Electronic mail security

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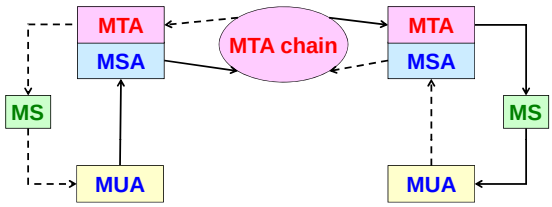
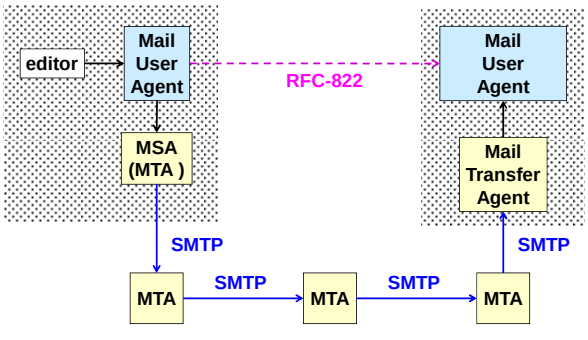
MHS (Message Handling System)

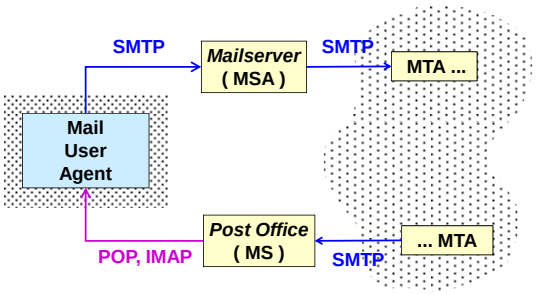


- MUA (Message User Agent)
- MSA (Message Submission Agent)
- MTA (Message Transfer Agent)
- MS (Message Store)

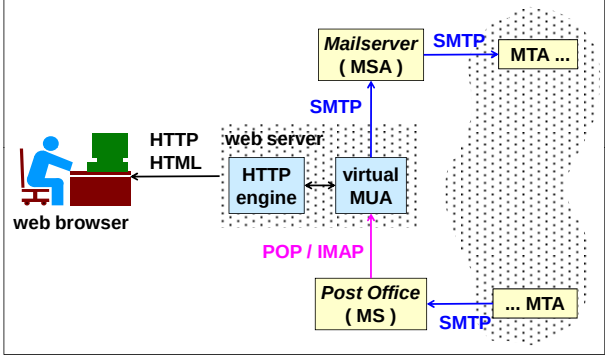
E-mail on multi-user systems



E-mail in client-server mode



Webmail



Protocols and ports

- **SMTP (Simple Mail Transfer Protocol)**
  - 25/tcp (MTA)
  - 587/tcp (MSA)
- **POP (Post Office Protocol)**
  - 110/tcp
- **IMAP (Internet Message Access Protocol)**
  - 143/tcp

RFC-822 messages

- **only US-ASCII characters on 7 bits**
- **lines terminated by <CR> <LF>**
- **messages composed by header + body**
- **header**
  - keywords at the beginning of the line
  - continuation lines start with a space
- **body**
  - separated from the header by an empty line
  - contains the message

Header RFC-822

From:	**sender (logical)**
Sender:	**sender (operational)**
Organization:	**organization of the sender**
To:	**destination**
Subject:	**subject**
Date:	**date and hour of sending**
Received:	**intermediate steps**
Message-Id:	**sending ID**
CC:	**copy to**
Bcc:	**copy (hidden) to**
Return-Receipt-To:	**return receipt to**

An SMTP / RFC-822 example

telnet duke.colorado.edu 25
  Trying .....
  Connected to duke.colorado.edu
  Escape character is '^]'
  220 duke.colorado.edu ...
HELO leonardo.polito.it
  250 Hello leonardo.polito.it ... Nice to meet you!
MAIL FROM: cat
  250 cat ... Sender ok
RCPT TO: franz
  250 franz ... Recipient ok
DATA
  354 Enter mail, end with "." on a line by itself

From: cat@athena.polito.it (Antonio Lioy)
To: franz@duke.colorado.edu
Subject: vacation

Hello Francesco,
I renew my invitation to come to my place during your vacation in Italy. Let me know when you arrive.

Antonio

.
250 Ok
QUIT
221 duke.colorado.edu closing connection
connection closed by foreign host

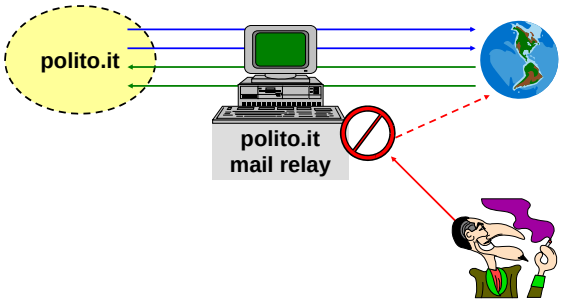
Problems in securing e-mail

- **connectionless system (store-and-forward, also because of MX records)**
- **MTA not trusted**
- **security of MS**
- **mailing-list**
- **compatibility with what is already installed**
- **concurrent solutions:**
  - Internet = PGP, PEM, MOSS, S/MIME
  - OSI = X.400

Mail spamming

- **also named UBE (Unsolicited Bulk Email)**
- **sending of unauthorised advertising (publicitary) messages**
- **common habits:**
  - hide the real sender
  - delegate the work to do to an MTA that operates as an “open mail relay”, that is one that accepts mail also from / to other users (not from his domain)
- **heavy load on the servers and on the communication channels**
- **(usually) bothers the users**
- **risk to end up in ORB, RBL or similar**

Mail relay



How to fight spamming

- **do not configure your own MTA as an "open relay" but restrict its use only to authorized users**
- **authentication strategies:**
  - IP address of the MUA
    - problem with the mobile users and IP spoofing
  - value of the field From
    - can be easily tricked with a fake mail
  - SMTP authentication
    - secure authentication?
    - SMTP on SSL with client authentication

Anti-spamming initiatives

- **MAPS (Mail Abuse Prevention System)**
  - http://maps.vix.org/
  - RBL (Realtime Blackhole List)
  - RSS (Relay Spam Stopper)
- **not easy to be removed once you've been inserted in such a system: it becomes a 'MUST' to configure correctly your own MTA**
- **activate/use the address abuse@domain, as required by RFC-2142**

ESMTP

- **Extended SMTP, defined in RFC-1869 and subsequently incorporated (wirh SMTP) in RFC-2821**
- **the base protocol and the communication channel is the same**
- **the ESMTP clients must identify themselves to the communicating parties with:**
  EHLO *hostname*
- **if the receiving server speaks ESMTP, it must declare the extensions that it supports, one per line, in its response to EHLO**

Standard ESMTP extensions

- **8BITMIME**
  - (RFC-1652) indicates that in the DATA part 8-bit characters are accepted and not mangled
- **SIZE dimension**
  MAIL FROM: address SIZE=dimension
  - (RFC-1870) declares the maximum dimension accepted by the server or the dimension of the message to be sent
- **PIPELINING**
  - (RFC-1854) sending several commands with no need to wait for the response to each one (exception: those that provoke a status change)

DSN extension (Delivery Status Notification)

- **extends the RCPT command with:**
  - **NOTIFY=*notify-list***
    possible values:
    NEVER, SUCCESS, FAILURE, DELAY
  - **ORCPT=*original-recipient***
    specifies the original recipient
- **extends the MAIL command with:**
  - **RET=*returned-message***
    possible values: FULL, HDRS
  - **ENVID=*sender-id***
    identifier created by the sender

Positive ESMTP examples

- **ESMTP mailer without extensions:**

```
   220 mail.polito.it - SMTP service ready
EHLO mailer.x.com
   250 Hello mailer.x.com - nice to meet you!
```

- **ESMTP mailer with extensions:**

```
   220 mail.polito.it - SMTP service ready
EHLO mailer.x.com
   250-Hello mailer.x.com - nice to meet you!
   250-EXPN
   250 8BITMIME
```

Negative ESMTP example

- **the mailer does not know the ESMTP protocol:**

```
   220 mail.polito.it - SMTP service ready
EHLO mailer.x.com
   500 Command not recognized: EHLO
```

SMTP-Auth

- **extension of ESMTP defined in RFC-4954**
- **command AUTH + options of MAIL FROM**
- **to authenticate a client …**
- **… before accepting messages from it!!!**
- **useful against spamming:**
  - after the EHLO command the server sends the authentication mechanisms supported
  - the client chooses one
  - the authentication protocol is executed
  - if the authentication fails, the communication channel is closed

Negative AUTH example

- **the mailer does not know (or does not accept) the authentication method proposed by the client:**

```
    220 example.polito.it - SMTP service ready
EHLO mailer.x.com
    250-example.polito.it
    250 AUTH LOGIN CRAM-MD5 DIGEST-MD5
AUTH PLAIN
    504 Unrecognized authentication type
```

AUTH: LOGIN method

```
    220 example.polito.it - SMTP service ready
EHLO mailer.x.com
    250-example.polito.it
    250 AUTH LOGIN CRAM-MD5 DIGEST-MD5
AUTH LOGIN
    334 VXNlcm5hbWU6 ---------> Username:
bGlveQ== ---------> lioy
    334 UGFzc3dvcmQ6 ---------> Password:
YW50b25pbw== ---------> antonio
    235 authenticated
```

AUTH: PLAIN method

- **syntax (RFC-2595):**
  AUTH PLAIN *id_pwd*$_{BASE64}$
- **id_pwd is defined as:**
  [authorize_id] \0 authentication_id \0 pwd

```
    220 example.polito.it - SMTP service ready
EHLO mailer.x.com
    250-example.polito.it
    250 AUTH LOGIN PLAIN
AUTH PLAIN bGlveQBsaW95AGFudG9uaW8=
    235 authenticated ---------> lioy \0 lioy \0 antonio
```

MAIL FROM with authentication

- the optional parameter AUTH of MAIL FROM indicates who sends the message
- it is used < > to indicate an unknown identity or not sufficiently authenticated
- allows to communicate the identity of the sender among cooperating MTA in a trusted environment
- each MTA must propagate the identity when sending (forwarding) the message
- possible use for authorisation policies

MAIL FROM with authentication: example

```
    220 example.polito.it - SMTP service ready
EHLO mailer.x.com
    250-example.polito.it
    250 8BITMIME
MAIL FROM:<rettore@polito.it> AUTH=profumo
    250 OK
```

Protection of SMTP with TLS

- RFC-2487 “SMTP Service Extension for Secure SMTP over TLS”
- STARTTLS = option of EHLO and command
- if the negotiation is succesful, the protocol status is reset (starts again from EHLO and the extensions supported can be different)
- if the negotiated security level is insufficient:
  - the client sends immediately QUIT and closes the connection
  - the server responds to each command with code 554 (refused due to low security)

Protection of SMTP with TLS: example

```
    220 example.polito.it - SMTP service ready
EHLO mailer.x.com
    250-example.polito.it
    250-8BITMIME
    250-STARTTLS
    250 DSN
STARTTLS
    220 Go ahead
... TLS negotiation is started between client and server
```

Security services for e-mail messages

- **integrity (without direct communication):**
  - the message cannot be modified
- **authentication**
  - identifies the sender
- **non repudiation**
  - the sender cannot deny of having sent the mail
- **confidentiality (optional):**
  - messages are not readable both in transit and when stored in the mailbox

E-mail security – main ideas (I)

- **no modification to the present MTA**
  - messages encoded to avoid problems when passing through gateways (e.g Internet-Notes) or MTA non 8BITMIME
- **no modification to the present UA**
  - inconvenient user interface
- **with modification to the present UA**
  - better user interface

E-mail security – main ideas (II)

- **symmetric algorithms**
  - for the encryption of messages
  - with message key
- **asymmetric algorithms**
  - to encrypt and exchange the symmetric key
  - for digital signature
- **use public key certificates (e.g. X.509) for non-repudiation**
- **the message security is based only on the security of the UA of the recipient, not on the security of MTA (not trusted)**

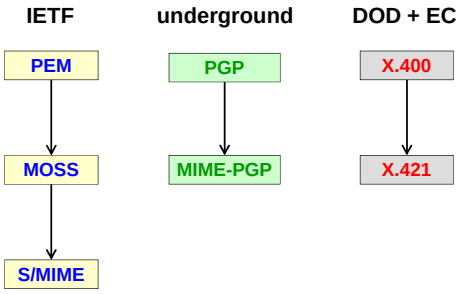
Types of secure messages

- **clear-signed**
  - msg in clear (so that anybody is able to read it) + digital signature
  - only who has a secure MUA can verify the signature
- **signed**
  - [msg + dsig] encoded (e.g. base64, uuencode)
  - only who has a secure MUA (or performs operations manually) can decode and verify the signature
- **encrypted / enveloped**
  - [encrypted msg + encrypted keys] encoded
  - only who has a secure MUA (and the keys!) can decrypt the message
- **signed and enveloped**

Secure messages: creation

- **transform in canonical form**
  - standard format, independent from OS / host / net
- **MIC (Message Integrity Code)**
  - integrity and authentication
  - typically: msg + { h(msg) } Kpri_sender
- **encryption**
  - confidentiality
  - typically: { msg } K_M + { K_M } Kpub_receiver
- **encoding**
  - to avoid modification by the MTA
  - typically: base64, uuencode, binhex

Secure electronic mail formats



PGP (Pretty Good Privacy)

- authentication, integrity and confidentiality for electronic mail or private files
- same objectives as PEM and similar structure but less structured
- peculiar way of public-key certification (trusted "friends" and trust propagation algebra)
- RFC:
  - RFC-1991 (informational)
  - RFC-4880 (OpenPGP)
- versions for UNIX, VMS, MS-DOS, Mac, Amiga, ...
- the author (Phil Zimmerman) and the program have become a symbol of the freedom in Internet

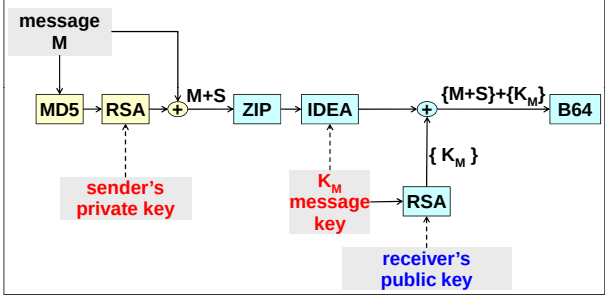
Phil Zimmermann

- releases PGP as freeware in 1991
- jailed, released on bail and investigated until 1996, when accusations are dropped and he creates PGP Inc. later acquired by NAI
- august 2002 leaves NAI and creates PGP Co.

PGP - algorithms (until v. 2.6)

- **fixed**
- **symmetric encryption:**
  - IDEA
- **digest:**
  - MD5
- **asymmetric encryption (for digital signature and symmetric key exchange):**
  - RSA
- **all free of charge for non-commercial purposes**

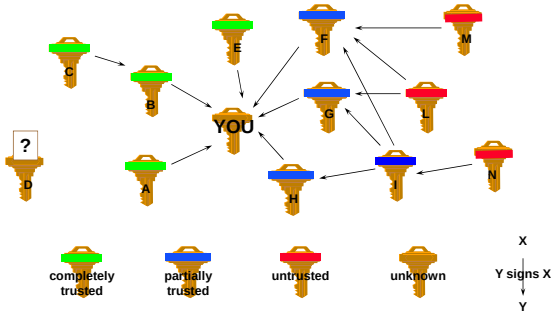
PGP 2.6 example: signature + encryption



PGP - certification

- **each certificate has several signatures (those of all persons that trust the key owner)**
- **trust is propagated transitively with some approximation:**
  - *completely*
  - *partially*
  - *untrusted*
  - *unknown*

PGP web of trust



PGP – key distribution

- **public-keys stored individually by each user (in its *key-ring*)**
- **keys distributed directly by the owner (at a PGP party!) or by a key-server (http, smtp, finger)**
- **projects for key distribution via X.500 or DNS (pgp.net):**
  - www.pgp.net
  - keys.pgp.net
  - ftp.pgp.net

PGP & NAI

- **rights of PGP acquired in december 1997 by NAI (Network Associates Inc.)**
- **new version, based on DSA, DH, 3DES**
- **integration with several MUAs**
- **attempted penetration of the corporate market:**
  - pseudo-CA (=super-signer)
  - acceptation of the X.509 format (sep'98)
- **august 2002: rights given to PGP Co.**

Gnu Privacy Guard (GPG)

- PGP is no more freeware (!) and it doesn't exist any more for Linux (!!) but only for Windows (!!!)
- GPG = PGP rewriting under GPL licence and without any patented algorithm
- interoperable with PGP 2.x (with some problems) and with OpenPGP (RFC-2440)
- DSA, RSA, AES, 3DES, Blowfish, Twofish, CAST5, MD5, SHA-1, RIPEMD-160 e TIGER
- several graphical front-ends
- for Linux, FreeBSD, OpenBSD, Windows (95/98/NT/2000/ME), ...

PGP – encrypted message

```
-----BEGIN PGP MESSAGE-----
Version: 2.6.1

hIwDpHi4wHwVW/0BA/9oop5thKhbkVXxf1nILrk5X1sUD/L7WsfCBuQQqCLAufgW
Cidy90kGO/zGKvrcPCK+CHQQqxxCbJDscFsmuQVArewaNIyxAvqVvNqOiVkhtc5Q
NjL5VN/J9PosNcwKBah3u7vtamse1EMLtVVZxAr+rc7NJcvdG8XTbRQ1ihCpuaYA
AADLVcTPRT1fpHVhO0zZn4kTpwjAty2sSpGh5hR8X8PTmWZvqjhS9joMHHTz5Esh
SJQXn1HHZn8NdtHPJ4BGgVJ0FoTKpbe9zFrburR7gVBNiaAu2s1q05VXmeKgE7NW
Lc74S0PHfSavpAbpHg+0dZDL6Pk9w0kVNlTbovWbjr6zuSb4Ga8Q27w9w3hF0bLX
0B0EpCy6vbOihr8OxVtO3KpRseshaCUs6LMd7kAaO5mjT+7JaqwH7U3GeKCAAa+z
I0bpLA/muWBOEtEUh9g=
=7T85
-----END PGP MESSAGE-----
```

PGP – authenticated message

```
-----BEGIN PGP SIGNED MESSAGE-----

Text of the message

-----BEGIN PGP SIGNATURE-----
Version: 2.6.1

iQCVAwUBLuAyudzgsuo2HSCtAQESeAQAkUReUyhlAsRFktzjgIOtCogCFl6/elbM
+20a71qpZWBoRviELK9sF7BQoQ3Moa35T18EeZtIHskj89mvDAAeuW3wzUcid5Hz
ZiQ7vjKWqWb2lWgZ9oNbMyNMoDA+jMSCr8H0p9NguQPnNK4Lo+Gn251dBhsh4ISy
vCzBoK7FLVM=
=7RAd
-----END PGP SIGNATURE-----
```

Security of multimedia electronic mail

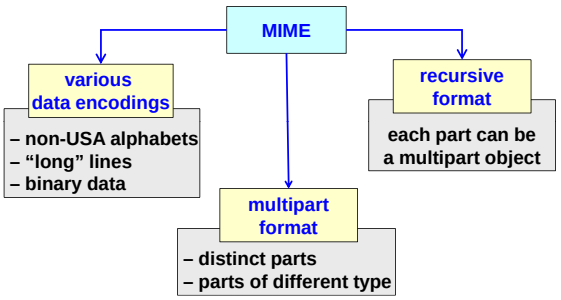
MOSS (MIME Objects Security Services)
- standard Internet
- RFC-1847/1848

S/MIME (Secure MIME)
- standard de-facto
- RSA

MIME-PGP
- RFC-2015 (PGP), RFC-3156 (OpenPGP)

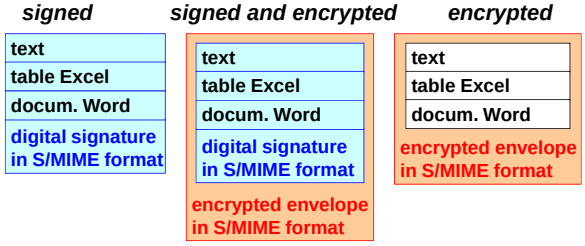
X.421
- multimedia extension of X.400

MIME (Multipurpose Internet Mail Extensions)



Secure multimedia electronic mail (MOSS o S-MIME)

- digital signature/encryption with X.509 certificates
- protection of MIME messages



RFC-1847

- **MIME extensions for message security**
- **for digital signature:**
  Content-Type: multipart/signed;
  protocol="TYPE/STYPE";
  micalg="...";
  boundary="..."
- **with N body parts:**
  - the first N-1 ones are those to be protected (content-type: ...)
  - the last one contains the digital signature (content-type: TYPE/STYPE)

RFC-1847

- **for the confidentiality:**
  Content-Type: multipart/encrypted;
  protocol="TYPE/STYPE";
  boundary="..."
- **with two body parts:**
  - the key (Content-Type: TYPE/STYPE)
  - the encrypted message (Content-Type: application/octet-stream)

S/MIME

- **security of MIME messages**
- **promoted by RSA**
- **v2 published as a series of informational RFC:**
  - RFC-2311 “S/MIME v2 message specification”
  - RFC-2312 “S/MIME v2 certificate handling”
  - RFC-2313 “PKCS-1: RSA encryption v.1-5”
  - RFC-2314 “PKCS-10: certification request syntax v.1-5”
  - RFC-2315 “PKCS-7: cryptographic message syntax v.1-5”

S/MIMEv3

- **proposed standard IETF**
- **RFC-2633**
  "S/MIME v3 message specification"
- **RFC-2632**
  "S/MIME v3 certificate handling"
- **RFC-2634**
  "Enhanced Security Services for S/MIME"
- **RFC-2314 "PKCS-10: certification request syntax v.1-5"**
- **RFC-2630**
  "CMS (Cryptographic Message Syntax)"

RFC-2634

- **Enhanced Security Services for S/MIME**
- **addresses the following subjects:**
  - signature on the return receipt of a mail
  - security labels
  - secure mailing-list
  - signature of certificate attributes

S/MIME architecture

Architecturally based on:

- **PKCS-7 (S/MIME v2)**
  CMS (S/MIME v3)
  specifies the cryptographic characteristics and the message types (equivalent to PEM)
- **PKCS-10**
  format of certificate request
- **X.509**
  format of public key certificates

S/MIME: algorithms

- **message digest:**
  - SHA-1 (preferred), MD5
- **digital signature:**
  - DSS (mandatory)
  - digest + RSA
- **key exchange:**
  - Diffie-Helmann (obbligatorio)
  - key encrypted with RSA
- **encryption of message:**
  - 3DES with 3 keys
  - RC2/40

MIME type

- **application/pkcs7-mime, used for:**
  - msg. encrypted (envelopedData)
  - msg. signed (signedData) addressed only to S/MIME users because are encoded in base64
  - msg. that contain only a public key (= certificate, in signedData)
  - standard extension: **.p7m**

MIME type

- **multipart/signed**
  - signed messages addressed also to users not supporting S/MIME
  - the message is in clear
  - the last MIME part is the signature
  - standard extension for the signature: **.p7s**
- **application/pkcs10**
  - used to send a certification request to a CA

S/MIME: signature example

```
Content-Type: multipart/signed;
 protocol="application/pkcs7-signature";
 micalg=sha1;
 boundary="-----aaaaa"

-----aaaaa
Content-Type: text/plain
Content-Transfer-Encoding: 7bit

Hello!
-----aaaaa
Content-Type: application/pkcs7-signature
Content-Transfer-Encoding: base64

MIIN2QasDDSdwe/625dBxgdhdsf76rHfrJe65a4f
fvVSW2Q1eD+SfDs543Sdwe6+25dBxfdER0eDsrs5
-----aaaaa-
```

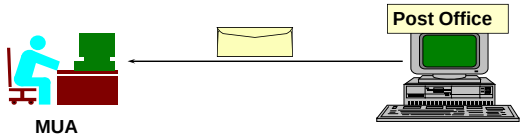
Naming in S/MIME

- **used for:**
  - selecting the certificate
  - verifying the sender's address
- **S/MIMEv2 uses the Email= or E= fields in the DN of the X.509 certificate, but it is possible to use the extension subjectAltName with rfc822 encoding**
- **S/MIMEv3 mandates the use of the subjectAltName extension with rfc822 encoding**

Naming and MUA

- **NS Messenger and MS Outlook Express check that the sender is the same as the value of e-mail (in the DN) or with the first rfc822 field (in the subjectAltName)**
- **typical behaviour of S/MIMEv2**
- **MS Outlook 2000 makes no verification among the sender and the certified e-mail address**
- **typical behaviour of S/MIMEv3**

Client-server e-mail services



- **authentication of the user**
- **authentication of the server**
- **confidentiality/integrity of mail messages**
  - on the server
  - while in transit

client - server e-mail services

- **POP (Post-Office Protocol)**
  - POP-2 (RFC-937), POP-3 (RFC-1939)
    user authentication by means of a password in clear (!!!)
  - APOP
    user authentication by means of a challenge
  - K-POP
    mutual authentication by means of tickets
- **IMAP (Internet Mail Access Protocol)**
  - username and password in clear
  - can use OTP, Kerberos or GSS-API

POP-3 example

```
    telnet pop.polito.it 110
+OK POP3 server ready <7831.84549@pop.polito.it>
    USER lioy
+OK password required for lioy
    PASS antonio
+OK lioy mailbox locked and ready
    STAT
+OK 2 320
.........
    QUIT
+OK POP3 server signing off
```

APOP

- APOP command replaces the set of commands USER + PASS
- the *challenge* is the part of the hello line contained among the parentheses < ... > (including the parentheses)
- syntax:
  APOP *user response-to-challenge*
- *response* = MD5(*challenge* + *password*)
- *response* encoded in hexadecimal
- supported by Eudora

APOP example

```
   telnet pop.polito.it 110
+OK POP3 server ready <7831.84549@pop.polito.it>
   APOP lioy 36a0b36131b82474300846abd6a041ff
+OK lioy mailbox locked and ready
   STAT
+OK 2 320
.....
   QUIT
+OK POP3 server signing off
```

POP: general considerations

- POP is acceptable only on a secure channel (e.g. on SSL)
- server APOP freeware by Qualcomm
- use a POP / APOP password different from the one for login because the post office must know it in clear
- the mail is transmitted however in clear
- there is no server authentication

IMAP security

- **by default weak authentication**
  LOGIN *user password*
- **strong authentication:**
  AUTHENTICATE KERBEROS_V4
  AUTHENTICATE GSSAPI
  AUTHENTICATE SKEY
- **mutual authentication only if Kerberos is used**
- **no protection of the transmission of messages**
- **recent versions of Netscape and MS mailer can use IMAP on SSL**

RFC-2595 (TLS per POP / IMAP)

- **RFC-2595**
  "Using TLS with IMAP, POP3 and ACAP"
- **first the communication channel is opened then the security characteristics are negotiated by means of a dedicated command:**
  - STARTTLS for IMAP and ACAP
  - STLS for POP3
- **client and server must allow to be configured to reject *user* and *password***
- **client compares the identity in the certificate with the identity of the server**

Separate ports for SSL/TLS?

- **discouraged by IETF due to the following reasons:**
  - involve different URLs (e.g. http and https)
  - involve an incorrect secure / insecure model (e.g. is 40-bit SSL secure SSL? is insecure an application without SSL but with SASL?)
  - not easy to implement "use SSL if available"
  - doubles the number of necessary ports
- **… but present some advantages:**
  - simple to filter traffic on packet-filter firewalls
  - SSL with client-authentication allows not to expose the applications to attacks