c:      GRST1-FRNIC
tech-c:      LM19215-FRNIC
tech-c:      TP630-FRNIC
zone-c:      NFC1-FRNIC
nsl-id:      NSL1519-FRNIC
registrar:   GIP RENATER
Expiry Date: 2022-12-31T23:00:00Z
created:     1994-12-31T23:00:00Z
last-update: 2021-12-31T23:36:35Z
source:      FRNIC
```

```
ns-list:     NSL1519-FRNIC
nserver:     dns.univ-lyon1.fr
nserver:     dns2.univ-lyon1.fr
source:      FRNIC

registrar:   GIP RENATER
type:        Isp Option 1
address:     Array
address:     75013 PARIS
country:     FR
phone:       +33 1 53 94 20 30
fax-no:      +33 1 53 94 20 31
e-mail:      domaine@renater.fr
website:     http://www.renater.fr
anonymous:   NO
registered:  1998-01-01T12:00:00Z
source:      FRNIC

nic-hdl:     INSA12-FRNIC
type:        ORGANIZATION
contact:     INSTITUT NAT SCIENCES APPLIQUEES LYON
address:     INSA LYON
address:     20, avenue Albert Einstein
address:     69621 Villeurbanne
country:     FR
phone:       +33 4 72 43 81 14
fax-no:      +33 4 72 43 85 00
e-mail:      webmaster@insa-lyon.fr
registrar:   GIP RENATER
changed:     2016-06-07T11:59:36Z nic@nic.fr
anonymous:   NO
obsoleted:   NO
eligstatus:  not identified
reachstatus: not identified
source:      FRNIC
```

DNSSEC key management (1)



DNSSEC key management (2)



TLS

- History:
  - SSL proposed in 1995 by Netscape (RIP)
  - TLS proposed by the IETF, starting 1999
  - Current version 1.3 (2018)
- TLS stands for Transport Layer Security
- It supersedes SSL
- Works on top of TCP/IP
- Application-independent, eg: HTTPs = HTTP+TLS, IMAPS = IMAP+TLS

TLS (cont'd)

Confidentiality

- Exchanged data is encrypted using **Symmetric-key cryptography**
- Encryption keys are re-newed for every session, ie TLS uses **session keys**

Authenticity

- Identity of communicating parties is authenticated using **Public-key cryptography**

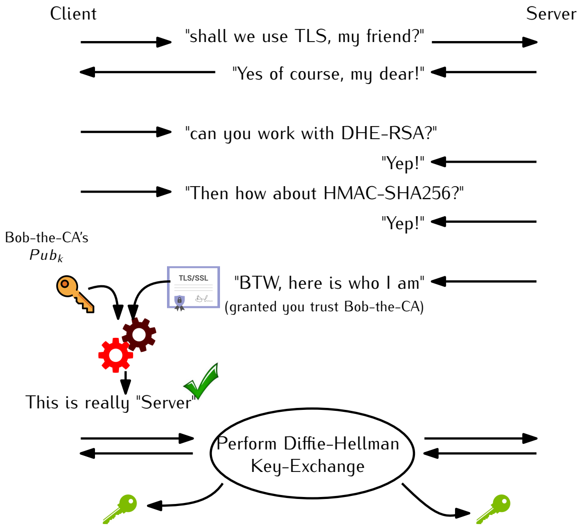
Integrity

- Each message includes a **Message Authentication Code** to prevent alteration

TLS (cont'd)

- Client and server **agree to use TLS**
- They perform a **handshake procedure** together (see next)
- Out of this handshake, they get (secret) encryption keys they can then use to perform **symmetric encryption**

TLS handshake

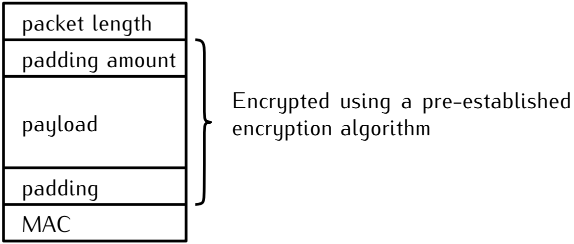


SSH

- SSH stands for Secured Shell
- Provides a way to connect (shell) to a distant computer while encrypting all data exchanged
- Before SSH:
  - data was sent unencrypted over the network
  - not so bad as internet was not there :)
- 1995: Tatu Ylönen proposed a secured version of a remote shell

Sending Data Through SSH

- Consider a TCP connexion between 2 machines
- SSH breaks data into a series of packets



Algorithms available

- EdDSA, ECDSA, RSA and DSA for public-key cryptography.
- ECDH and Diffie–Hellman for key exchange.
- HMAC, AEAD and UMAC for MAC.
- AES (and deprecated RC4, 3DES, DES[29]) for symmetric encryption.
- AES-GCM] and ChaCha20-Poly1305 for AEAD encryption.
- SHA (and deprecated MD5) for key fingerprint.

SSH properties

- Channel multiplexing: You can open a number of different channels to send different data to/from different partners
- Tunneling: on can redirect a (eg) TCP flow into an ssh tunnel
- Distant shell
- File transfer
- Port redirection

SSH Authentication

Client-side

- password
- public/private key

Server-side

- at 1st connection, server stores client's key footprint
- for follow-up connection, server checks footprint
- if key is invalid: connection refused

NB

No guarantee on 1st connection $\Longrightarrow$ "*opportunistic security*"

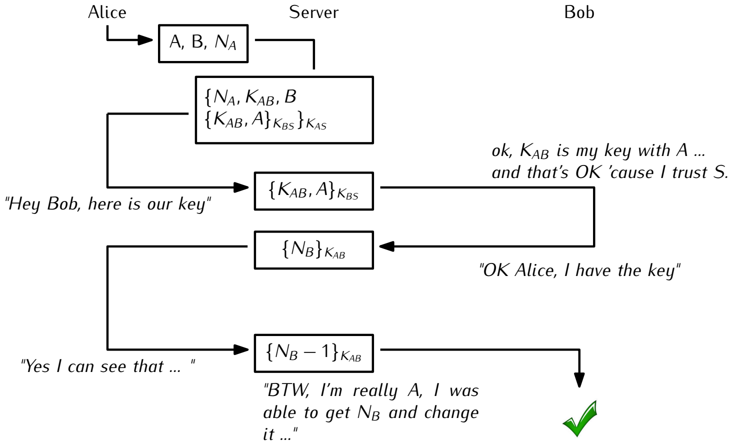
OpenSSH

OpenSSH is a software suite that includes command-line utilities and daemons:

- `scp` (replacement for `rcp`) to copy files through encryted channel
- `sftp`, replacement for `ftp`
- `ssh` itself
- `ssh-agent` to hold keys and ease authentication
- `ssh-keygen` to generate RSA, DSA or elliptic-curve keys
- `sshd` the ssh server daemon

Needham-Schroeder Symmetric Protocol (1978)

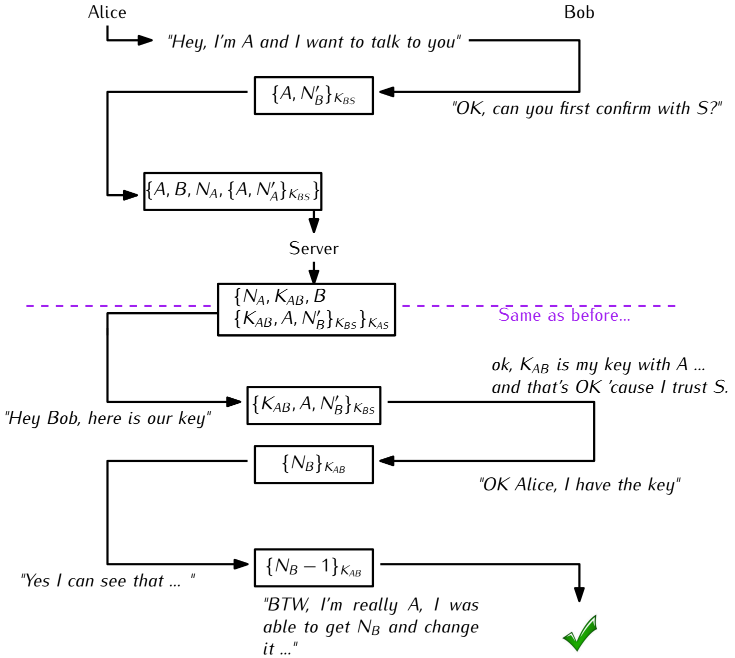
- A and B want to talk
- A (resp B) has a private key with server S, k_{AS} (resp k_{BS})



NB: Vulnerable to replay attack:

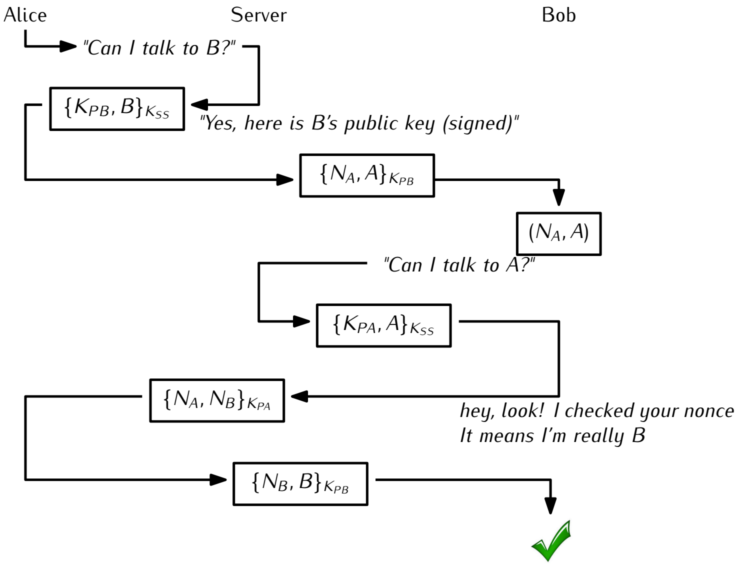
- Charlie gets an old compromised key K_{AB} and pretends to be A by sending $\{K_{AB}, A\}_{K_{BS}}$ to B

Needham-Schroeder: fixing the Replay Attack



Needham-Schroeder Public-Key (Asymetric) Protocol

A: (k_{PA}, k_{SA}) B: (k_{PB}, k_{SB}) S: (k_{PS}, k_{SS})



Kerberos

- Active Directory's main authentication protocol
- No public key (symmetric keys only)
- How to share keys ?
  - No key exchange protocol (eg Diffie-Hellman)
  - No certificate verification
- Idea: Use passwords and long-term keys to derive symmetric session keys
- Trust a server to provide session keys
- The connection with the server relies on pre-established long-term keys

Kerberos architecture (1)

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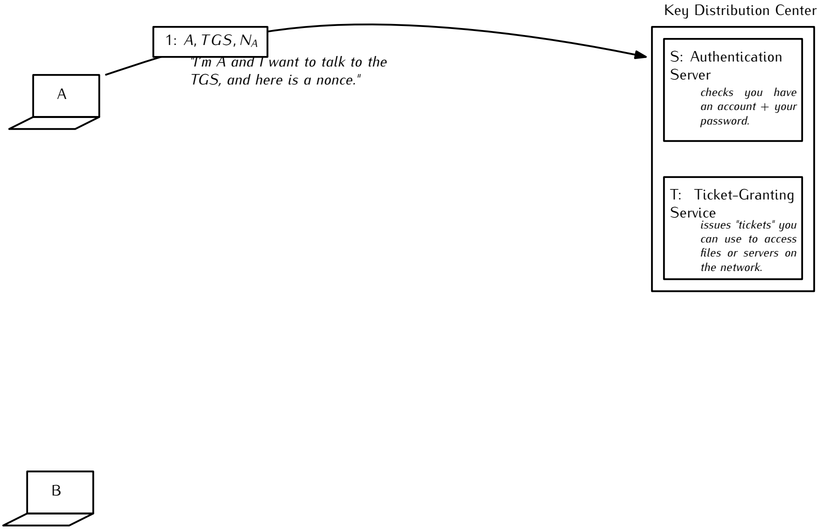

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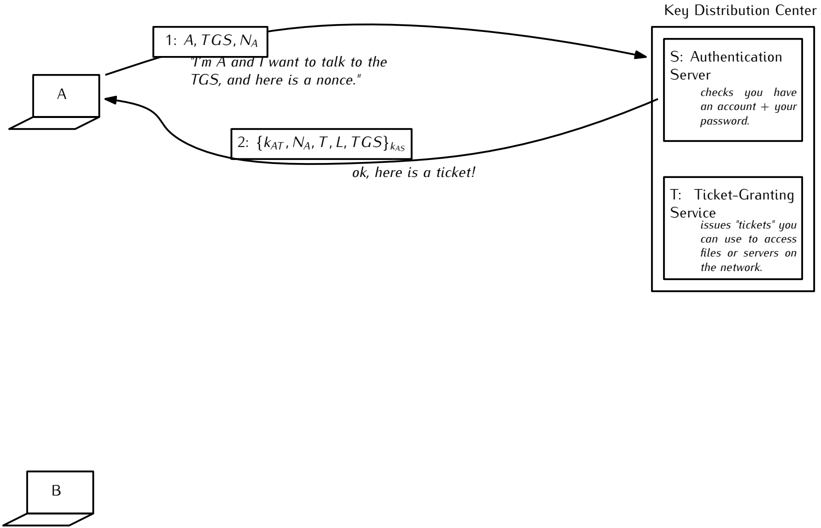

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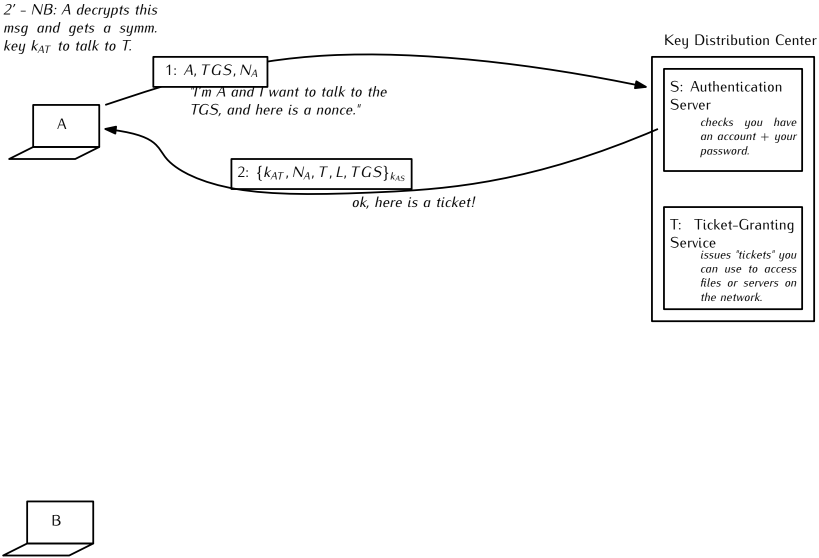

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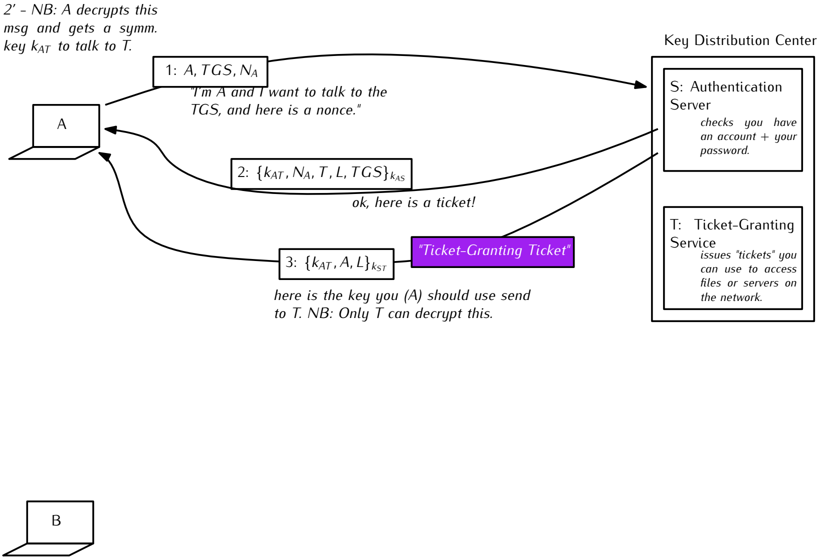

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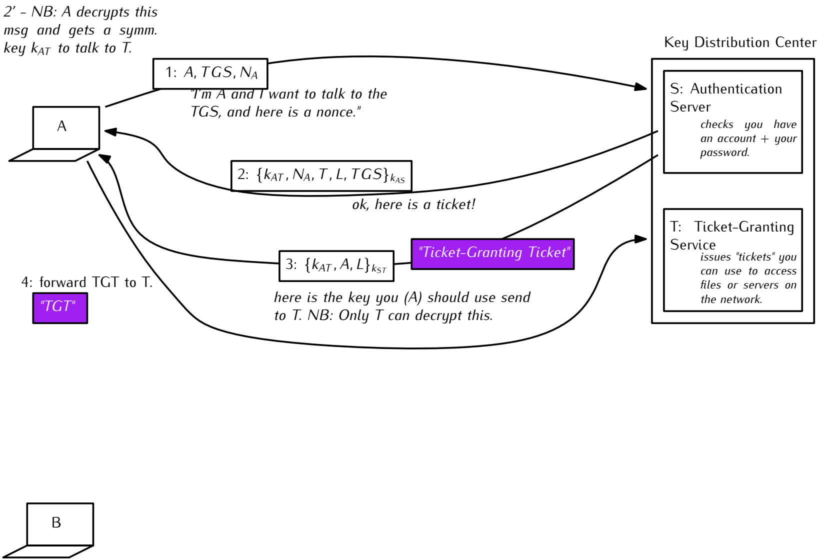
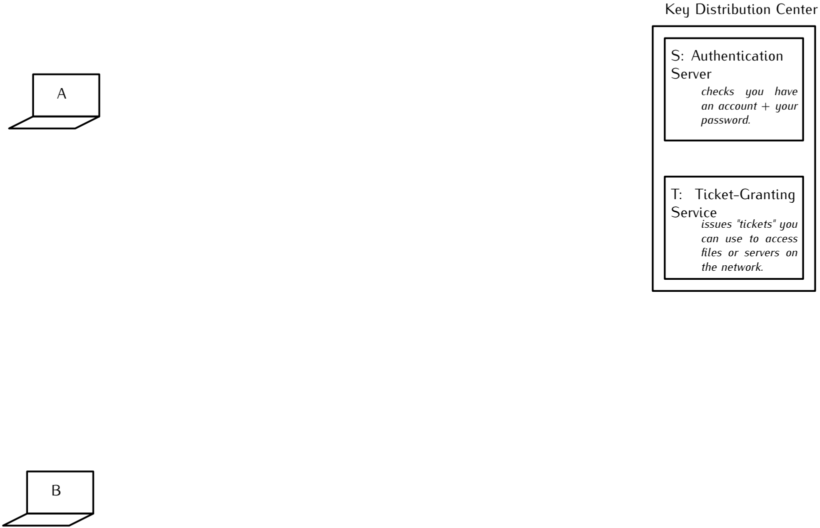


Kerberos architecture (2)



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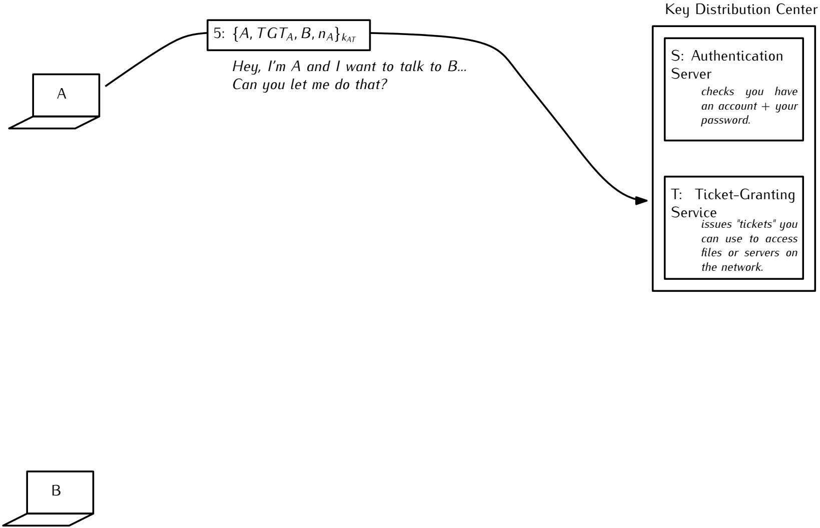

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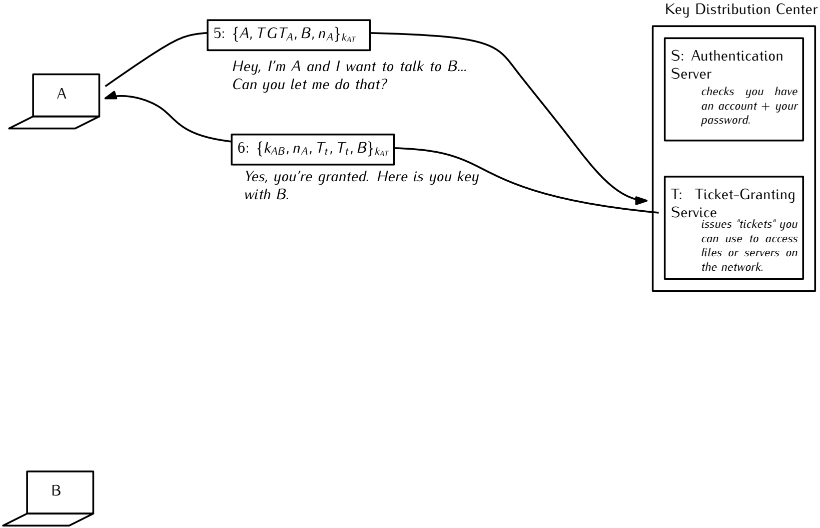

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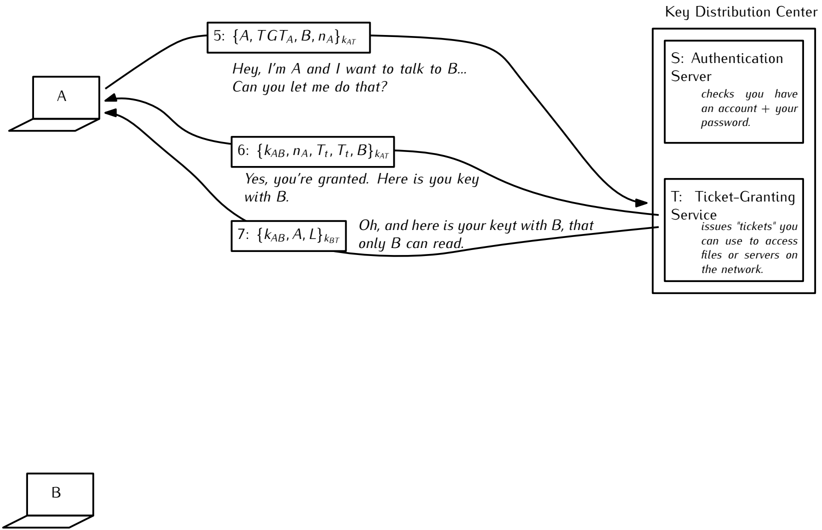

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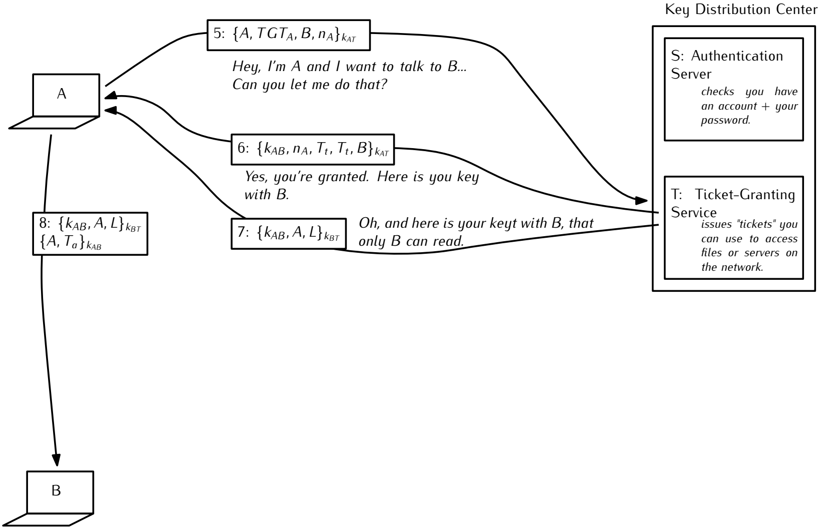

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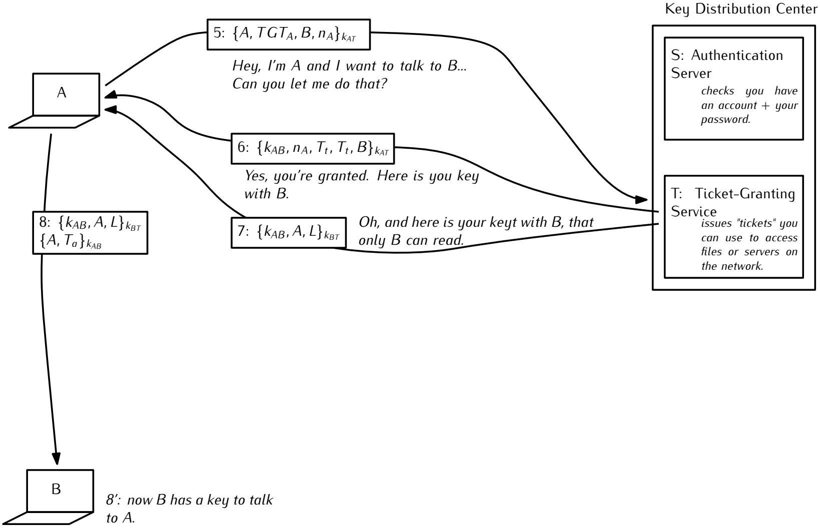

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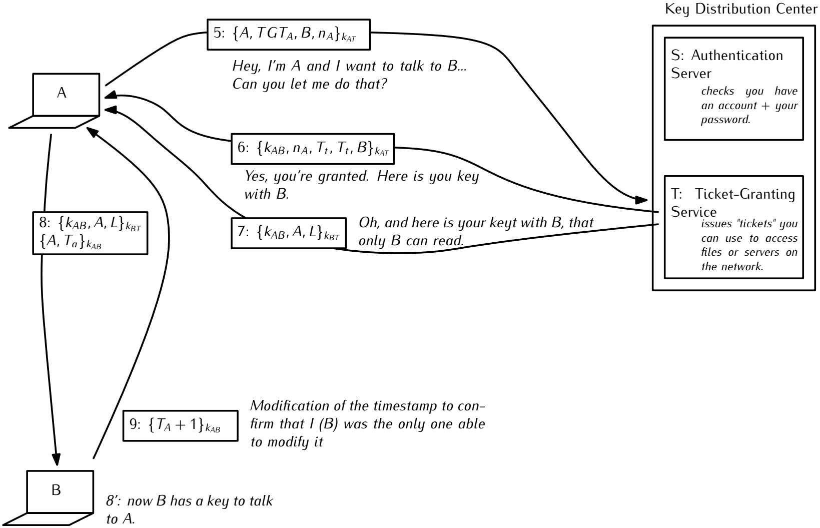


Conclusion (1/2)

- Today, cryptography is ahead of (civilian) cryptanalysis: that has not always been the case (and may not be the case in the future)
- Cryptography is a complex world
- It's based on math!
- The security of cryptographic algorithms relies on a great number of implementation details
- Cryptography is useful only if used ...
  - correctly
  - wisely

Conclusion (2/2)

Your living minimum is to:

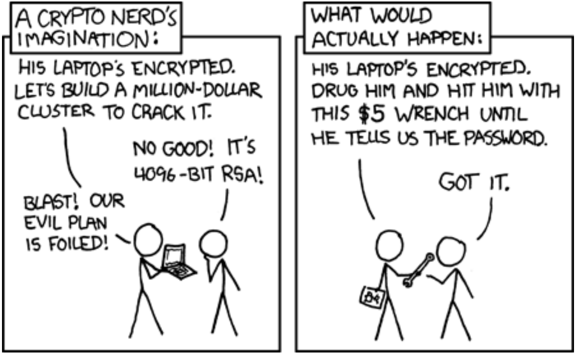
- Know what cryptography can and cannot do for you
- Know when cryptography is adequate
- Use known libraries (eg OpenSSL) and not your own home-made reimplementations

Key management is the crux

- Without the correct key, cryptography is useless!
- With the correct key, cryptography only garanties the security of the connexion (not outsiders' truthfulness). . .)

- The whole security of internet relies on encryption keys
- Good, that was the goal
- But key management is still a major issue

In practice. . .



http://xkcd.com/538/