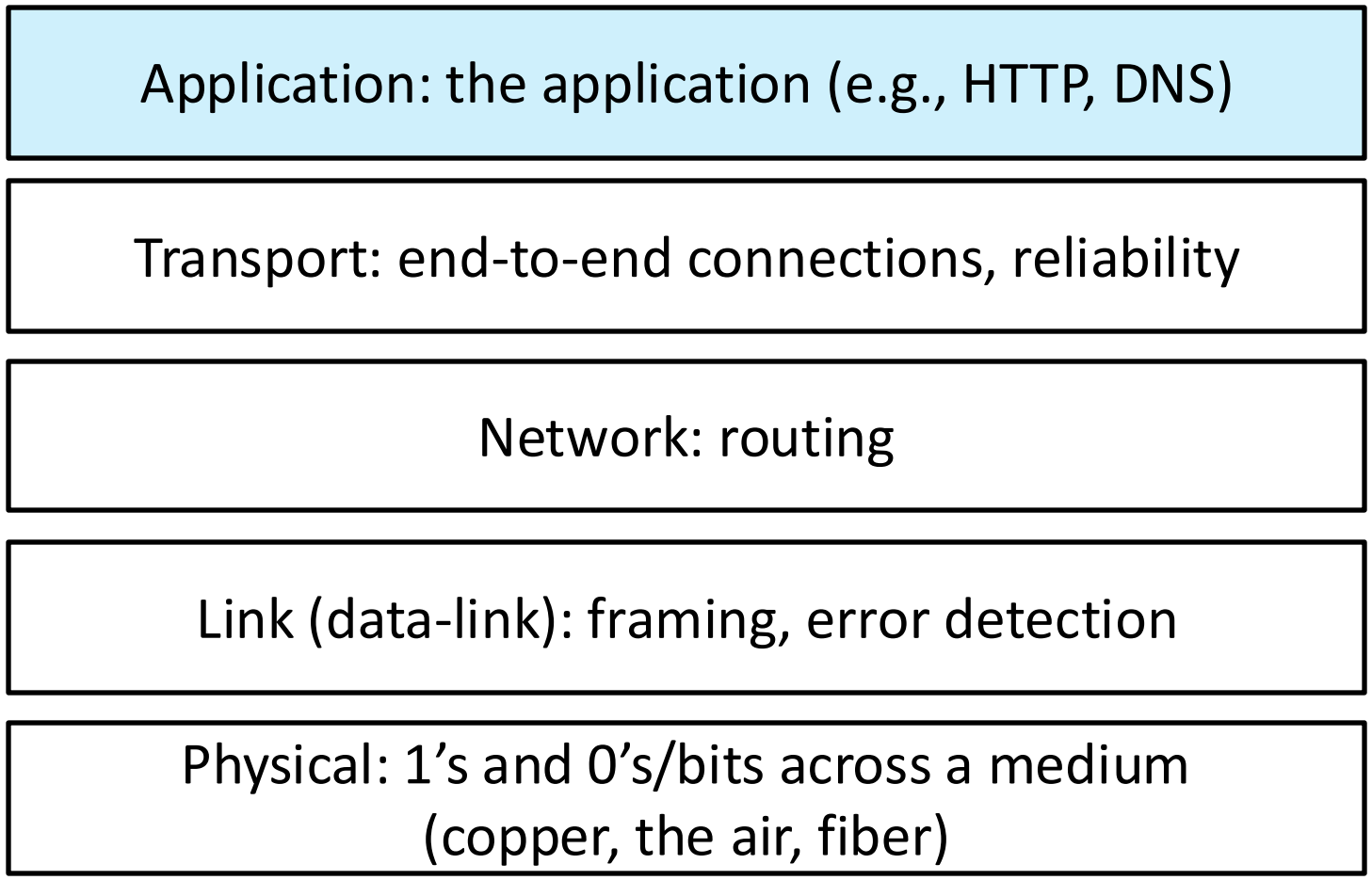
CS 43: Computer Networks

Email

October 01, 2025

Where we are


Application: the application (e.g., HTTP, DNS)
Transport: end-to-end connections, reliability
Network: routing
Link (data-link): framing, error detection
Physical: 1's and 0's/bits across a medium
(copper, the air, fiber)

Today

- Three main parts to email:
  - Mail User Agent
  - Mail Transfer Agent
  - SMTP protocol used to negotiate transfers
- SMTP Protocol
- Mail Access Protocols
  - POP3
  - IMAP
  - Webmail

Electronic Mail – Major Components

- Mail user agent (MUA)
  - "email client"
  - the software users interact with to send/receive emails
  - takes many forms (Gmail web interface, Thunderbird, phone app, etc.)
- Mail transfer agent (MTA)
  - "email server"
  - takes custody of messages, delivers them
- Simple mail transfer protocol (SMTP)
  - defines message format and transfer procedure

Electronic Mail – Major Components

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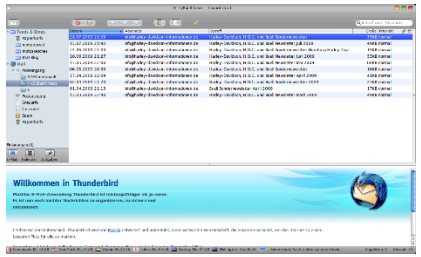
"mail client"



Alice

Electronic Mail – Major Components

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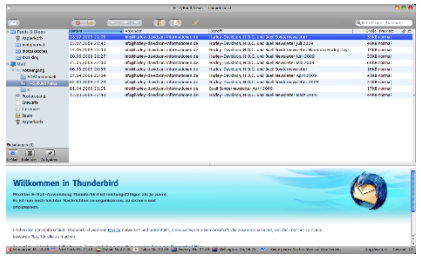
"mail client"



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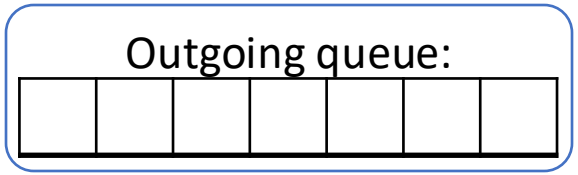
Mail transfer agent (MTA)
"mail server"



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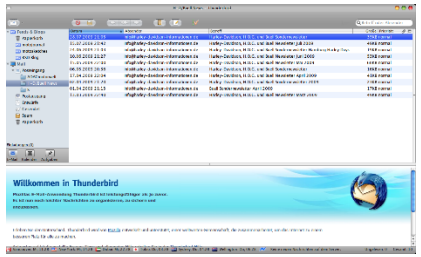

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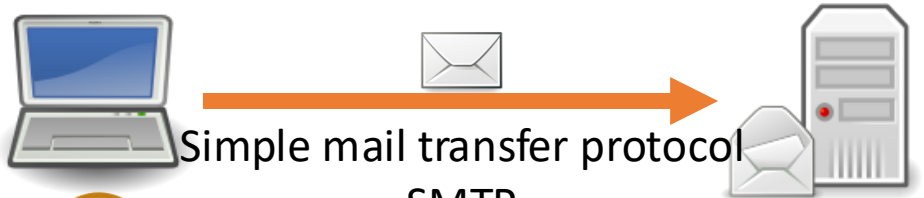
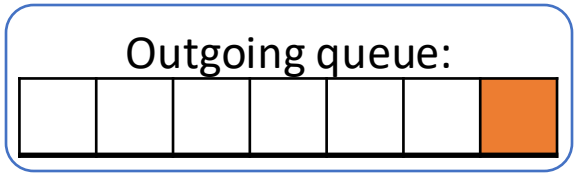


Simple mail transfer protocol
SMTP



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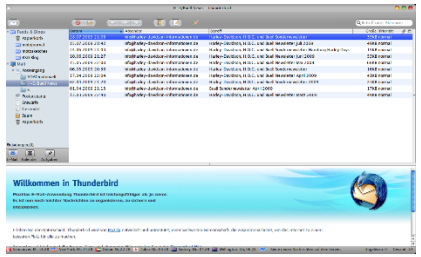

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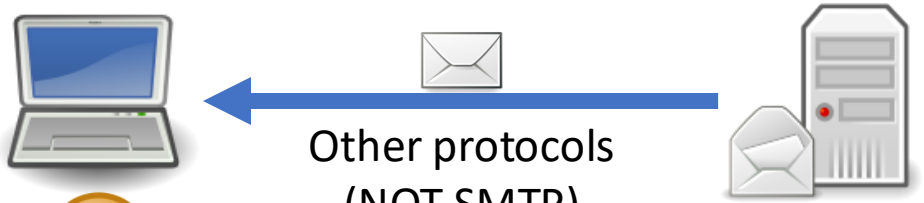
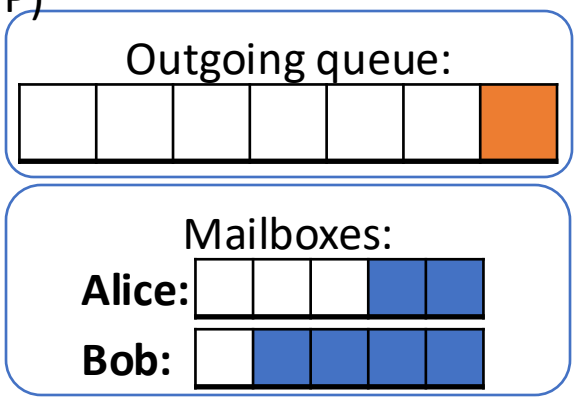


Other protocols
(NOT SMTP)

Alice



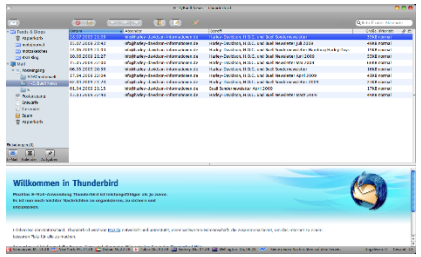
Mail Servers: Ever Vigilant

- Always on, because they always need to be ready to accept mail.

- Usually owned by ISP
  - You use the email server for Swarthmore College (outsourced to Google / Gmail)

Same organization, one server

Mail user agent (MUA)
"mail client"



Alice

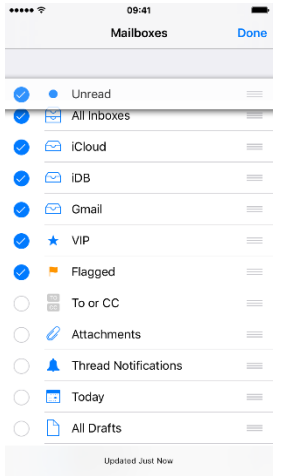
Mail transfer agent (MTA)
"mail server"

Outgoing queue:

Mailboxes:

Alice:

Bob:



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Same organization, one server

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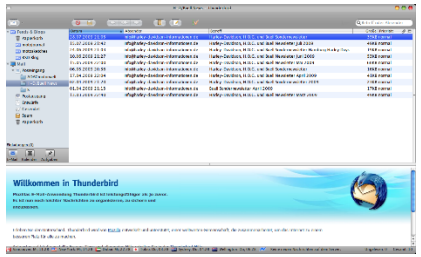

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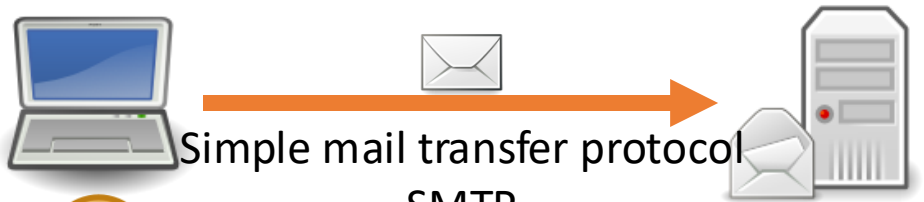

Simple mail transfer protocol
SMTP

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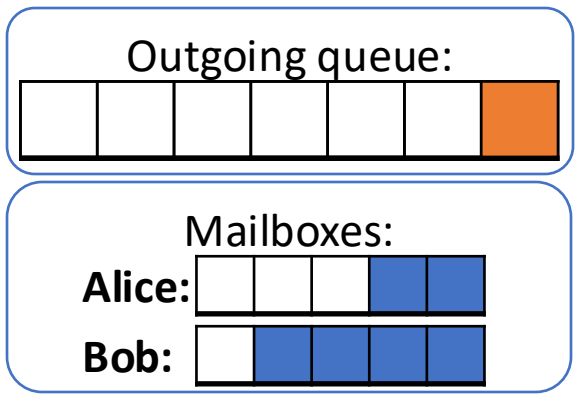

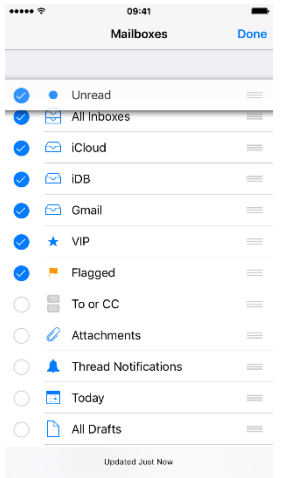

Bob

Same organization, one server

Mail user agent (MUA)
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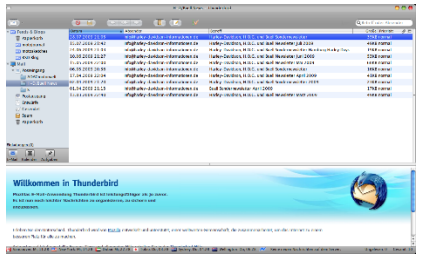

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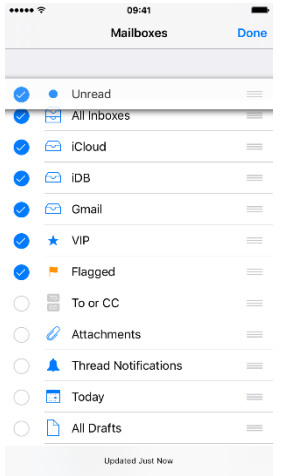

Bob

Same organization, one server

Mail user agent (MUA)
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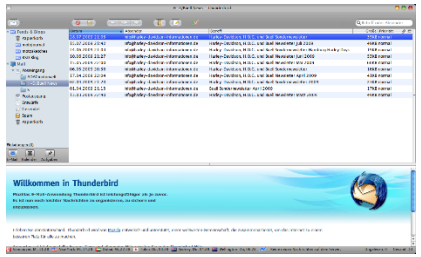

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Other protocols
(NOT SMTP)

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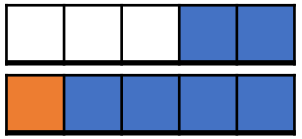
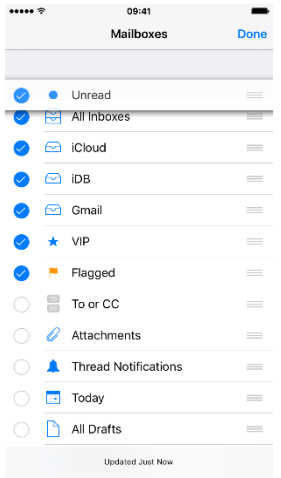




What should happen if Alice sends an email to Bob, but they're in different organizations (different mail servers)?

A. Her mail **client** sends a message to his mail **server**

B. Her mail **server** sends a message to his mail **server**

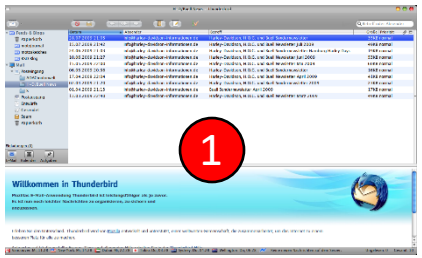
C. Her mail **server** sends a message to his mail **client**

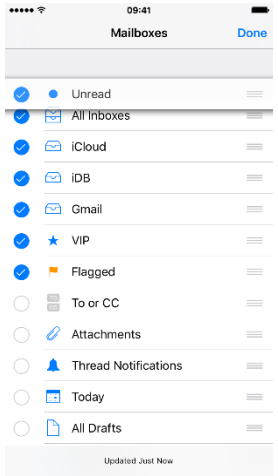
D. Her mail **client** sends a message to his mail **client**

Different organizations, two servers

(1) Alice composes message in mail client.
(2) Alice's client transfers message to her server, via SMTP, where it goes in a queue.

Mail user agent (MUA)
"mail client"





Mail transfer agent (MTA)
"mail server"

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"mail server"

Alice

SMTP

2

Outgoing queue:

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Mailboxes:
Alice:

Mailboxes:
Bob:

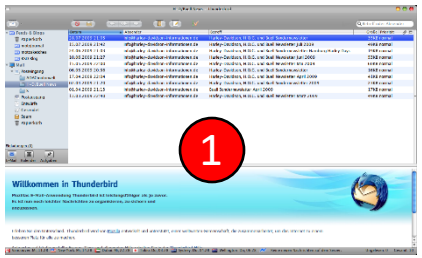
Bob

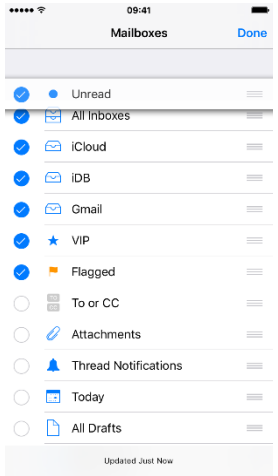
Different organizations, two servers

(3) Alice's server uses SMTP to transmit message to Bob's server.

If this fails for some reason, Alice's server will try again (details depend on server configuration).

Mail user agent (MUA)
"mail client"





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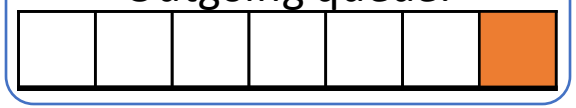

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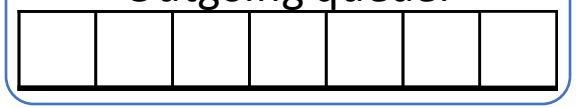

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Different organizations, two servers

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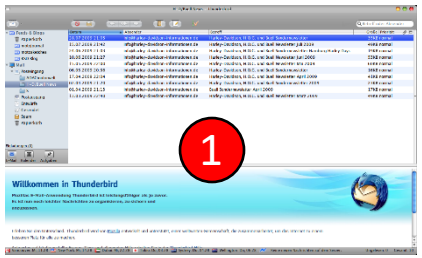
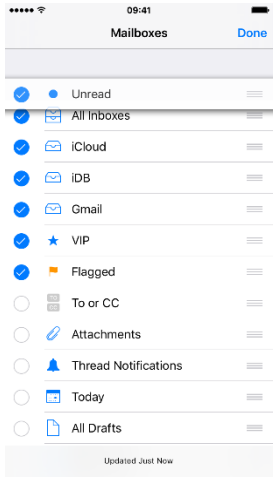


(4) Bob's server places the message in Bob's mailbox, waiting for him to retrieve it.
(5) Eventually, Bob comes along asking for new messages.



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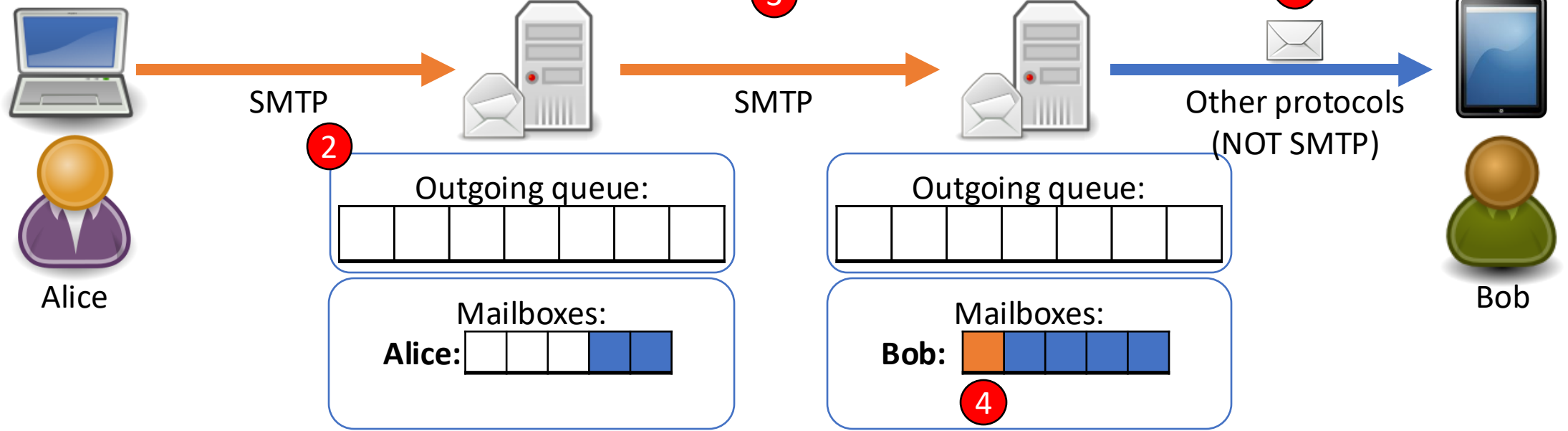


Simple Mail Transfer: SMTP [RFC 2821]

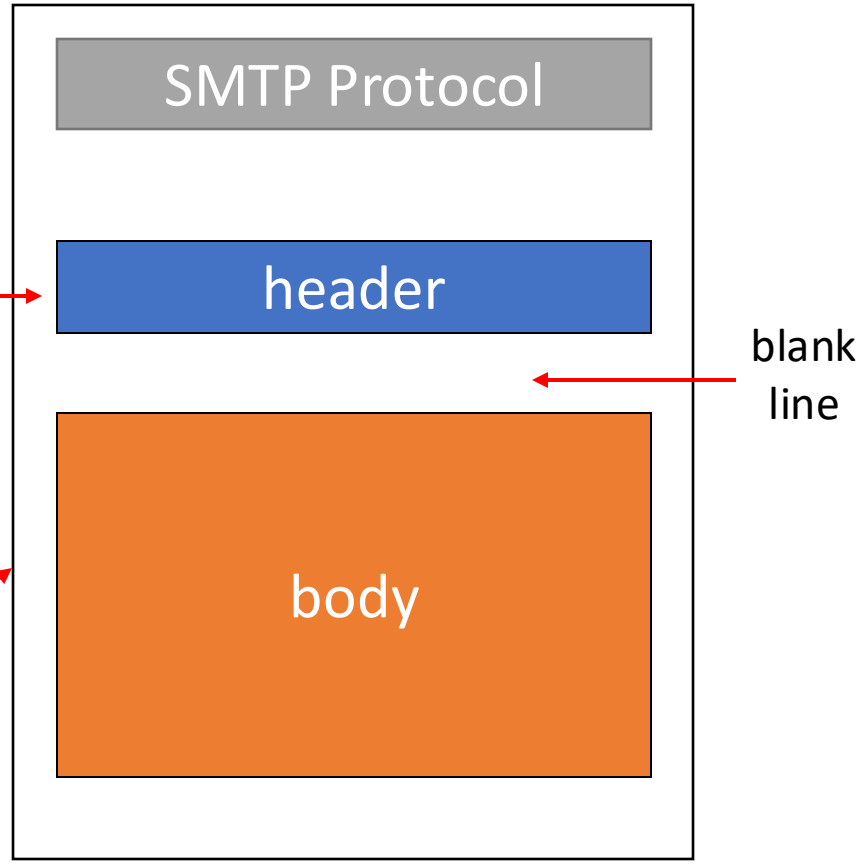
- Uses TCP to reliably transfer email message from client to server, port 25
- Direct transfer: sending server to receiving server (no intermediate servers)
- Three phases of transfer
  - handshaking (greeting)
  - transfer of messages
  - closure
- Command/response interaction (like HTTP, FTP)
  - commands: ASCII text
  - response: status code and phrase
- Messages must be in 7-bit ASCII

SMTP Message Format

RFC 822: standard for text message format:

- header lines, e.g.,
  - To:
  - From:
  - Subject:

  different from SMTP MAIL FROM, RCPT TO: commands!
- Body: the "message"
  - ASCII characters only
  - Signal EOM with "\r\n.\r\n"



SMTP messages

- HELO <domain> (or) EHLO <domain>
- MAIL FROM:<address>
- RCPT TO:<address> (can repeat)
- DATA
- (message goes here)
- CRLF.CRLF

- (greeting)identify the sender's domain name
- Identify sender's address
- Identify recipient address(es)
- End of SMTP phase, message data comes next
- End of message data (done)

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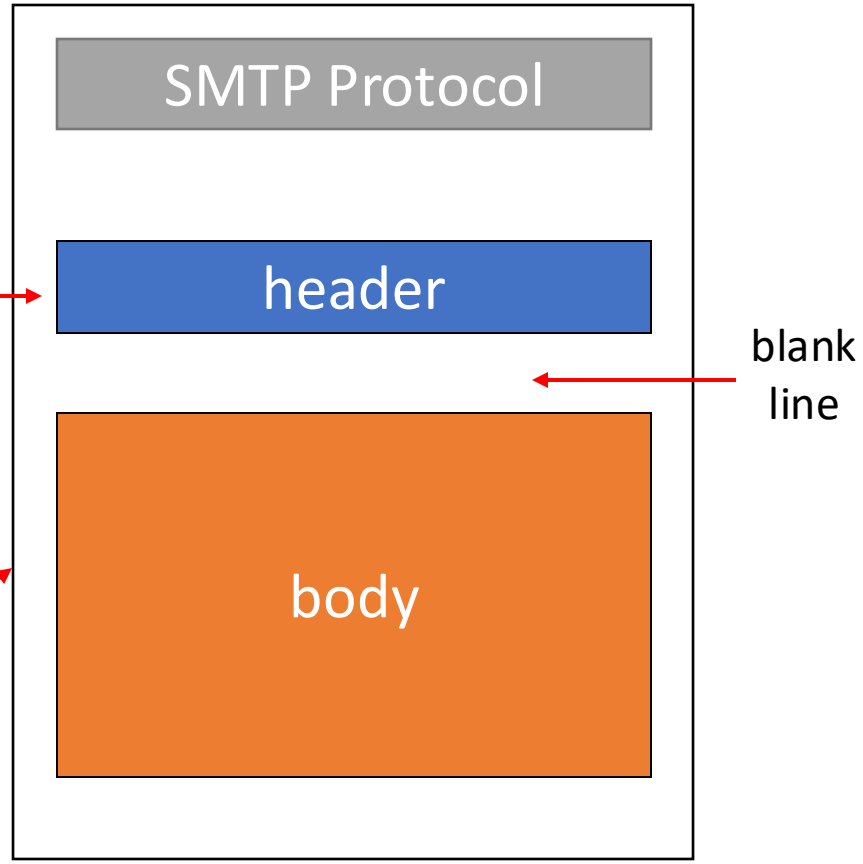


Try SMTP interaction for yourself:

- **`telnet allspice.cs.swarthmore.edu 25`**
- You should see a 220 reply from the server.
- enter HELO, MAIL FROM, RCPT TO, DATA, QUIT commands

(lets you send email without using email client (MUA))

Demo

Sample SMTP interaction

```
$ telnet allspice.cs.swarthmore.edu 25
Trying 130.58.68.9…
Connected to allspice.cs.swarthmore.edu
220 allspice.cs.swarthmore.edu ESMTP Postfix
HELO cs.swarthmore.edu
250 allspice.cs.swarthmore.edu
MAIL FROM:<rware@cs.swarthmore.edu>
250 2.1.0 OK
RCPT TO:<rware@cs.swarthmore.edu>
250 2.1.5 OK
DATA
354 End data with <CR><LF>.<CR><LF>
To: Ranysha Ware <rware@cs.swarthmore.edu>
From: Ranysha Ware <rware@cs.swarthmore.edu>
Subject: Telnet test message

This is a test message, via telnet, to myself.
.
```

Sample SMTP interaction

```
$ telnet allspice.cs.swarthmore.edu 25
Trying 130.58.68.9…
Connected to allspice.cs.swarthmore.edu
220 allspice.cs.swarthmore.edu ESMTP Postfix
HELO cs.swarthmore.edu
250 allspice.cs.swarthmore.edu
MAIL FROM:<rware@cs.swarthmore.edu>
250 2.1.0 OK
RCPT TO:<rware@cs.swarthmore.edu>
250 2.1.5 OK
DATA
354 End data with <CR><LF>.<CR><LF>
To: Ranysha Ware <rware@cs.swarthmore.edu>
From: Ranysha Ware <rware@cs.swarthmore.edu>
Subject: Telnet test message

This is a test message, via telnet, to myself.
```

End of message:
CRLF (Dot) CRLF

What keeps us from entering a fake information (e.g., FROM address)?

A. Nothing.

B. The MTA checks that the FROM is valid.

C. We enter a name/password logging into the MTA.

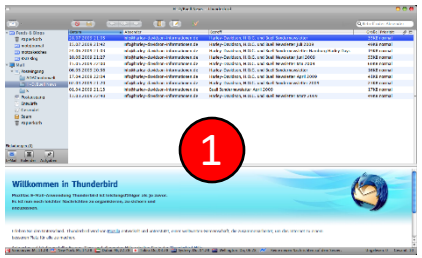
Fun Demo

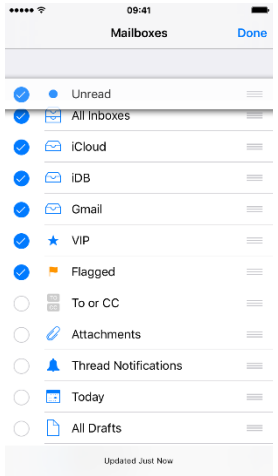
Wait…why does this work?

(3) Alice's server uses SMTP to transmit message to Bob's server.

If this fails for some reason, Alice's server will try again (details depend on server configuration).

Mail user agent (MUA)
"mail client"





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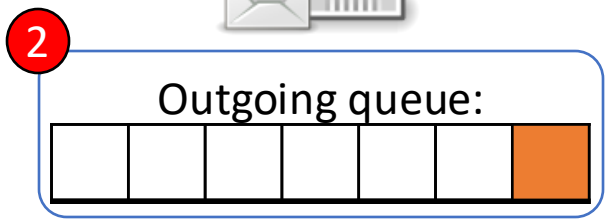
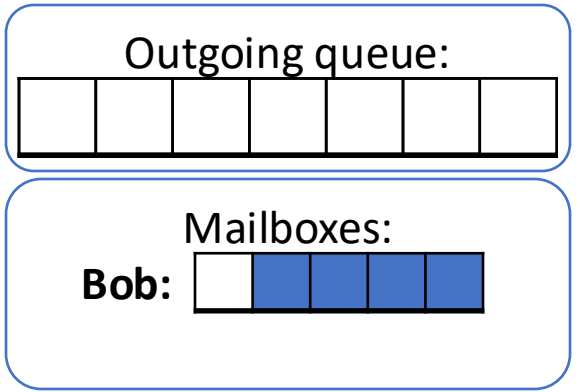




This seems too horrible to be true. Surely we can prevent header forging?

(How or why not?)

A. Yes

B. No

Message Signing

1. Sender creates cryptographic public/private key pair, publishes public key to the world.

2. Sender uses private key to sign messages.

3. Receiver can verify*, using published public key, that only the holder of the corresponding private key could have sent the message.

* With very high probability.

Message Signing: Challenges

- Disseminating public keys
  - How do you trust that the published public key isn't also a lie?

- It's more work, can't be bothered…
  - Adoption is very low

Server to Server Verification

- Published lists of "bad" IP addresses for blocklists
- LOTS of other techniques
  - See: https://en.wikipedia.org/wiki/Anti-spam_techniques
- Big problem: false positives

SMTP versus HTTP

- HTTP: pull
- SMTP: push

- Both have ASCII command/response interaction, status codes

- HTTP: each object encapsulated in its own response message

- SMTP: multiple objects sent in multipart message

SMTP: final words

- SMTP uses persistent connections
  - Can send multiple emails in one session
- SMTP requires message (header & body) to be in 7-bit ASCII
- SMTP server uses CRLF.CRLF to determine end of message

If SMTP only allows 7-bit ASCII, how do we send pictures/videos/files via email?

A. We encode these objects as 7-bit ASCII

B. We use a different protocol instead of SMTP

C. We're really sending links to the objects, rather than the objects themselves

Base 64

- Designed to be an efficient way to send binary data as a string
- Uses A-Z, a-z,0-9, “+” and “/” as digits
- A number with digits $d_n d_{n-1} \ldots\ldots d_1 d_0$ = $64^n * d_n + 64^{n-1} * d_{n-1} + \ldots + 64^* d_1 + d_0$
- Recall from CS 31: Other non-base-10 number systems (binary, octal, hex).

Multipurpose Internet Mail Extensions (MIME)

- Special formatting instructions

- Indicated in the header portion of message (not SMTP)
  - SMTP does *not* care, just looks like message data

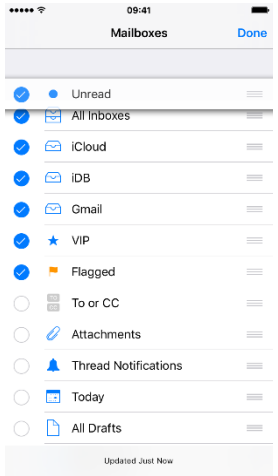
- Supports
  - Text in character sets other than ASCII
  - Non-text attachments
  - Message bodies with multiple parts
  - Header information in non-ASCII character sets

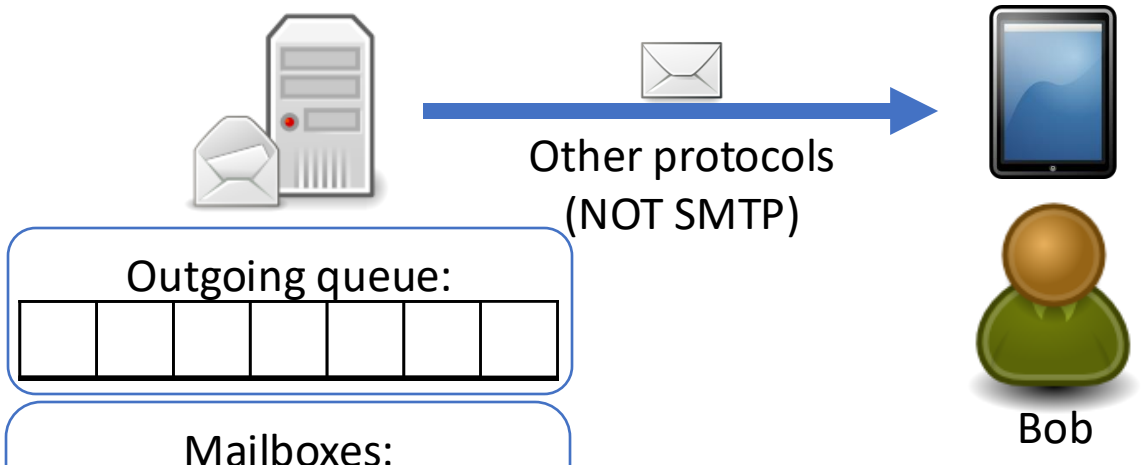
MIME

- Adds optional headers
  - Designed to be compatible with non-MIME email clients
  - Both clients must understand it to make sense of it
- Specifies content type, other necessary information
- Designates a boundary between email text and attachments

Mail Access Protocols

- Post Office Protocol: authorization, download
- Internet Mail Access Protocol (IMAP): more features, including manipulation of stored messages on server
- Webmail: gmail, Hotmail, Yahoo! Mail, etc.
- Proprietary protocols (Microsoft Exchange)





POP3 protocol

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 1 contents>
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off
```

More about POP3

- Previous example uses "download and delete" mode
  - Bob cannot re-read e-mail if he changes client
- POP3 "download-and-keep": copies of messages on different clients
- POP3 is stateless across sessions
- Limitations:
  - Can't retrieve just the headers
  - Can't impose structure on messagesa

IMAP

- Keeps all messages in one place: at server
- Allows user to organize messages in folders
- Keeps user state across sessions:
  - names of folders and mappings between message IDs and folder name
- Can request pieces of a message (e.g., text parts without large attachments)

Webmail

- Uses a web browser
- Sends emails using HTTP rather than POP3 or IMAP
- Mail is stored on the 3rd party webmail company's servers

Summary

- Three main parts to email:
  - Mail User Agent (mail client): read / write for humans
  - Mail Transfer Agent: server that accepts / sends messages
  - SMTP protocol used to negotiate transfers

- No SMTP support for fraud detection

- Extensions (MIME) and encodings (Base64) for sending non-text data