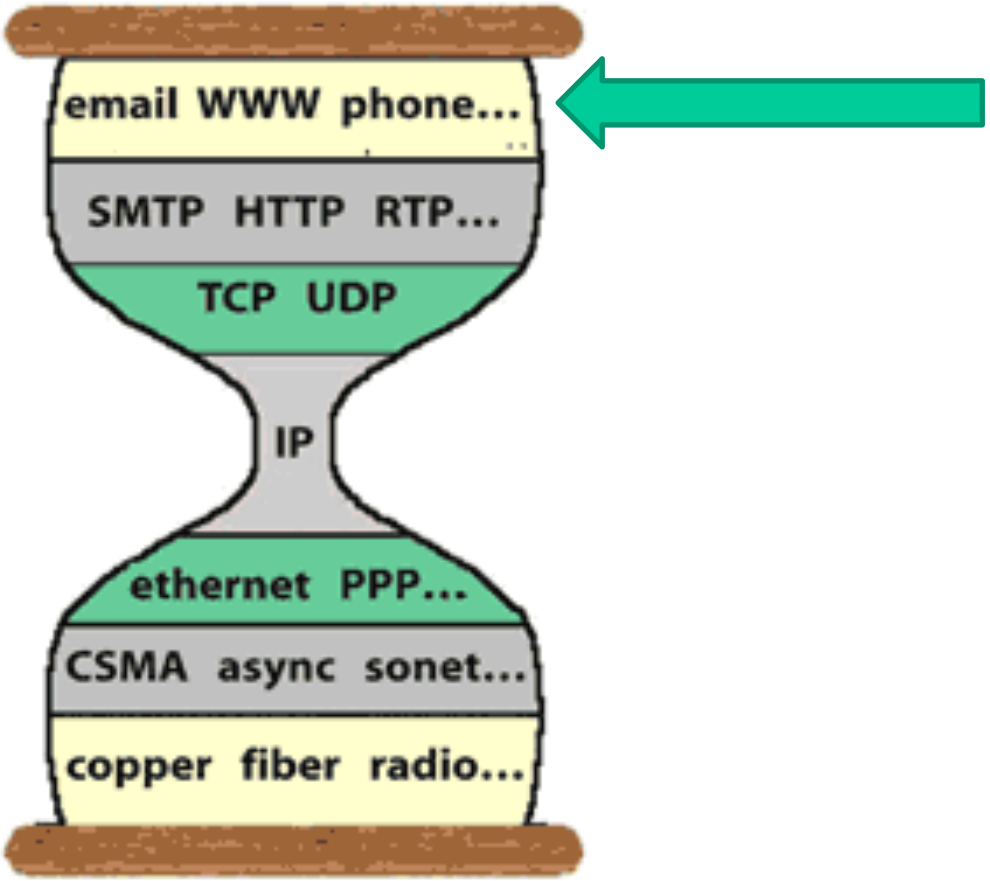
Plan for today: More on Application Layer

- Finish with HTTPS
- Electronic Mail
  - How many parts in email delivery system
  - Simple Mail Transfer Protocol (SMTP)
  - Mail retrieval protocols:
    - POP3
    - IMAP
  - Basics of email security
- P2P

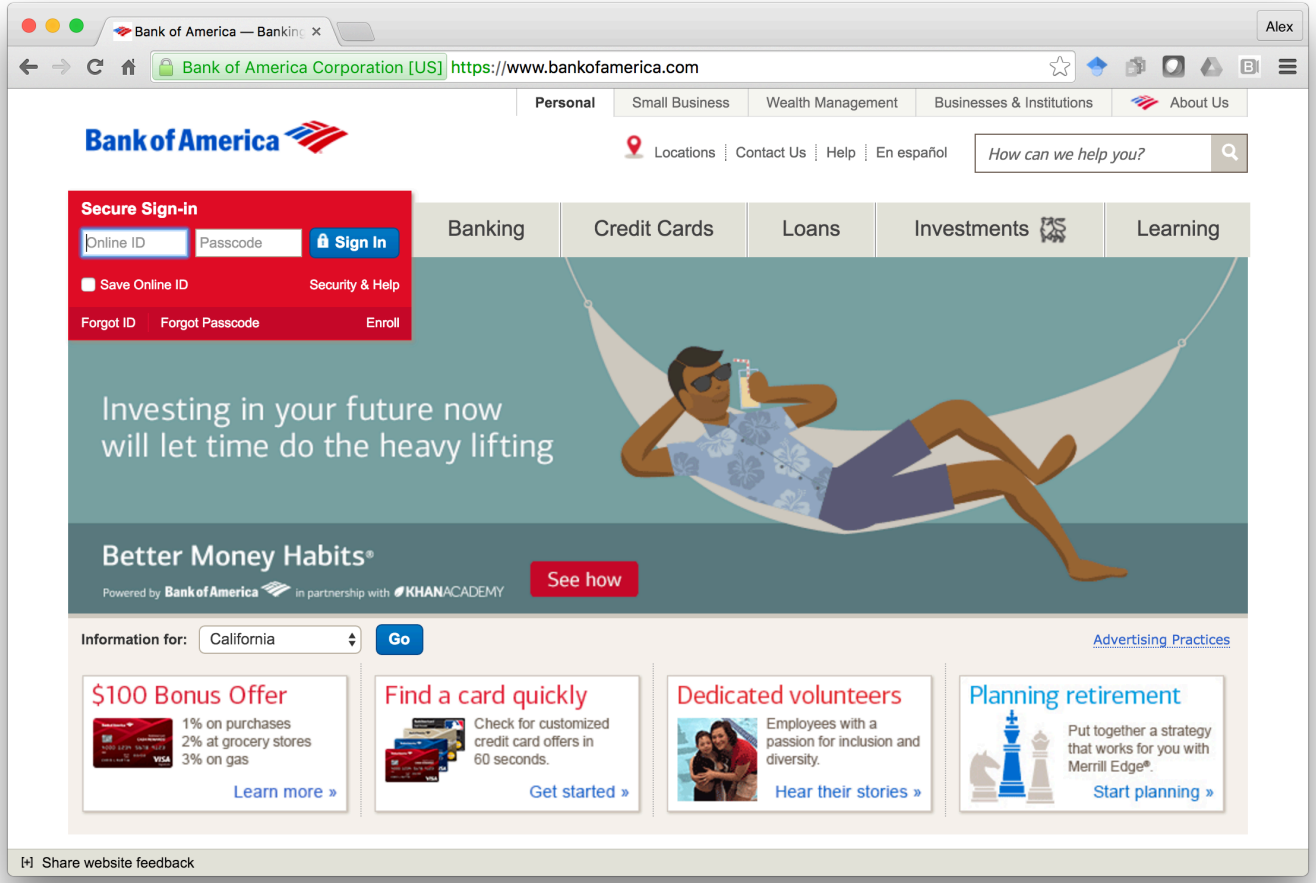


Storage-Less Cookies (last lecture question)

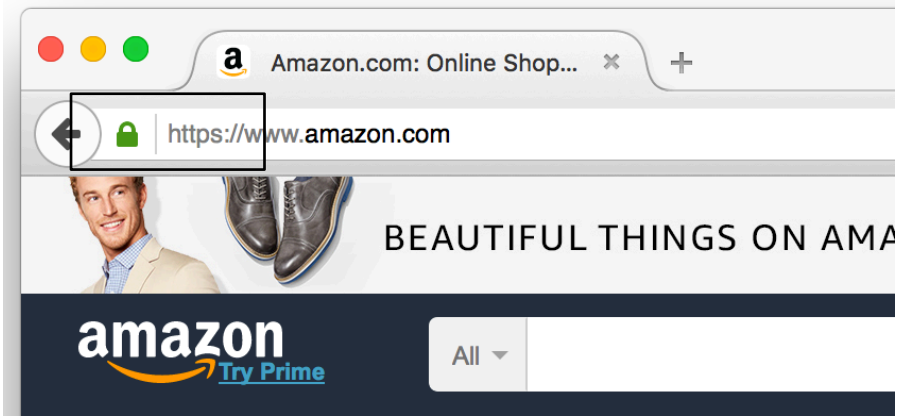
- Say, server has databases of users
- Whenever users wants to login, users sends login/password and server wants to remember that user authenticated for the future requests
- ”Standard” solution
  - Server generates a long unique ID, creates a state file (state record) in the database, and set unique ID as a cookie for the client to repeat
  - “Bad guys” cannot easily guess such ID
- ”Storage-Less” solution
  - Server encrypts/signs statement (user=x has been authenticated) and sets the whole encrypted blob as a cookie for the client
  - “Bad guys” cannot guess what’s inside nor pretend that user=y is authenticated.

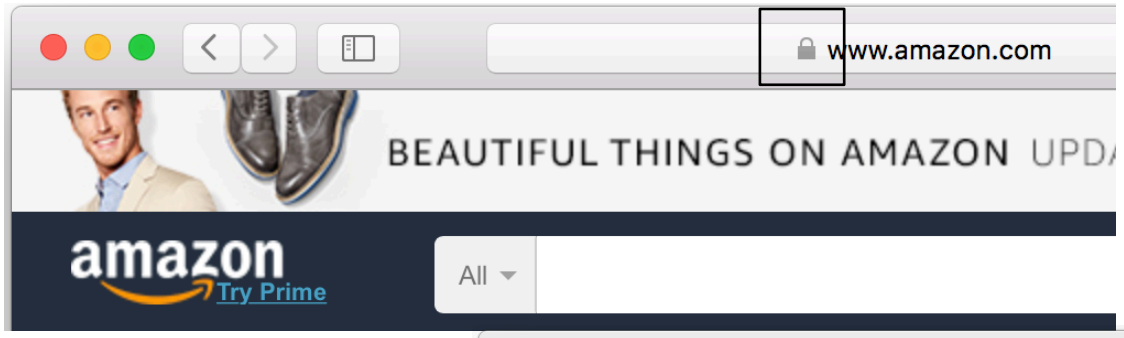
HTTPS: Secure HTTP

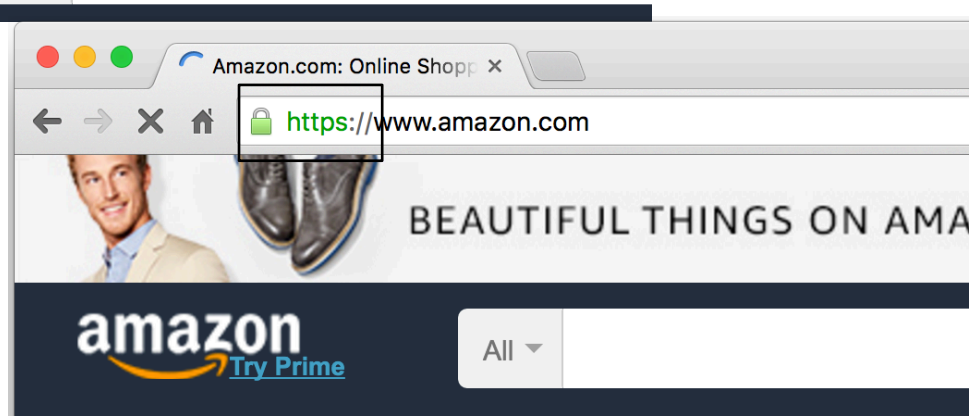
- Ensure that you're receiving data from place you think you do
- Ensure secrecy of information exchanges



HTTPS: Sites with Domain Validation (DV) Certificates

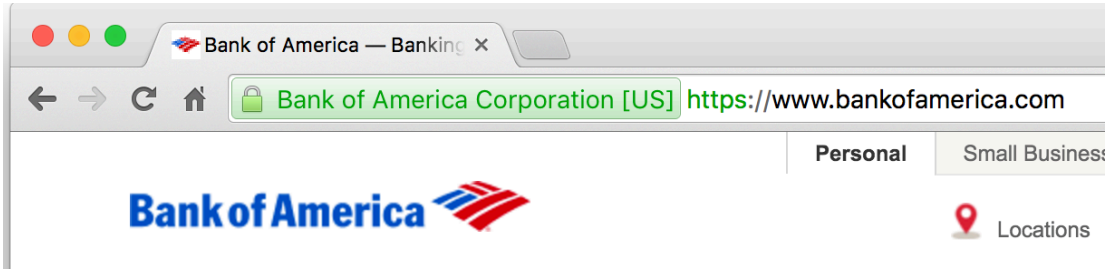




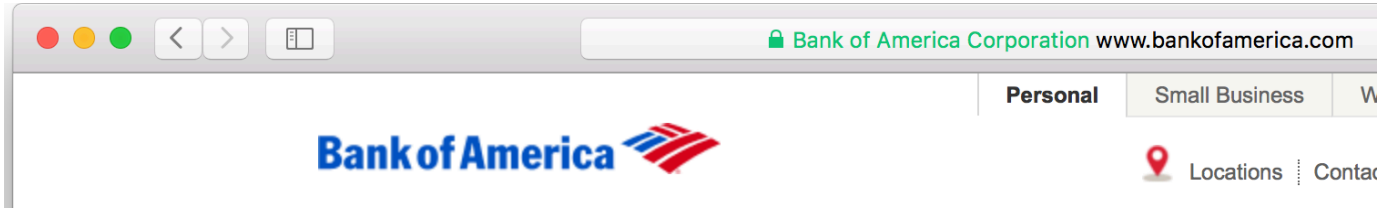


HTTPS: Sites with Extended Validation (EV) Certificates

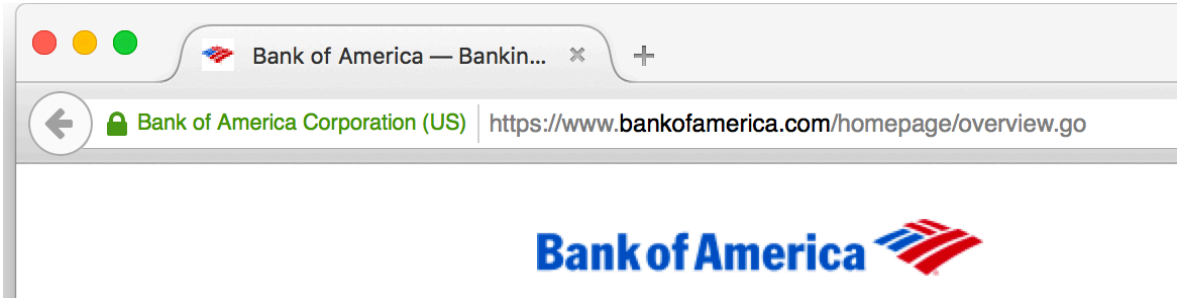
- the Certificate Authority (CA) checks the right of the applicant to use a specific domain name PLUS it conducts a THOROUGH vetting of the organization



Chrome

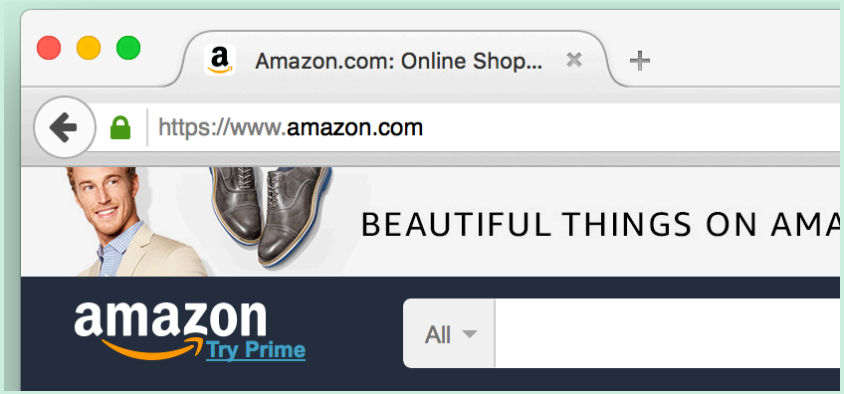


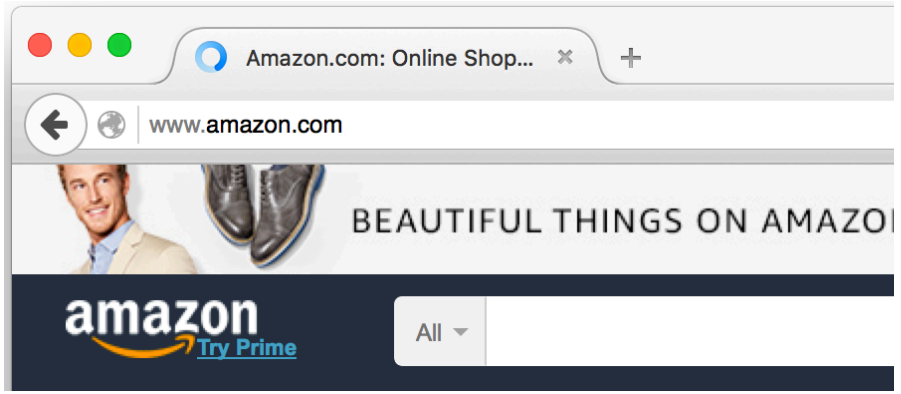
Safari

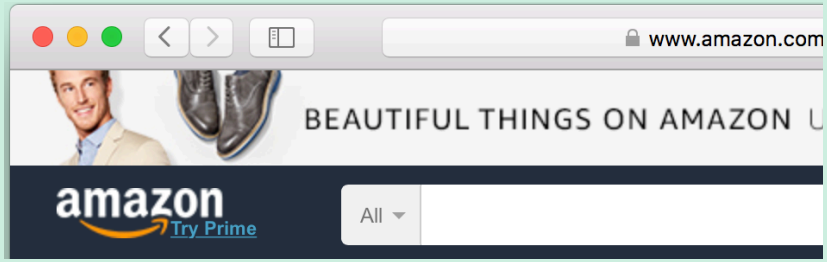


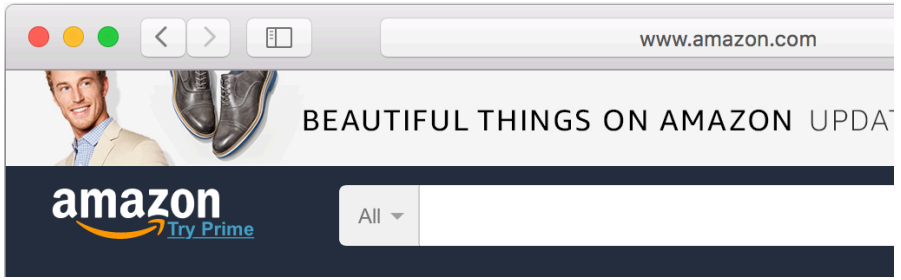
Firefox

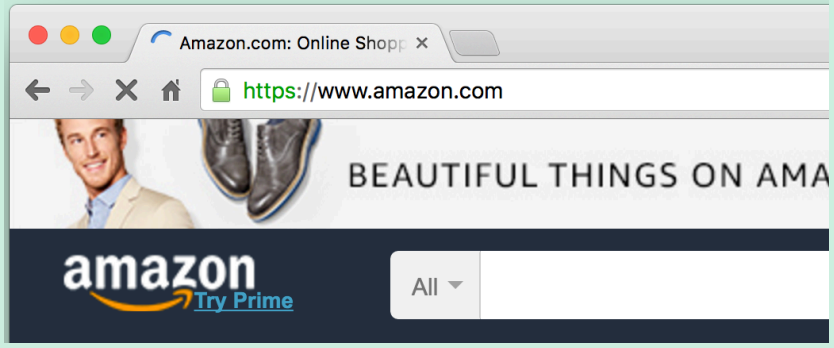
Beware: Some Sites use HTTPS Optionally

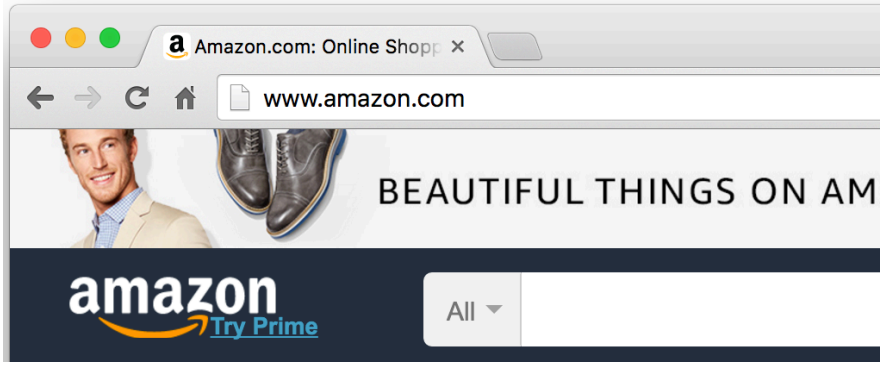




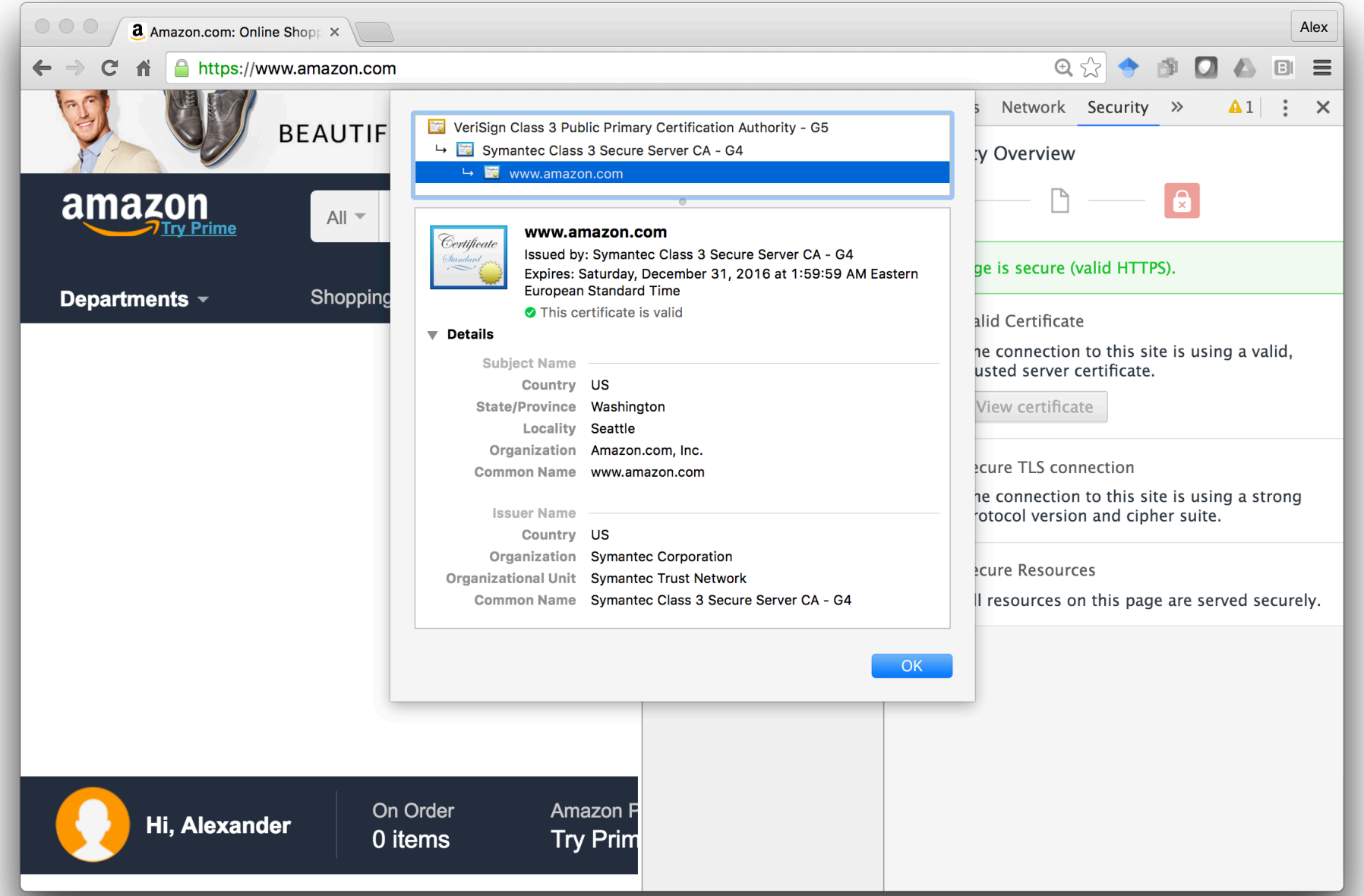






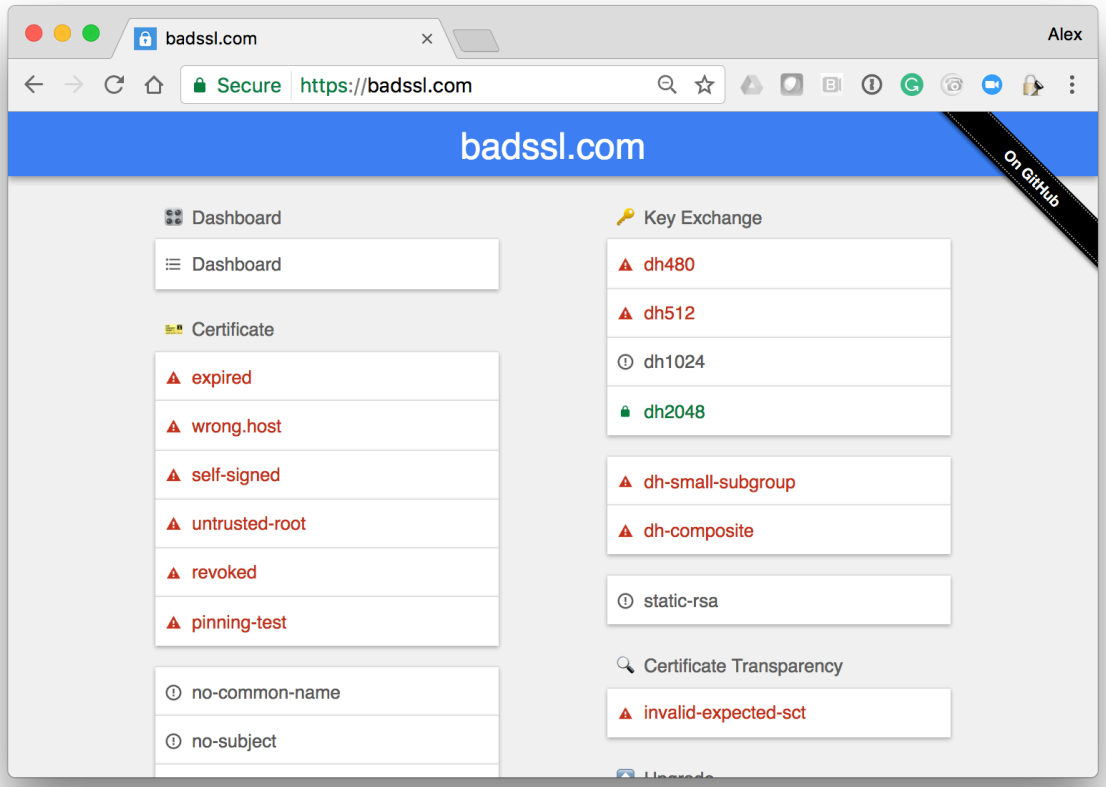


HTTPS: Checking Certificate Manually



HTTPS (TLS) Certificate States

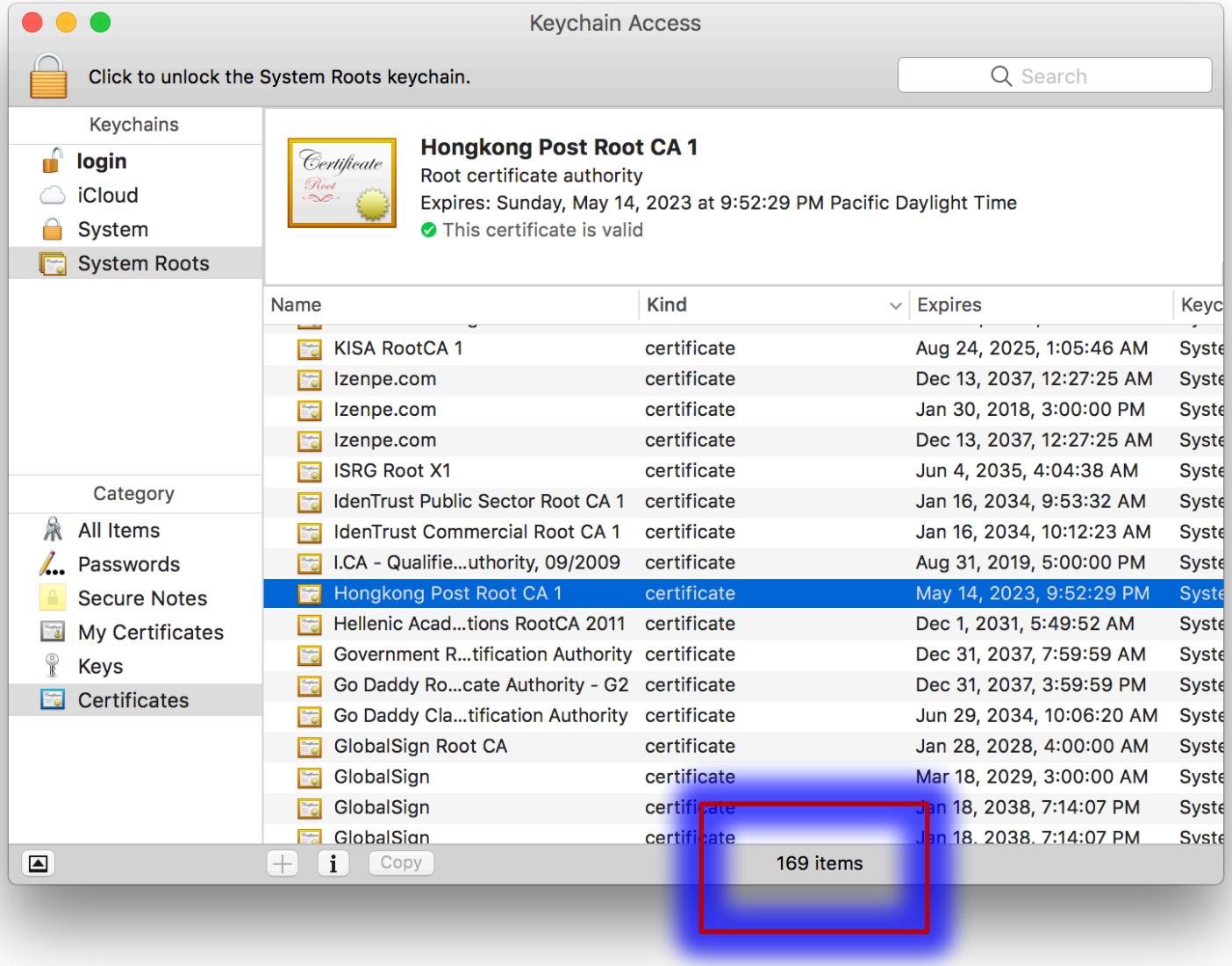
- Valid
- Expired
- Wrong host
- Untrusted root
- Revoked
- Pinned



- \+ more

Is your browser safe?

Whom You Trust?

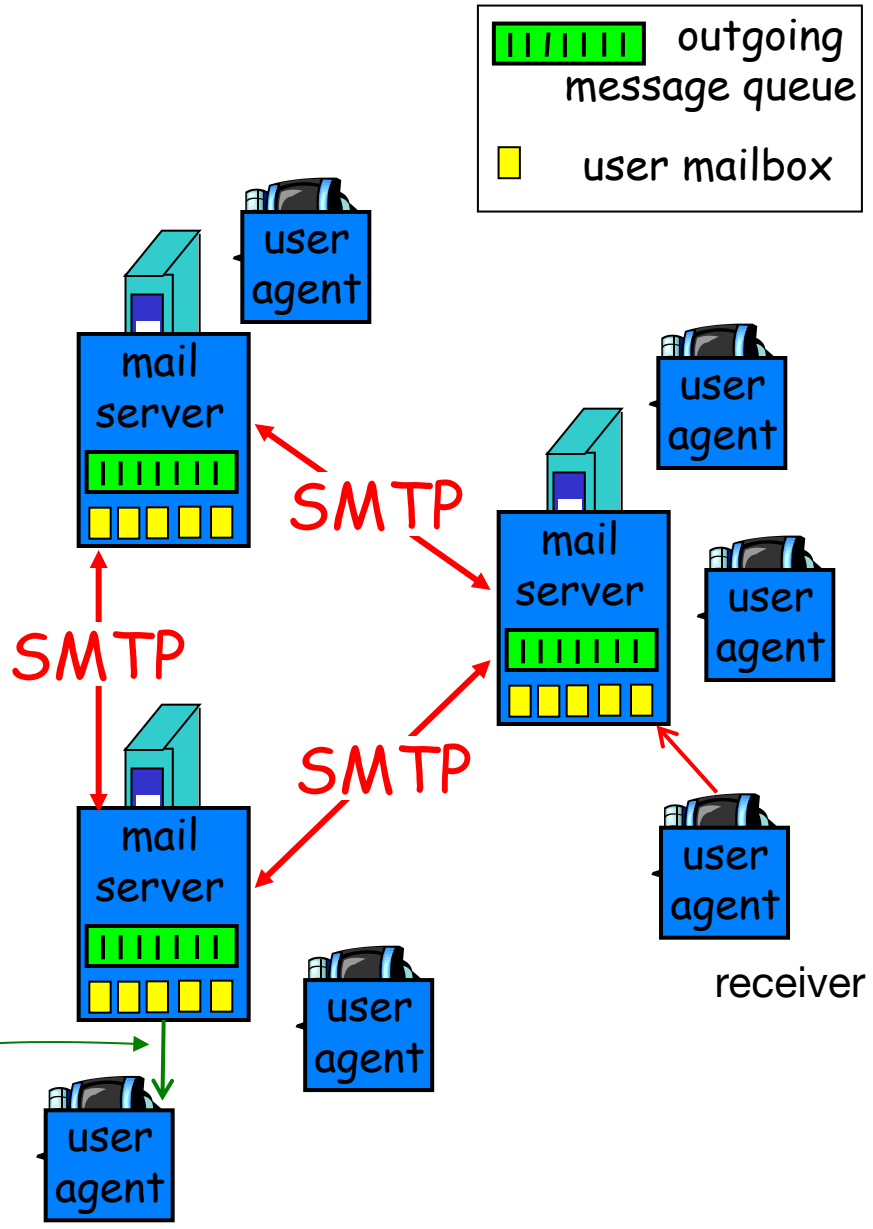


E-Mail

Not so simple protocol(s)

E-Mail: 4 major components

- ***User Agents***: a.k.a. "mail app": composing, editing, reading mail messages
  - Gmail, Apple Mail, Outlook, Thunderbird, etc.
- ***Mail Servers***:
  - (sendmail, postfix, etc.)
  - mailbox contains incoming messages for user
  - message queue of outgoing (to be sent) mail messages
- ***Simple Mail Transfer Protocol*** (*SMTP,* RFC 2821): transfer email messages from user client to servers and *between mail servers*
- ***Mail Retrieval Protocols*** (IMAP, ~~POP3~~, Exchange, +)



Example: Alice sends a message to Bob

1) Alice writes a msg "to" bob@someschool.edu

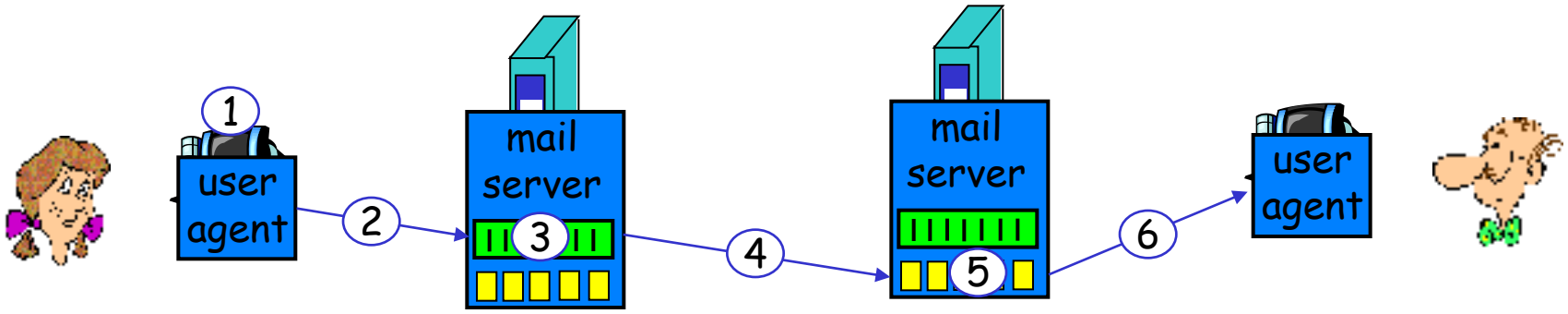
2) Alice's UA sends message to her mail server; message placed in message queue

3) The mail server opens TCP connection with Bob's mail server

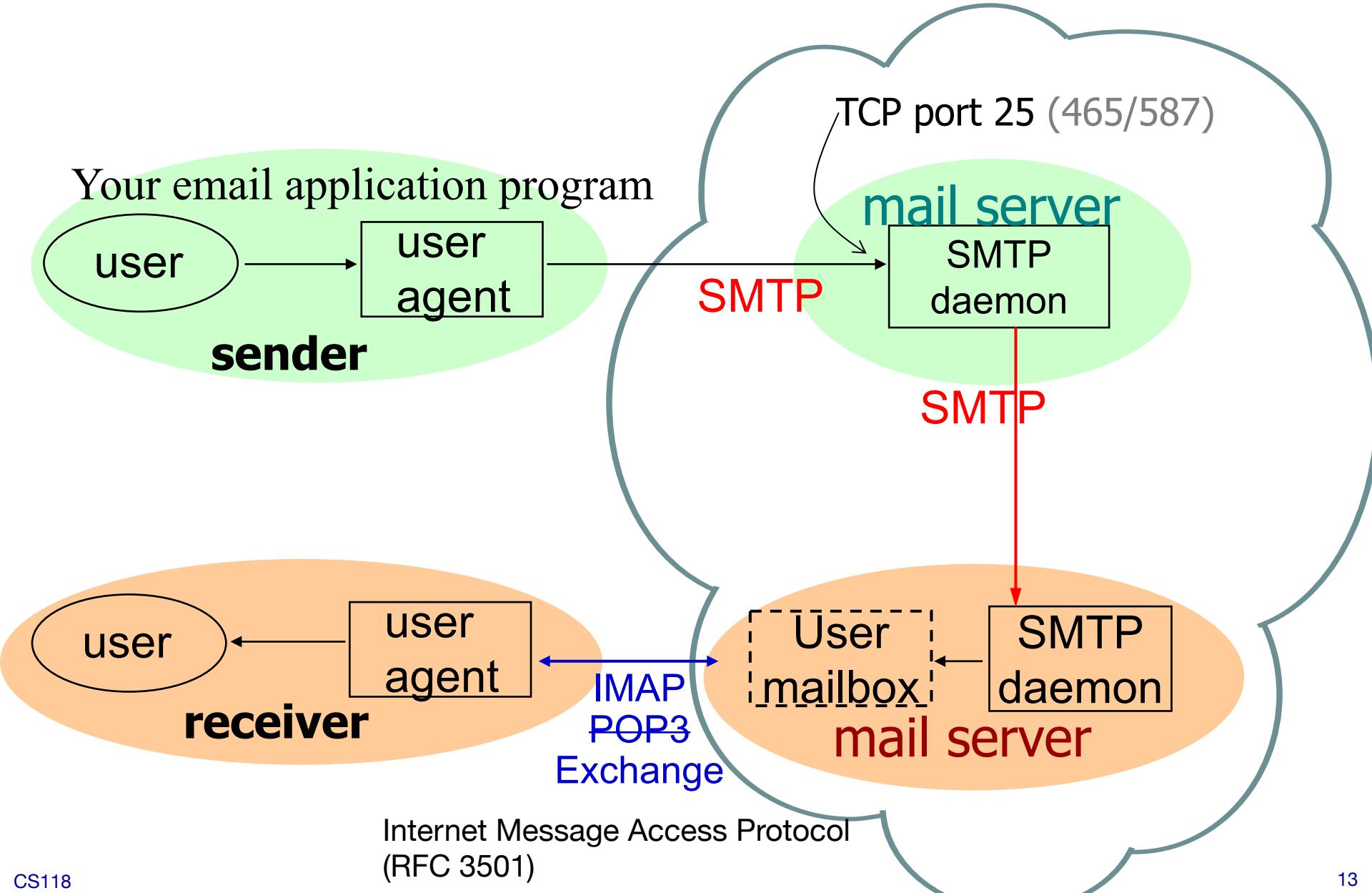
4) Alice's server sends the msg over the TCP connection

5) Bob's mail server places the msg in Bob's mailbox

6) Bob invokes his user agent to fetch message



Email delivery



Internet Message Access Protocol (RFC 3501)

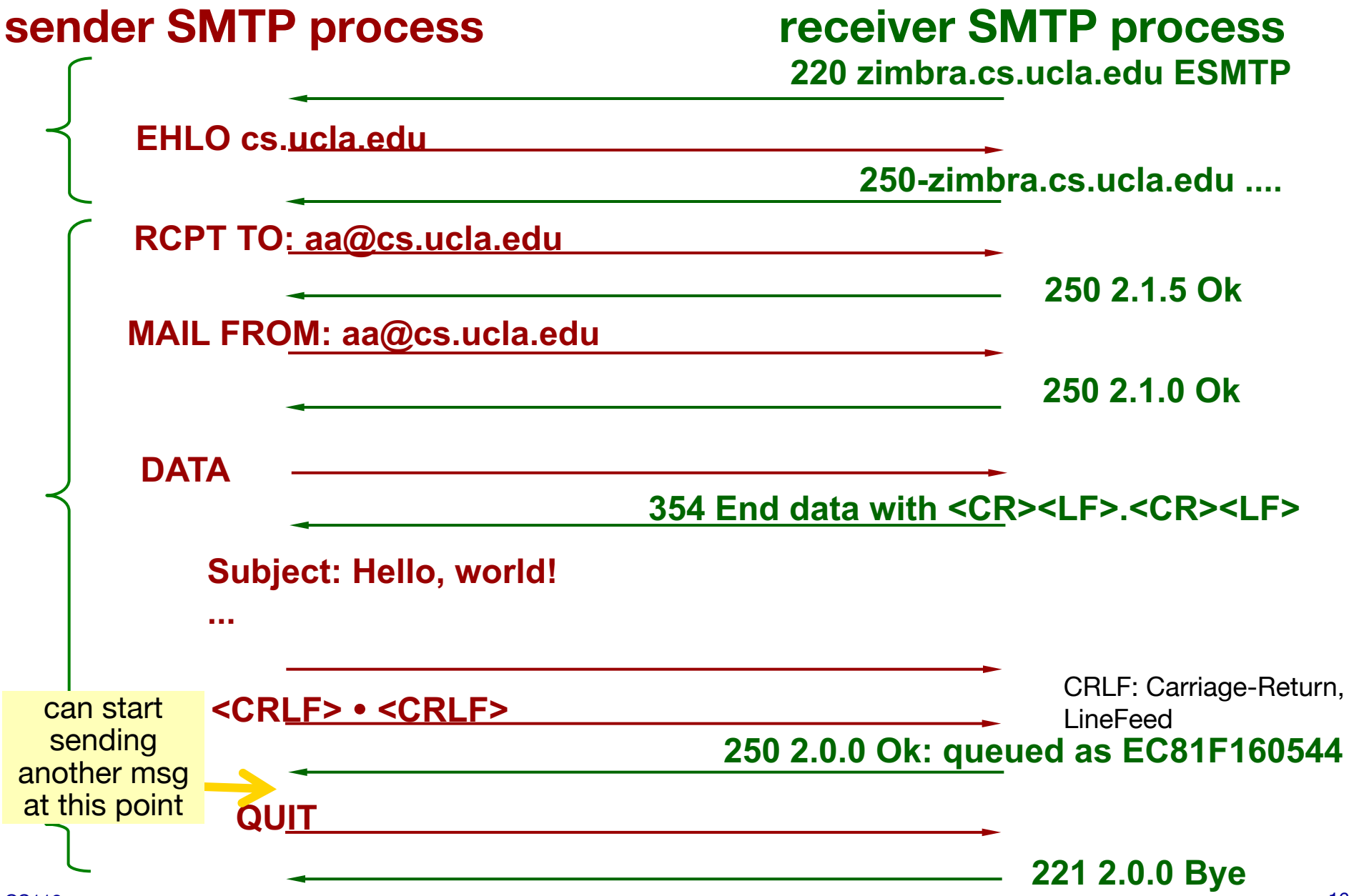
Simple Mail Transfer Protocol [RFC 2821]

- Three phases of transfer
  - handshaking (greeting)
  - (starting secure session / STARTTLS)
  - transfer of messages
  - closing
    - Note this is *not* TCP connection close (to be covered in next lectures)
- Each phase: command/response interaction
  - commands: ASCII text
  - response: status code and phrase
- messages must be encoded in 7-bit ASCII

Example of Sending Email over SMTP

```
x  16:52 ~ $ telnet
zimbra.cs.ucla.edu 25
Trying 131.179.128.68...
Connected to zimbra.cs.ucla.edu.
Escape character is '^]'.
220 zimbra.cs.ucla.edu ESMTP
Postfix

ehlo cs.ucla.edu
250-zimbra.cs.ucla.edu
250-PIPELINING
250-SIZE 40000000
250-VRFY
250-ETRN
250-STARTTLS
250-ENHANCEDSTATUSCODES
250-8BITMIME
250 DSN

rcpt to: aa@cs.ucla.edu
250 2.1.5 Ok

mail from: aa@cs.ucla.edu
250 2.1.0 Ok


data
354 End data with <CR><LF>.<CR><LF>
Subject: Hello, world!

Hello, world!  Duh.
.
250 2.0.0 Ok: queued as EC81F160544


quit
221 2.0.0 Bye
Connection closed by foreign host.
```

A typical SMTP message exchange (after the TCP connection setup)



Reply Status Codes: Look Familiar?

Code	meaning
220	service ready
221	I'm closing too
250	requested action OK
500	error, command not recognized
550	no such mbox, no action taken

Common practices

1st digit: whether response is good/bad/incomplete

e.g. 2= positive completion, 5=negative completion

2nd digit: encodes responses in specific categories

e.g. 2=connections, 5=mail system (status of the receiver mail system)

3rd digit: a finer gradation of meaning in each category specified by the 2nd digit.

SMTP: A Few Highlights

FYI

- SMTP server uses `CRLF.CRLF` to determine end of message
- SMTP msg body: use an empty line to separate header and body
- Message (header & body) must be encoded in 7-bit ASCII
- Multipurpose Internet Mail Extensions (MIME) to support
  - Header information or text in non-ASCII char. set
  - Non-text attachments
  - Message bodies with multiple parts

Find similarities with HTTP

Comparison between SMTP and HTTP

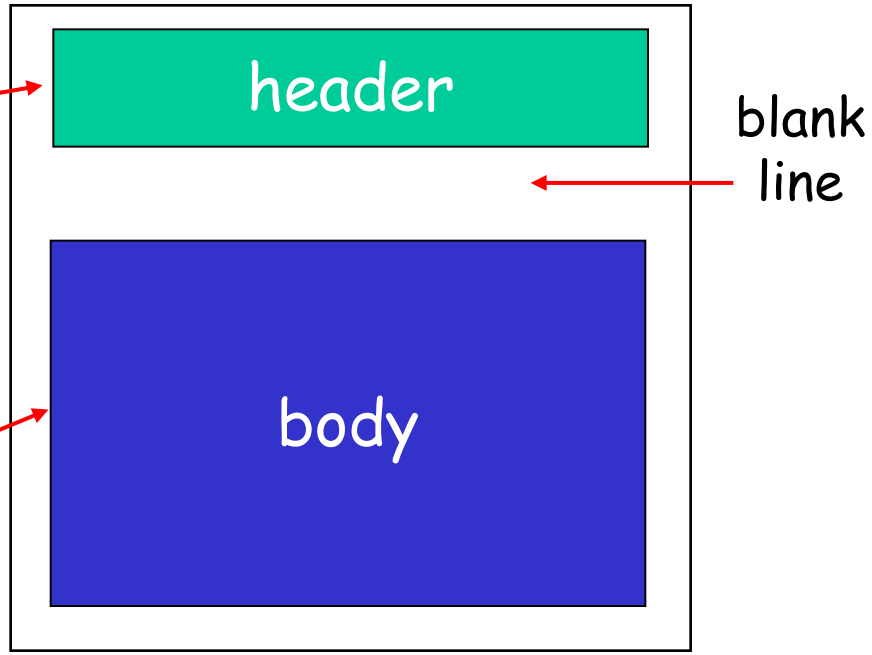
- HTTP: pull
- SMTP: push
- both use ASCII command/response interaction, responses with status codes
  - Both also use empty line for header-body separation
- HTTP: each object encapsulated in its own response message
- SMTP: multiple objects can be encoded in one multipart message

Mail message format

FYI

- RFC 822: standard for text message format:
- header lines, e.g.,
  - To:
  - From:
  - Subject:

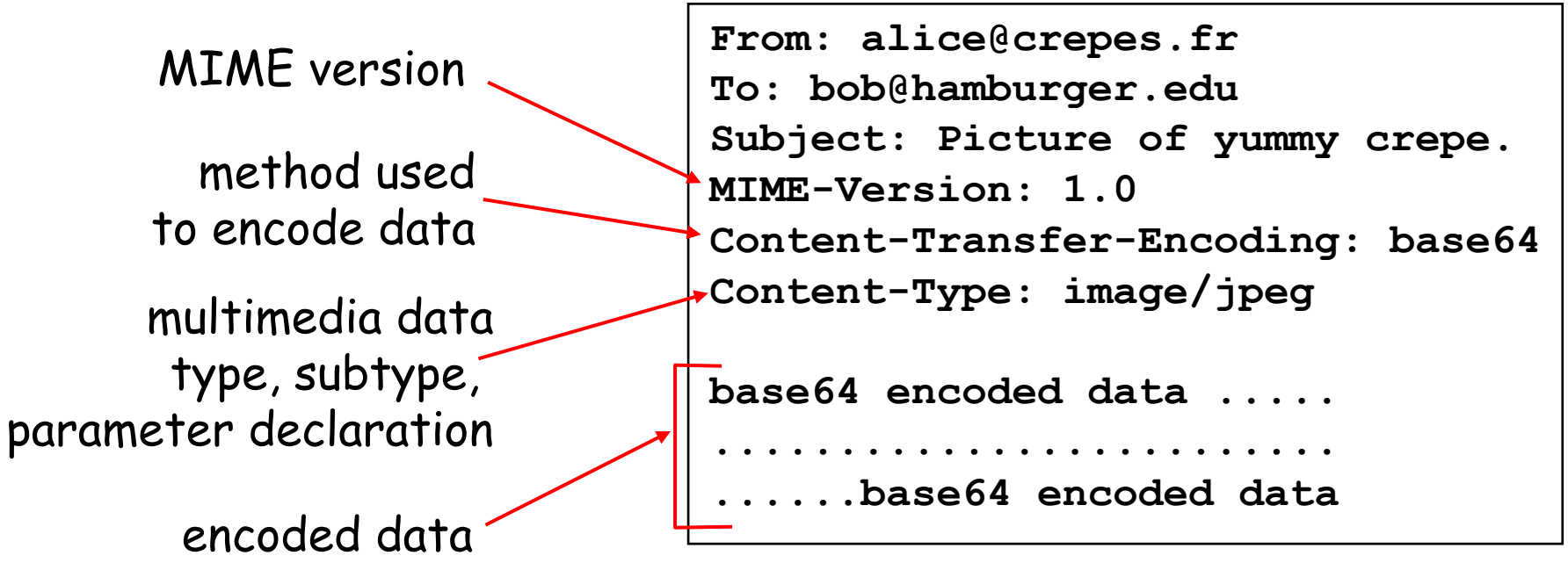
  These are independent from what's used in SMTP
- body
  - the "message", ASCII characters only



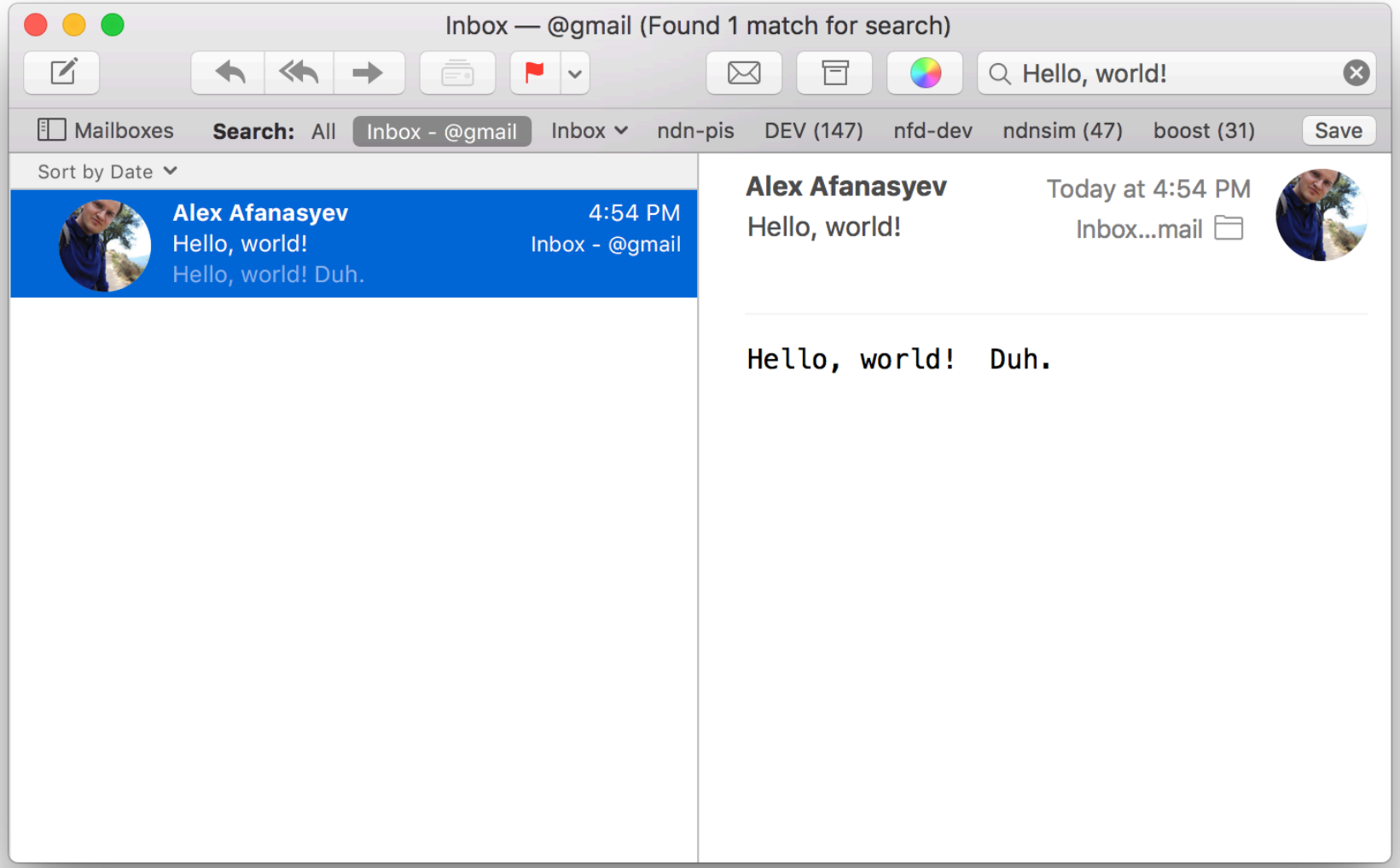
Multipurpose Internet Mail Extensions (MIME)

FYI

- To support
  - Header information or text in non-ASCII char. set
  - Non-text attachments
  - Message bodies with multiple parts
- additional lines in msg header for MIME content type



Here is my email



Received message (Cmd-Opt-U in Apple Mail)

```
Delivered-To: cawka1@gmail.com
Received: by 10.157.5.104 with SMTP id 95csp742023otw;
        Wed, 6 Apr 2016 07:54:12 -0700 (PDT)
X-Received: by 10.98.79.205 with SMTP id f74mr38989594pfj.68.1459954452037;
        Wed, 06 Apr 2016 07:54:12 -0700 (PDT)
Return-Path: <aa@cs.ucla.edu>
Received: from zimbra.cs.ucla.edu (zimbra.cs.ucla.edu. [131.179.128.68])
        by mx.google.com with ESMTPS id f90si5095225pff.83.2016.04.06.07.54.11
        for <cawka1@gmail.com>
        (version=TLS1_2 cipher=ECDHE-RSA-AES128-GCM-SHA256 bits=128/128);
        Wed, 06 Apr 2016 07:54:11 -0700 (PDT)
Received-SPF: pass (google.com: domain of aa@cs.ucla.edu designates 131.179.128.68 as permitted
sender) client-ip=131.179.128.68;
Authentication-Results: mx.google.com;
       spf=pass (google.com: domain of aa@cs.ucla.edu designates 131.179.128.68 as permitted
sender) smtp.mailfrom=aa@cs.ucla.edu
Received: from localhost (localhost [127.0.0.1])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id A445B16127A;
          Wed,  6 Apr 2016 07:54:11 -0700 (PDT)
Received: from zimbra.cs.ucla.edu ([127.0.0.1])
          by localhost (zimbra.cs.ucla.edu [127.0.0.1]) (amavisd-new, port 10032)
          with ESMTP id w9ONfWSmRntW; Wed,  6 Apr 2016 07:54:11 -0700 (PDT)
Received: from localhost (localhost [127.0.0.1])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id 103E516126F;
          Wed,  6 Apr 2016 07:54:11 -0700 (PDT)
```

```
X-Virus-Scanned: amavisd-new at zimbra.cs.ucla.edu
Received: from zimbra.cs.ucla.edu ([127.0.0.1])
          by localhost (zimbra.cs.ucla.edu [127.0.0.1]) (amavisd-new, port 10026)
          with ESMTP id b3lcNgHG14vP; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
Received: from mailman.cs.ucla.edu (Mailman.CS.UCLA.EDU [131.179.128.30])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id EF118160544
          for <afanasev@zimbra.cs.ucla.edu>; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
Received: by mailman.cs.ucla.edu (Postfix)
          id EDA0D7D6F4; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
Delivered-To: aa@cs.ucla.edu
Received: from zimbra.cs.ucla.edu (zimbra.CS.UCLA.EDU [131.179.128.68])
          by mailman.cs.ucla.edu (Postfix) with ESMTP id E3BE27D6F3
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
Received: from localhost (localhost [127.0.0.1])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id 6100F16126F
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:54:09 -0700 (PDT)
X-Virus-Scanned: amavisd-new at zimbra.cs.ucla.edu
Received: from zimbra.cs.ucla.edu ([127.0.0.1])
          by localhost (zimbra.cs.ucla.edu [127.0.0.1]) (amavisd-new, port 10024)
          with ESMTP id dqevBkdxYCo9 for <aa@cs.ucla.edu>;
          Wed,  6 Apr 2016 07:54:08 -0700 (PDT)
Received: from cs.ucla.edu (wlan-141-23-116-69.tubit.tu-berlin.de [141.23.116.69])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id EC81F160544
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:53:23 -0700 (PDT)
Subject: Hello, world!
Message-Id: <20160406145331.EC81F160544@zimbra.cs.ucla.edu>
Date: Wed,  6 Apr 2016 07:53:23 -0700 (PDT)
From: aa@cs.ucla.edu

Hello, world!  Duh.
```

What Happened?

- Me → zimbra.cs.ucla.edu

```
Received: from cs.ucla.edu (wlan-141-23-116-69.tubit.tu-berlin.de [141.23.116.69])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id EC81F160544
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:53:23 -0700 (PDT)
```

- zimbra → localhost (virus scan)

```
Received: from zimbra.cs.ucla.edu ([127.0.0.1])
          by localhost (zimbra.cs.ucla.edu [127.0.0.1]) (amavisd-new, port 10024)
          with ESMTP id dqevBkdxYCo9 for <aa@cs.ucla.edu>;
          Wed,  6 Apr 2016 07:54:08 -0700 (PDT)
```

- localhost → zimbra.cs.ucla.edu (?)

```
Received: from localhost (localhost [127.0.0.1])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id 6100F16126F
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:54:09 -0700 (PDT)
```

- zimbra → mailman.cs.ucla.edu (local delivery)

```
Received: from zimbra.cs.ucla.edu (zimbra.CS.UCLA.EDU [131.179.128.68])
          by mailman.cs.ucla.edu (Postfix) with ESMTP id E3BE27D6F3
          for <aa@cs.ucla.edu>; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
```

- mailman → zimbra (redirecting)

```
Received: from mailman.cs.ucla.edu (Mailman.CS.UCLA.EDU [131.179.128.30])
          by zimbra.cs.ucla.edu (Postfix) with ESMTP id EF118160544
          for <afanasev@zimbra.cs.ucla.edu>; Wed,  6 Apr 2016 07:54:10 -0700 (PDT)
```

What Happened? (cont.)

- zimbra → localhost (virus scan)
- localhost → zimbra
- zimbra → localhost
- localhost → zimbra
- zimbra → mx.google.com
- → 10.98.79.205
- → 10.157.5.104

How to send emails?

- SMTP servers for the domain normally allow emails only for this domain
- Use “provider’s” SMTP service
  - Allow customers to send email to any domain name
- Use your email provider SMTP service with authentication
  - Google’s SMTP
  - Yahoo SMTP

Other way to send email?

- Contact domain's SMTP directly

- Drawbacks?

Securing channel to SMTP server

- Remember HTTPS
- Similar can/should be used for SMTP
  - Don’t allow others to see your login password

```
openssl s_client -starttls smtp -crlf -connect
smtp.gmail.com:25

EHLO testing

AUTH LOGIN
base64('username')
base64('password')
```

Does secure channel between SMTP makes email secure?

Additional Security Layers in SMTP

- DKIM
  - https://en.wikipedia.org/wiki/DomainKeys_Identified_Mail
  - Allows the receiver to check that an email claimed to have come from a specific domain was indeed authorized by the owner of that domain
- SPF
  - https://en.wikipedia.org/wiki/Sender_Policy_Framework
  - A mechanism to check that incoming mail from a domain comes from a host authorized by that domain's administrators

Is your email secure?

- No
- Why?

Is there away to secure your email?

- How to ensure that others know your email is indeed from you?
  - Solve challenges I posted on Piazza yesterday.

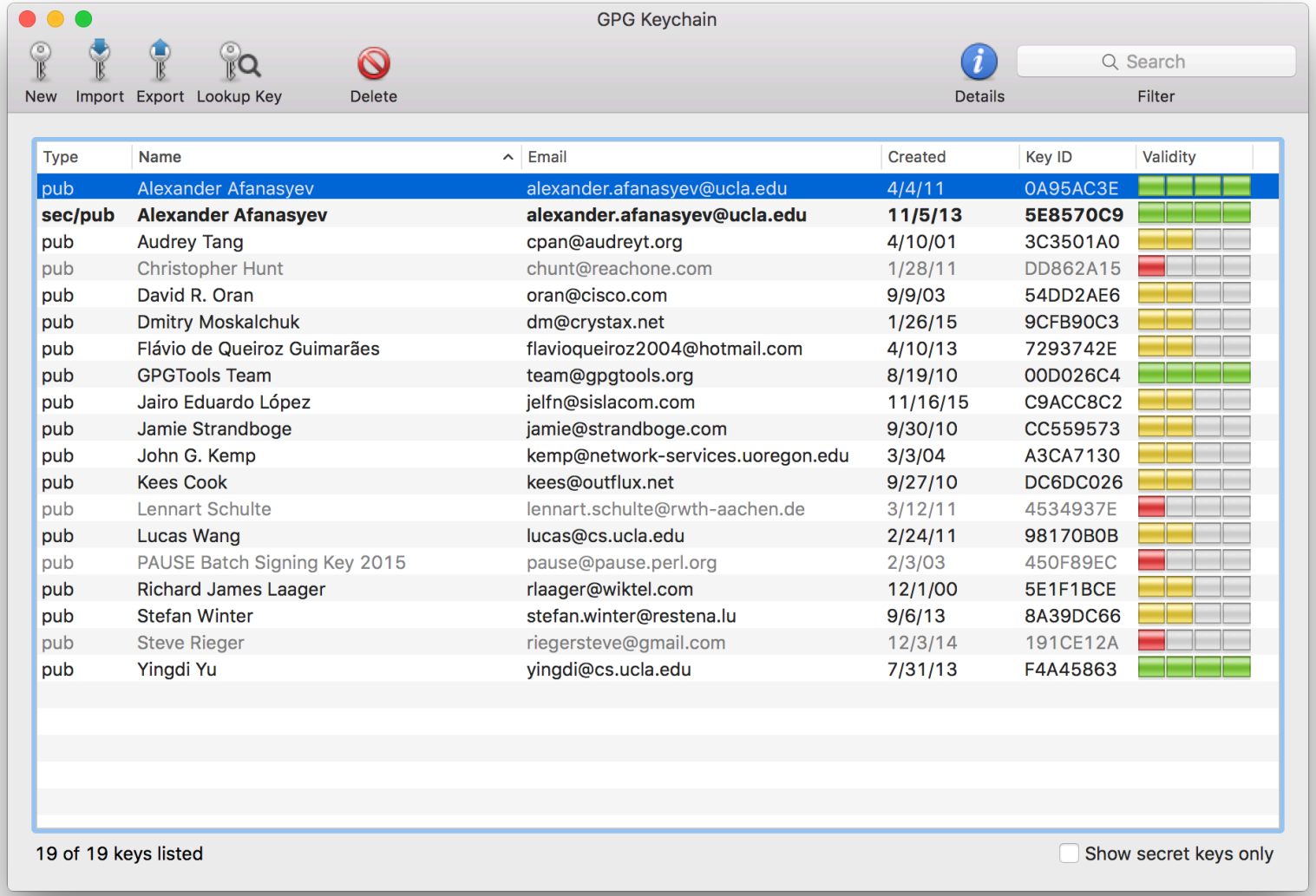
Securing Email

- Sign with a valid certificate
  - issued by some certification authority
    - can check and vouch that it is indeed you who sent the email
    - can simply check you own the email
      - https://startssl.com/ (free one)
      - many others
  - Web-of-Trust certificate (PGP, GPG)
    - others can vouch for you
- Encrypt with somebody else's public key
  - How can you get this public key?

Getting started with PGP

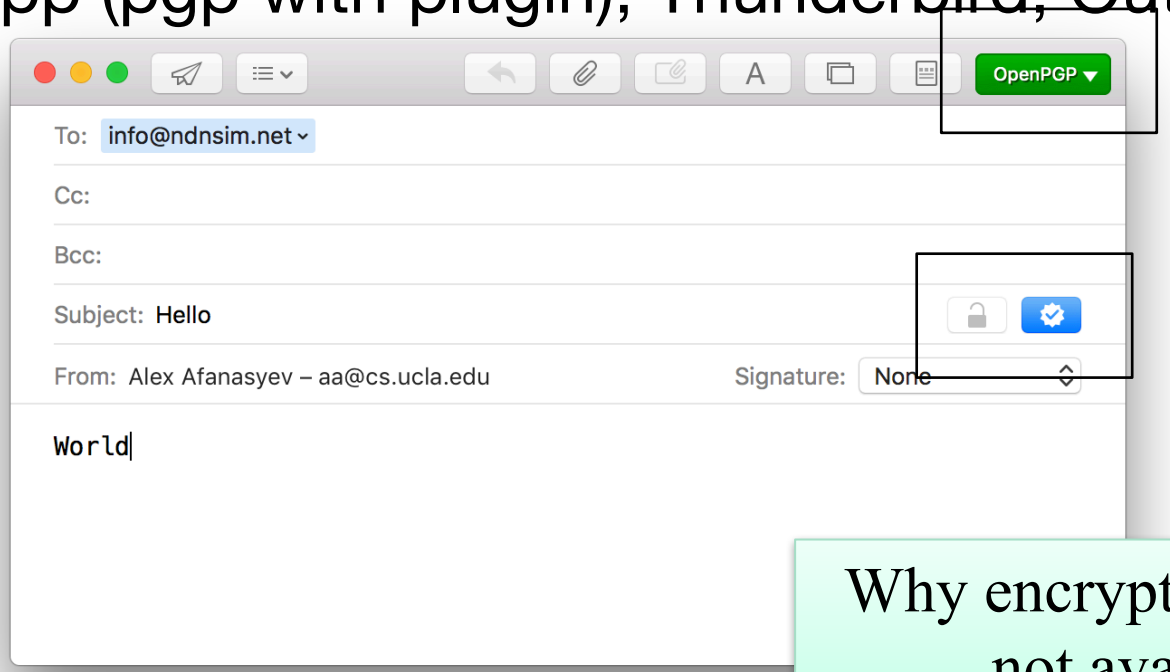
- OSX
  - https://gpgtools.org/
- Windows
  - https://www.gpg4win.org/
- Linux
  - https://help.ubuntu.com/community/GnuPrivacyGuardHowto

GPG Keychain (OSX)



Signing outgoing emails

- Manually
  - Gmail and most others web-based systems ☹
  - You can sign up with https://Keybase.io
- Automatically
  - Mail.app (pgp with plugin), Thunderbird, Outlook, etc.



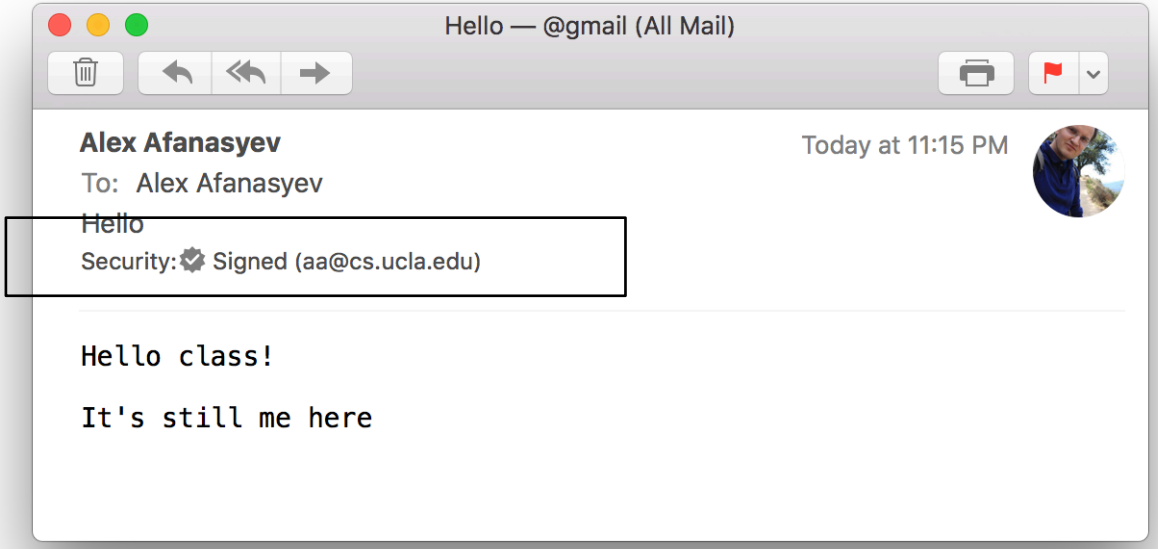
Why encryption option is not available?

Manual signing of things

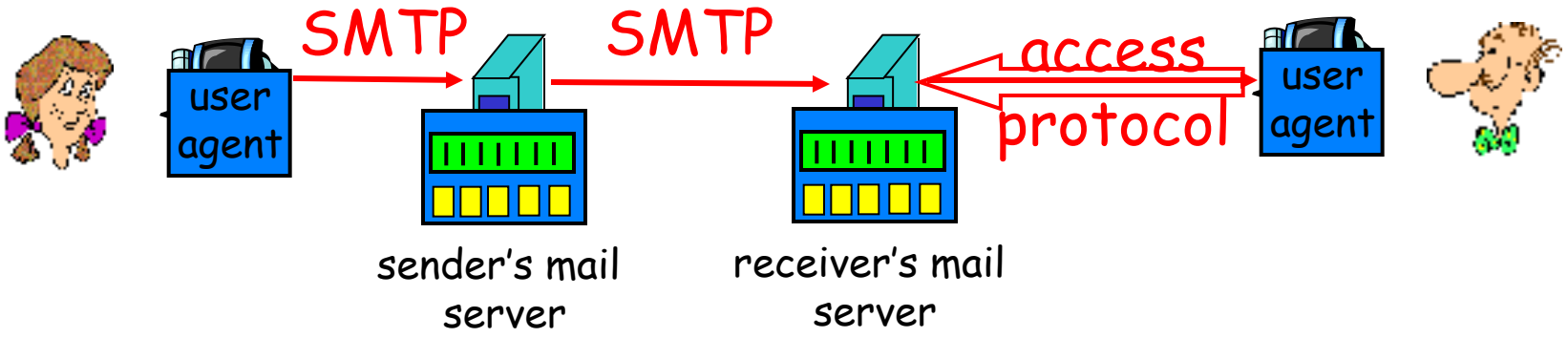
```
✔  23:11 ~ $ gpg --clearsign

You need a passphrase to unlock the secret key for
user: "Alexander Afanasyev <alexander.afanasyev@ucla.edu>"
4096-bit RSA key, ID 5E8570C9, created 2013-11-05

Hello class,

This is defintely me who wrote this text.
-----BEGIN PGP SIGNED MESSAGE-----
Hash: SHA256

Hello class,

This is defintely me who wrote this text.
-----BEGIN PGP SIGNATURE-----
Comment: GPGTools - http://gpgtools.org

iQIcBAEBCAAGBQJXBXusAAoJEJFqoM1ehXDJ02wQAKby89gO282XOPDdVKR0OyAu
BR/9Ztd1x+fWNJPZKbDVJ7e6oN4S6ggk/ZUJ1XXJxg5PFdGLGinTHp/vgH4oU0pU
G+YNRUYLb3olrkvaJlCKKLfA+OdVGhhoCivOZ1zH9wBi+zVv7ObPoXFwbLfOezQ8
yrsgB/e0etTI3A2hAP17+RvSlXE+IWbyriJh/6nsU/u2CsjE/yTjdjrJXDYcIKEN
/a2fhxqcbvwoT1kNgBa5Z9fntd+/1+qCsJcRqeF4ok6b2w8CB+TApec6JXRkuzsR
fMvNbLvKbV3DTpdYWTPADOyP6tEfzd5oG0Mah5gZzwhVAfyqf9ETUBx8cVQ+QmDU
KJ7oFlWExKYiSoPuB3pep1XjHYWQkejdyhRp4wOUOGbR0JkPYlu1b3s+X0TNu3Ng
JZIYP0FJ0ElL8PM3zTMuMKfIIbHVPOtjJlncNSJrt6IVHjkJrDloSN08bBXr29R3
X+BoRid51+j3mQ43yK9wub1bi81tPX2fo++HLMg7AQBBW6pv3eZR5fomaN4xfHOe
SRyBwy5EANdiS2JWNvjPBlFzrhoNsSsp0qAh2+gZW9ZrPo4yZ3KK/SVrWOSrNq/5
j9Y/Nh6aJrOkkO3dE/pyDFmuLJ3m9FDt/DhiIbcx6RJiKQISQx3pt0ERXEiRu4qy
FBiIFKZAQ4GwrPyF8Fod
=tlZn
-----END PGP SIGNATURE-----
```

Verification

- Manually
  - gpg + paste text and signature
- Automatically



Mail access protocols



- SMTP: deliver mail to receiver's server
- Mail access protocol: retrieval from server
  - POP: Post Office Protocol [RFC 1939]
    - authorization (agent <—>server) and download
  - IMAP: Internet Mail Access Protocol [RFC 1730]
    - more features (e.g. multiple folders)
    - manipulation of stored messages on server
  - HTTP: gmail, Hotmail , Yahoo! Mail

POP3 protocol

FYI

authorization phase

- client commands:
  - **`user:`** declare username
  - **`pass:`** password
- server responses
  - **`+OK`**
  - **`-ERR`**

transaction phase, client:

- **`list:`** list message numbers
- **`retr:`** retrieve message by number
- **`dele:`** delete
- **`quit`**

```
S: +OK POP3 server ready
C: user bob
S: +OK
C: pass hungry
S: +OK user successfully logged on
```

```
C: list
S: 1 498
S: 2 912
S: .
C: retr 1
S: <message 1 contents>
S: .
C: dele 1
C: retr 2
S: <message 2 contents>
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off
```

POP3 and IMAP

FYI

More about POP3

- Previous example uses "download and delete" mode.
- Bob cannot re-read e-mail if he changes client
- "Download-and-keep": copies of messages on different clients
- POP3 is stateless across sessions

IMAP

- Keep all messages in one place: the server
- Allows user to organize messages in folders
- IMAP keeps user state across sessions:
  - names of folders and mappings between message IDs and folder name

What You Learned Today

- Email
  - Even more complicated
  - Need to use signatures/encryption to make sure your communication is safe
  - **! be cautions of any emails, even if it is from your friends unless they are signed or you expect those emails !**
  - And I haven't mentioned all the security measures added to try to limit spam and fraud