Network Applications: Overview, Email, DNS

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https://sngroup.org.cn/courses/cnns-xmuf23/index.shtml

9/26/2023

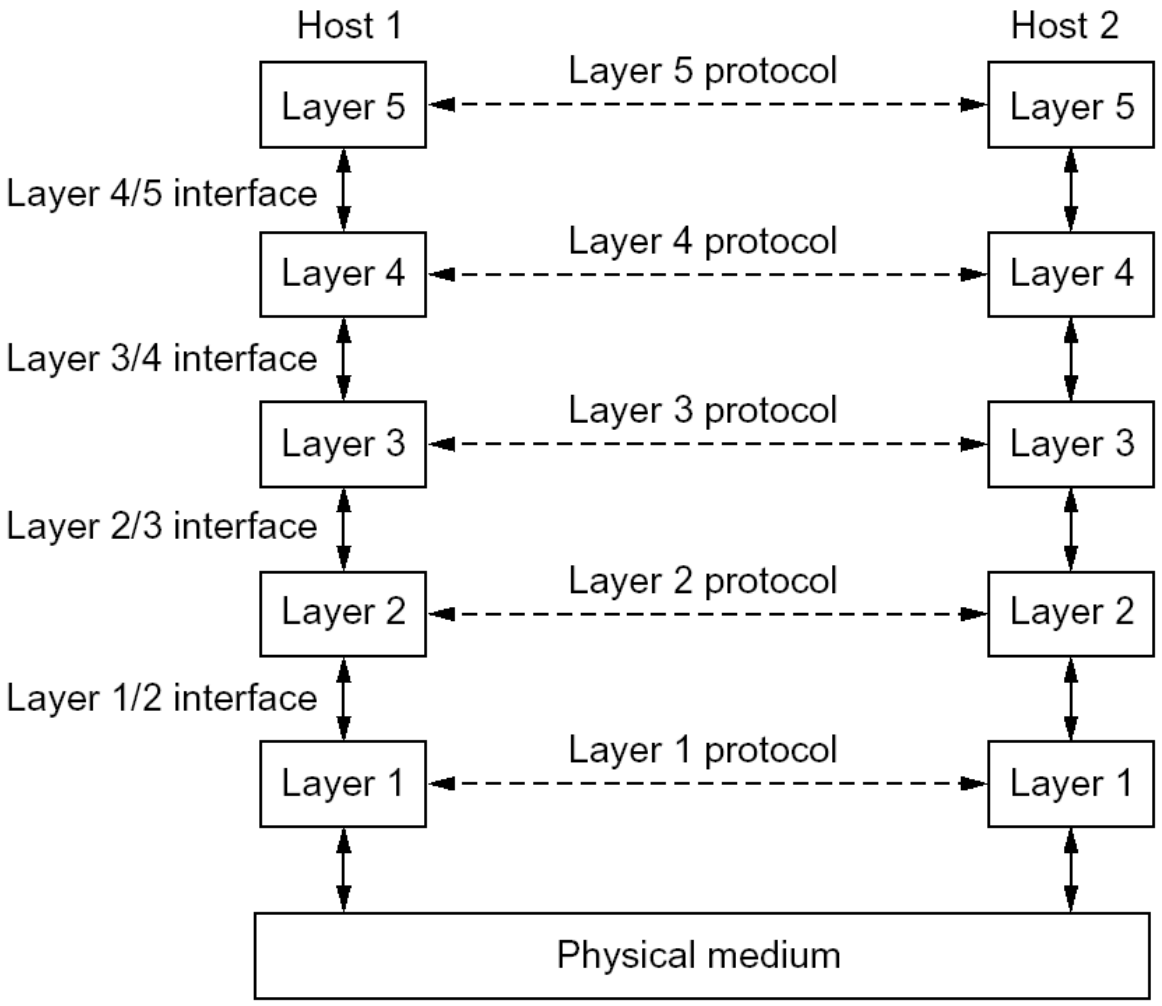
This deck of slides are heavily based on CPSC 433/533 at Yale University, by courtesy of Dr. Y. Richard Yang.

Outline

- Admin. and recap
- Application layer overview
- Network applications
  - Email
  - DNS

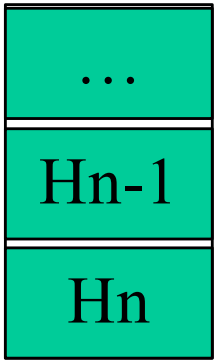
Recap: Layering

- Why layering
  - reference model
  - modularization
- Concepts
  - service, interface, and protocol
  - physical vs logical communication
- Key design decision
  - end-to-end argument to place functions in layers

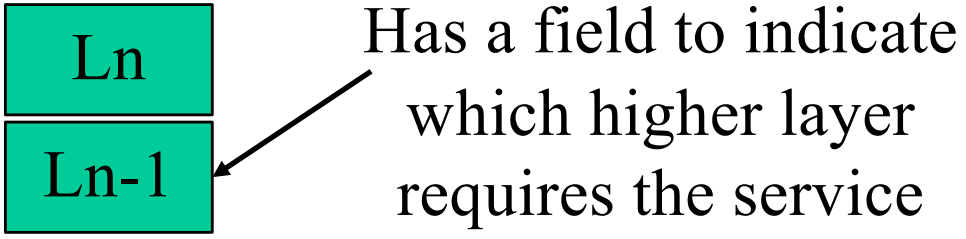


Some Implications of Layered Architecture

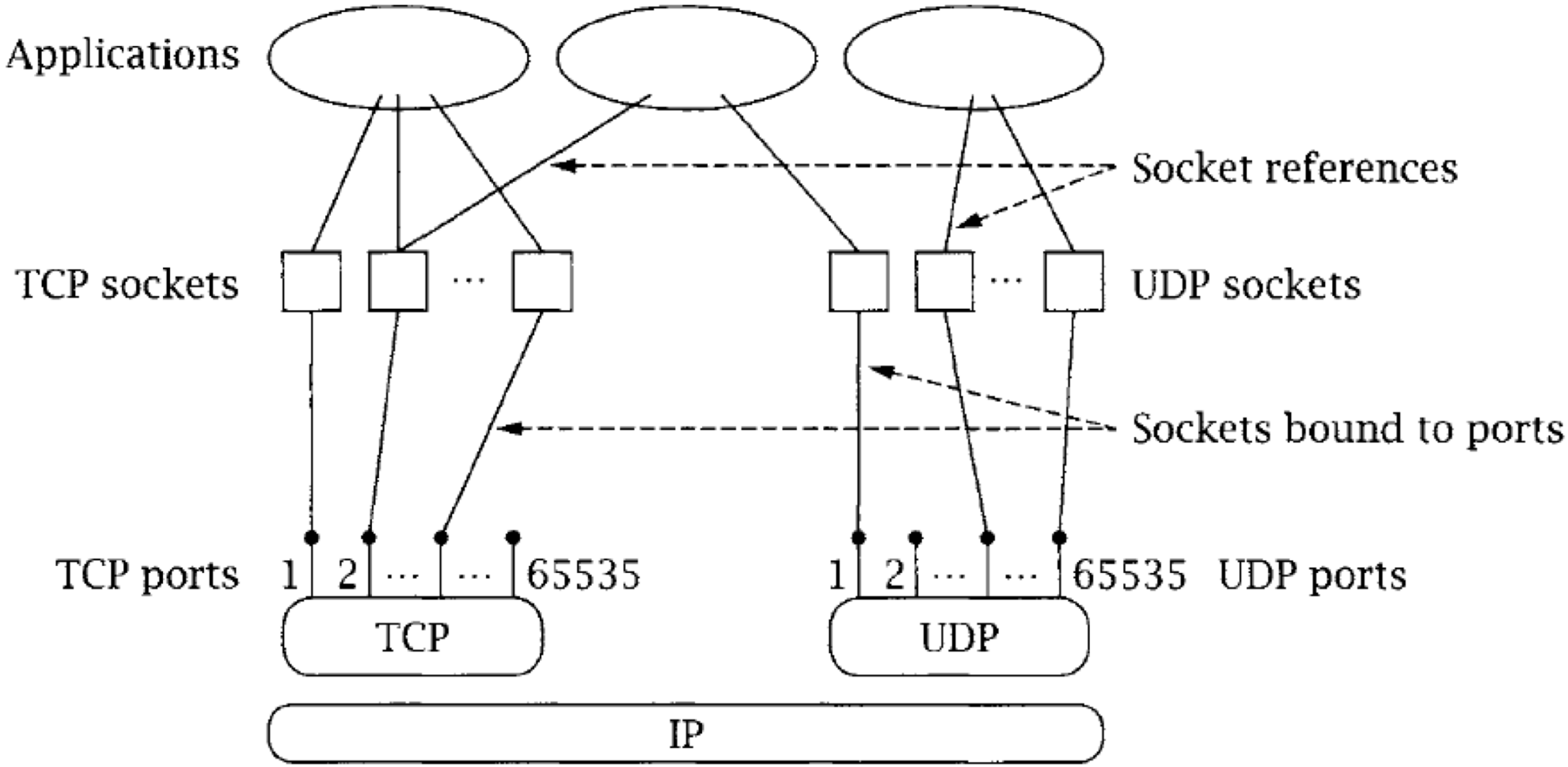
- A packet as a stack container



- Each layer needs multiplexing and demultiplexing to serve layer above

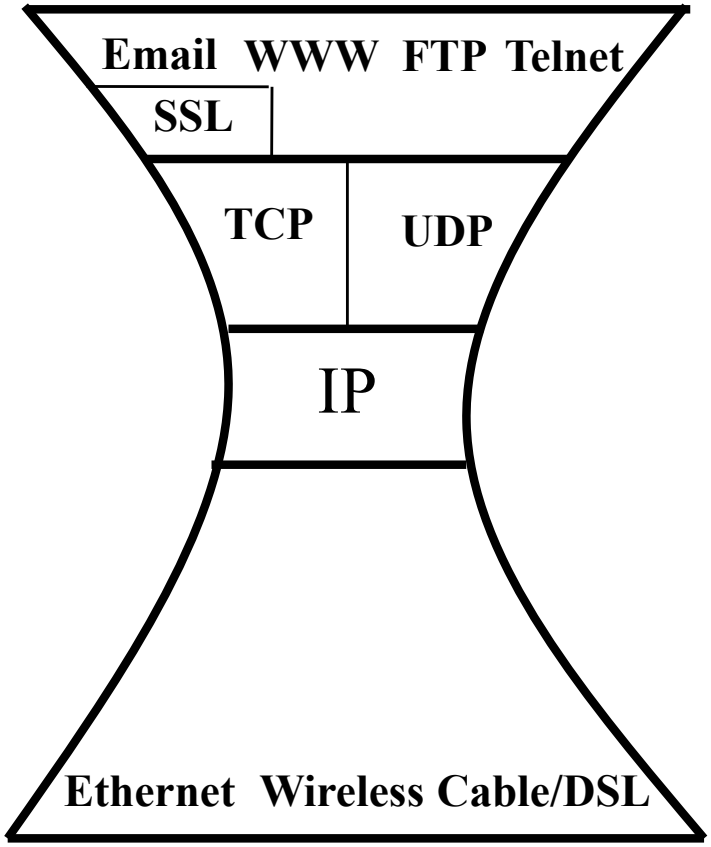


Multiplexing/Demultiplexing

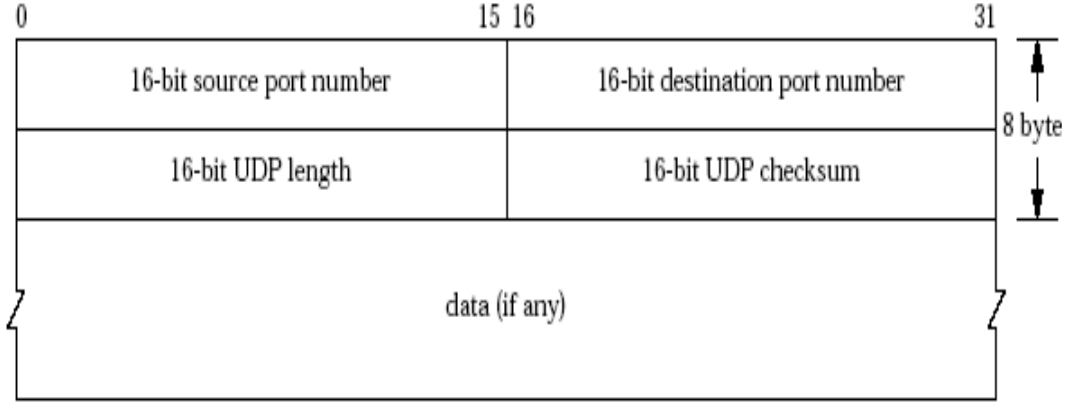


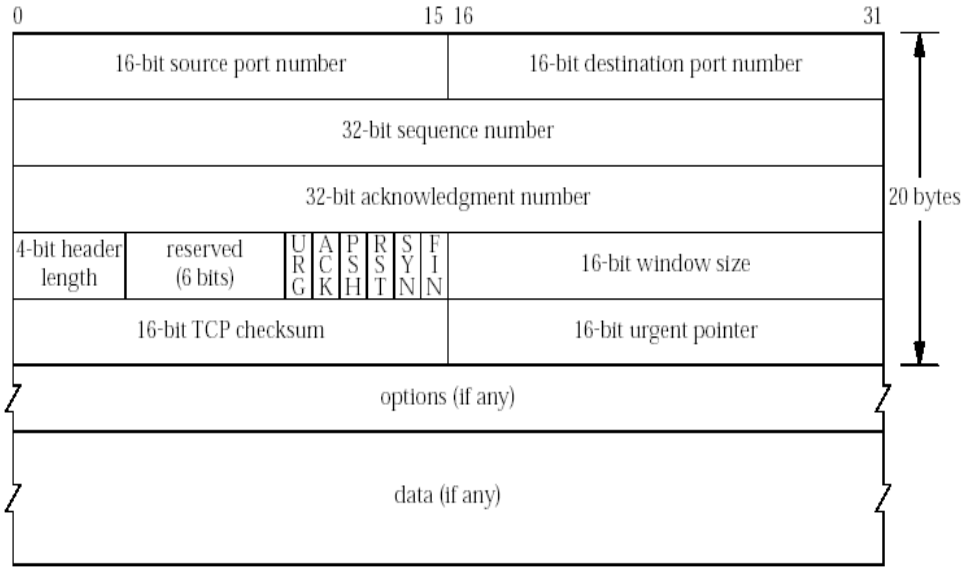
Recap: The Big Picture of the Internet

- Hosts and routers:
  - ~ 1 bill. hosts
  - organized into ~50K networks
  - backbone links 100 Gbps
- Software:
  - datagram switching with virtual circuit support
  - layered network architecture
    - use end-to-end arguments to determine the services provided by each layer
    - the 5-layer hourglass architecture of the Internet

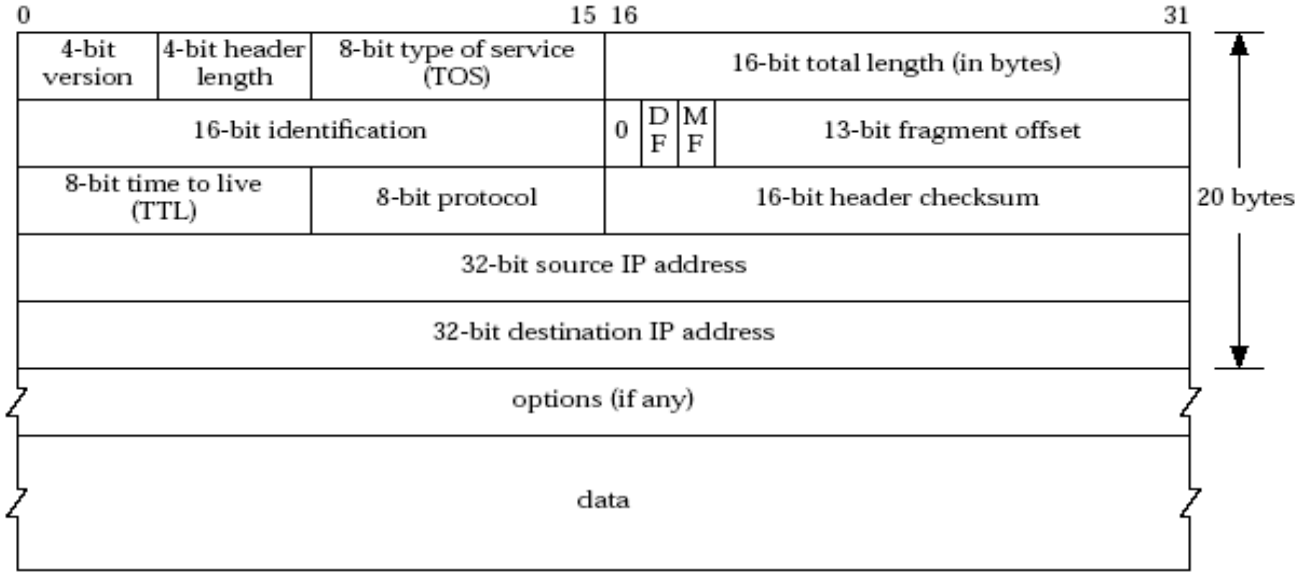


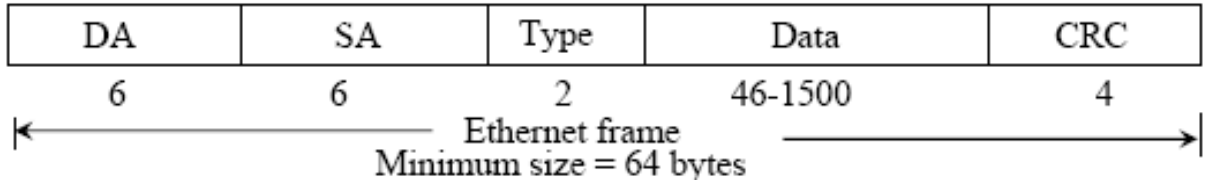
Formats of main protocols





Tip: services map to header fields





Outline

- Admin. and recap
- *Application layer overview*

Application Layer: Goals

- Conceptual + implementation aspects of network application protocols
  - client server paradigm
  - peer to peer paradigm
  - network app. programming

- Learn about applications by examining common applications
  - smtp/pop
  - dns
  - http (1, 1.1, /2)
  - content distribution
  - peer-to-peer

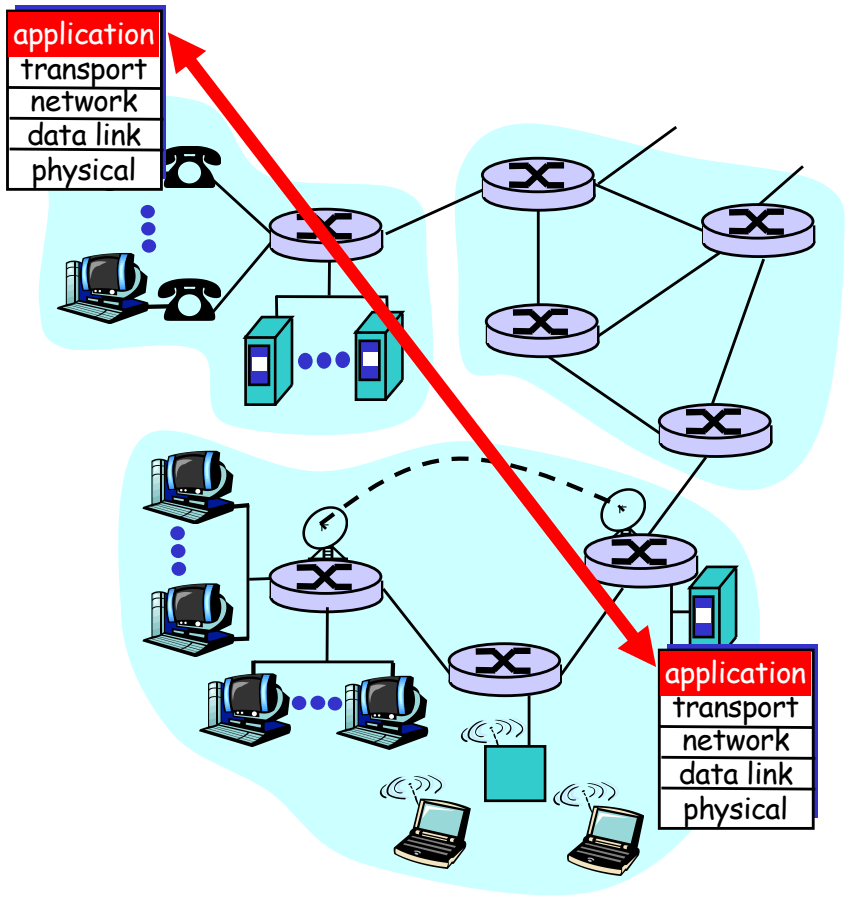
Network Applications vs. Application-layer Protocols

Network application: communicating, distributed processes

- a process is a program that is running within a host
  - a user agent is a process serving as an interface to the user
    - web: browser
    - streaming audio/video: media player
- processes communicate by an application-layer protocol
  - e.g., email, Web

Application-layer protocols

- one "piece" of an app
- define messages exchanged by apps and actions taken
- implementing services by using the service provided by the lower layer, i.e., the transport layer



App. and Trans.: App. Protocols and their Transport Protocols

- An application needs to choose the transport protocol

Application	Application layer protocol	Underlying transport protocol
e-mail	smtp [RFC 821]	TCP/SSL
remote terminal access	telnet [RFC 854]	TCP
Web	http [RFC 2068]	TCP/SSL
file transfer	ftp [RFC 959]	TCP
Internet telephony	proprietary (e.g., Vocaltec)	typically UDP
remote file server	NFS	TCP or UDP
streaming multimedia	proprietary	typically UDP but moving to http

Client-Server Paradigm

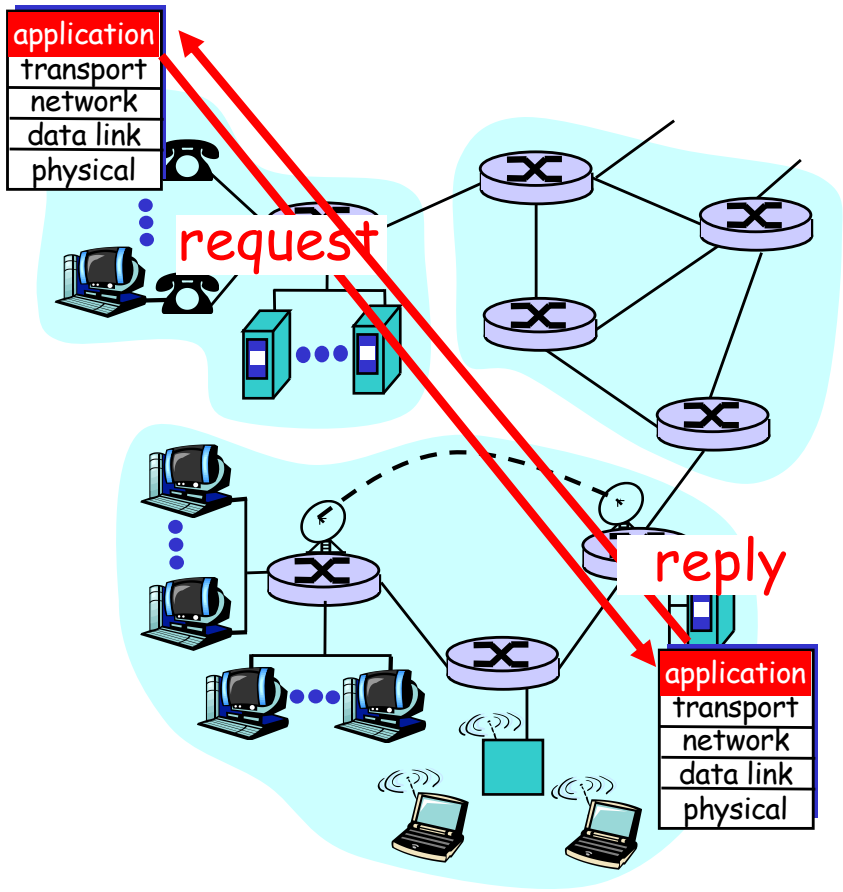
Typical network app has two pieces: *client* and *server*

Client (C):

- initiates contact with server ("speaks first")
- typically requests service from server
- for Web, client is implemented in browser; for e-mail, in mail reader

Server (S):

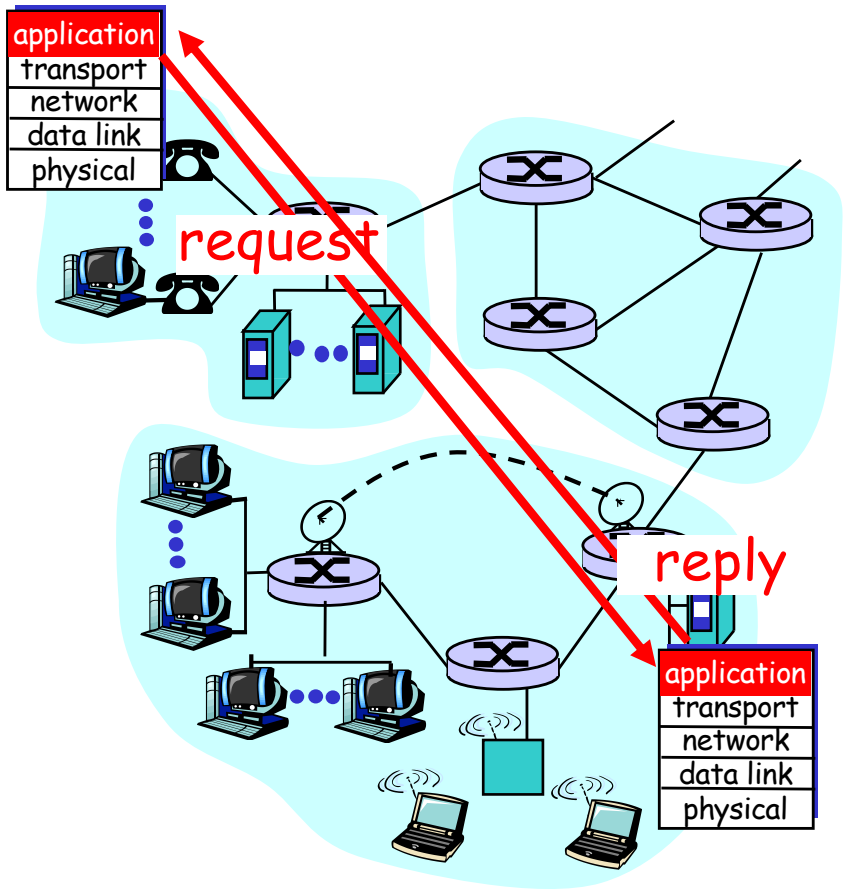
- provides requested service to client
- e.g., Web server sends requested Web page; mail server delivers e-mail



Client-Server Paradigm: Key Questions

Key questions to ask about
a C-S application

- Is the application **extensible**?
- Is the application **scalable**?
- How does the application handle server failures (being **robust**)?
- How does the application handle **security**?



Outline

- Admin. and recap
- Application layer overview
- Network applications
  - *Email*

Electronic Mail

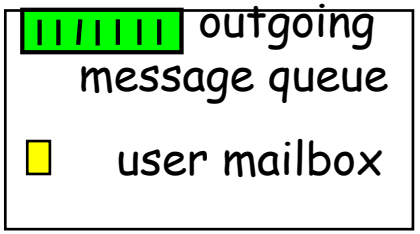
- Still active
  - 80B emails/day
  - 3.9B active email boxes

- A highly recommended reading: a history of Email development
  - linked on the Schedule page

Demo: SMTP

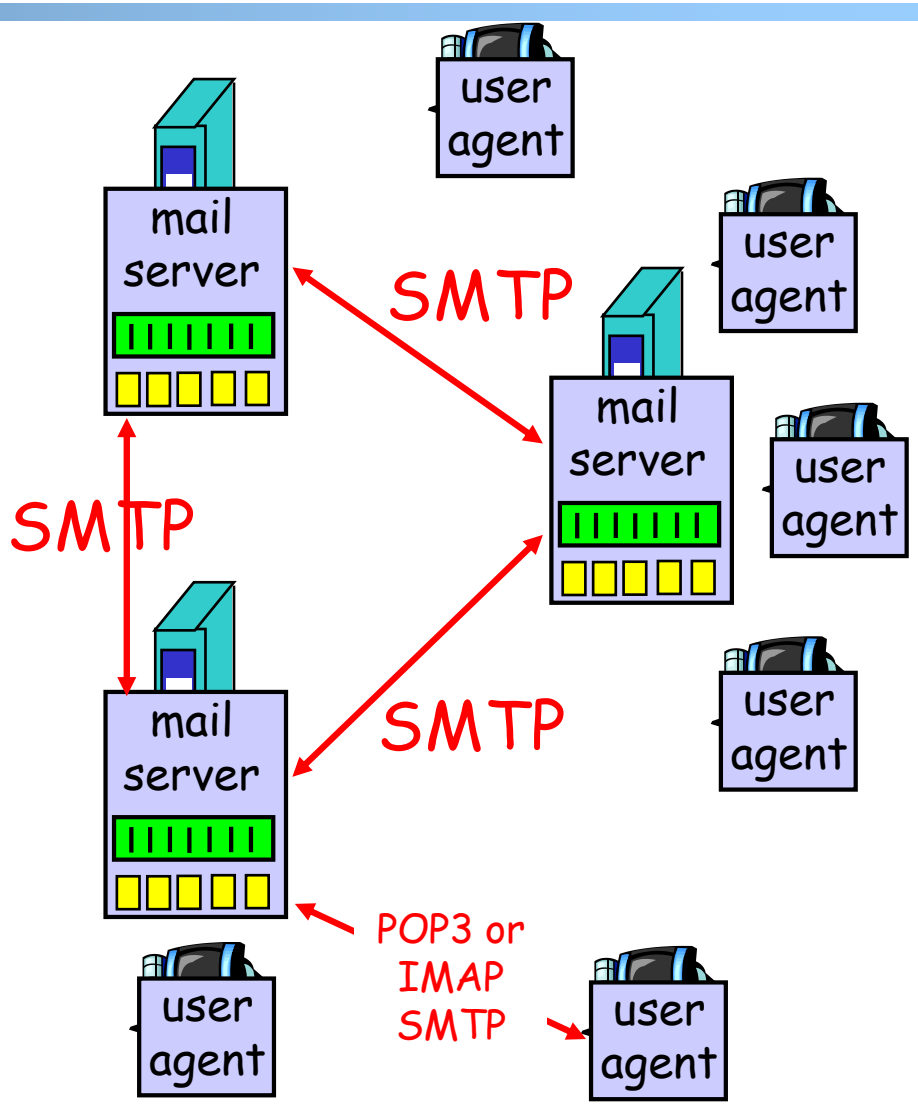
telnet smtp.sina.com 25
C: auth login
S: 334 VXNlcm5hbWU6
C: eG11Y25ucw==
S: 334 UGFzc3dvcmQ6
C: MzM0ZjU2MDVkZjE1MDRmOQ==
S: 235 OK Authenticated
C: mail from:xmucnns@sina.com
S: 250 ok
C: rcpt to:qiaoxiang@xmu.edu.cn
S: 250 ok
C: data
S: 354 End data with <CR><LF>.<CR><LF>
C: Date:2023-9-26 12:36
C: From:xmucnns@sina.com
C: To:qiaoxiang@xmu.edu.cn
C: Subject:test smtp
C:
C: Hello, Qiao.
C:
C: .
S: 250 ok queue id 11479549283321
C: quit
S: 221 smtp-97-27.smtpsmail.fmail.bx.sinanode.com
S: Connection closed by foreign host.

Electronic Mail: Components



Three major components:

- User agents
- Mail servers
- Protocols
  - Mail transport protocol
    - SMTP
  - Mail access protocols
    - POP3: Post Office Protocol [RFC 1939]
    - IMAP: Internet Mail Access Protocol [RFC 1730]



Email Transport Architecture

MUA: User Agent

Mediator: User-level Relay

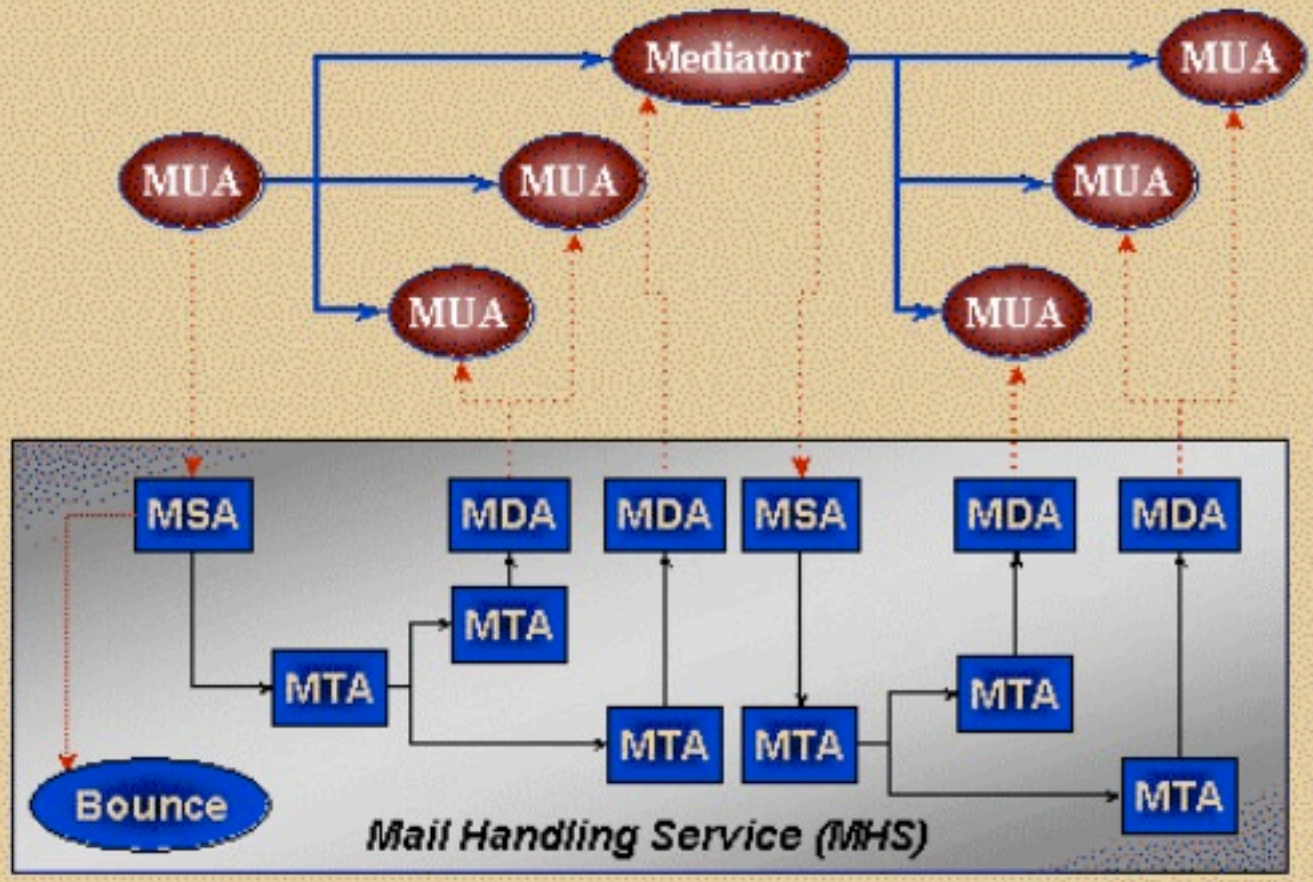
MHS: Mail Handling (transit) Service

MSA: Submission

MTA: Transfer

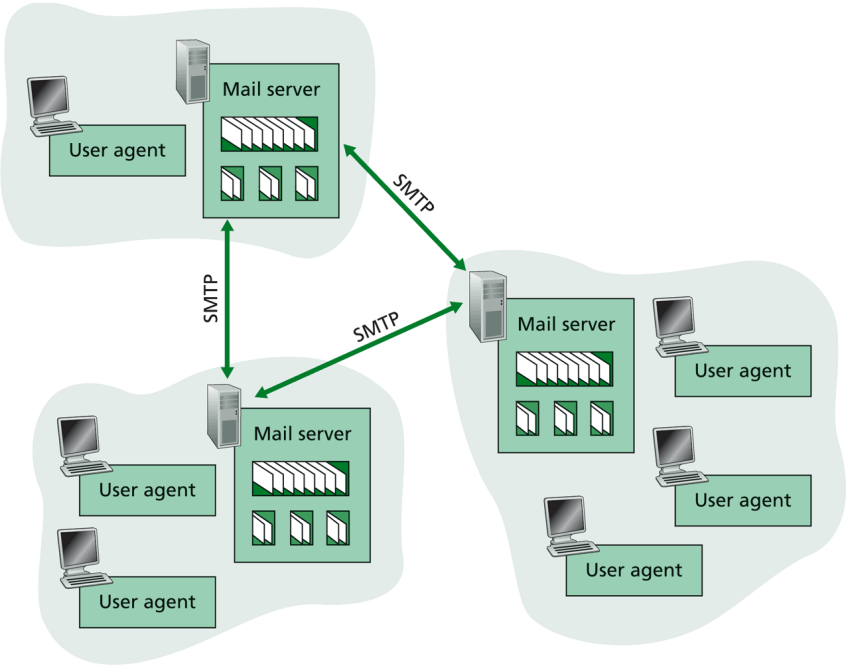
MDA: Delivery

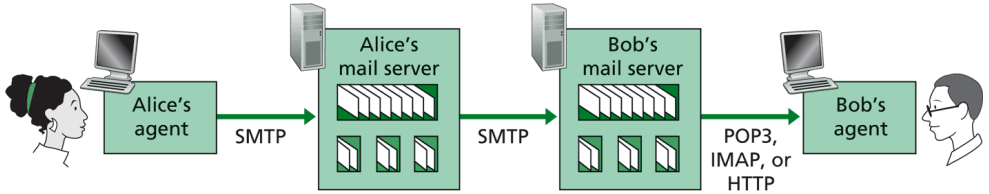
Bounce: Returns



http://www.maawg.org/sites/maawg/files/news/MAAWG_Email_Authentication_Paper_2008-07.pdf

SMTP: Mail Transport Protocol Messages (Envelop Messages)





C: auth login
S: 334 VXNlcm5hbWU6
C: eG11Y25ucw==
S: 334 UGFzc3dvcmQ6
C: MzM0ZjU2MDVkZjE1MDRmOQ==
S: 235 OK Authenticated
C: mail from:xmucnns@sina.com
S: 250 ok
C: rcpt to:qiaoxiang@xmu.edu.cn
S: 250 ok
C: data
S: 354 End data with <CR><LF>.<CR><LF>
C: Date:2023-9-25 12:36
C: From:xmucnns@sina.com
C: To:qiaoxiang@xmu.edu.cn
C: Subject:test smtp
C:
C: Hello, Qiao.
C:
C: .
S: 250 ok qu
C: quit
S: 221 smtp-
S: Connectio

Email text different from SMTP protocol message

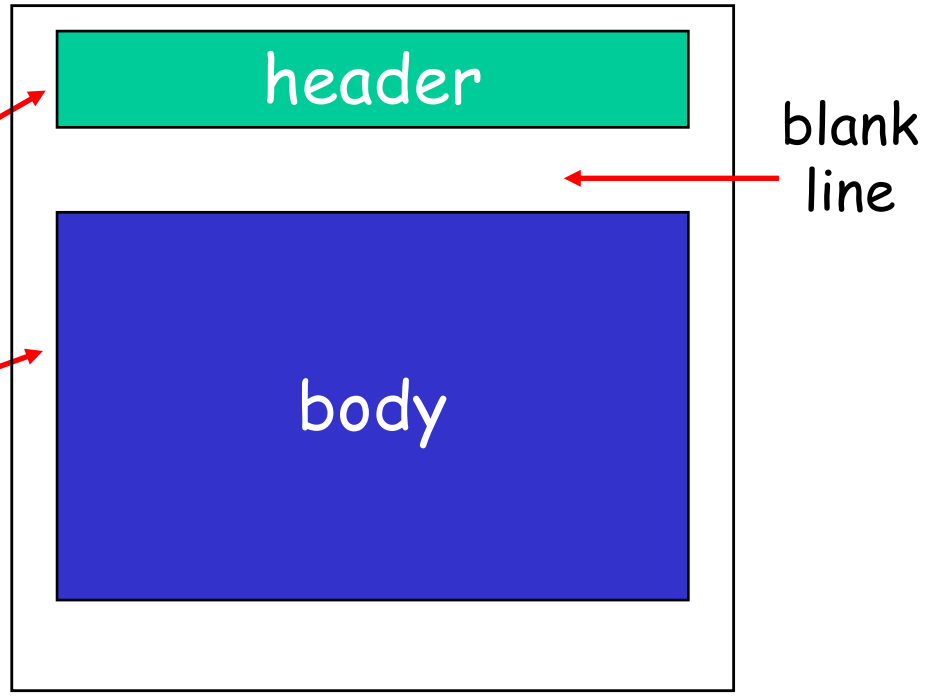
%telnet smtp.sina.com 25

Mail Message Data

SMTP: protocol for exchanging email msgs

RFC 822: standard for text message format:

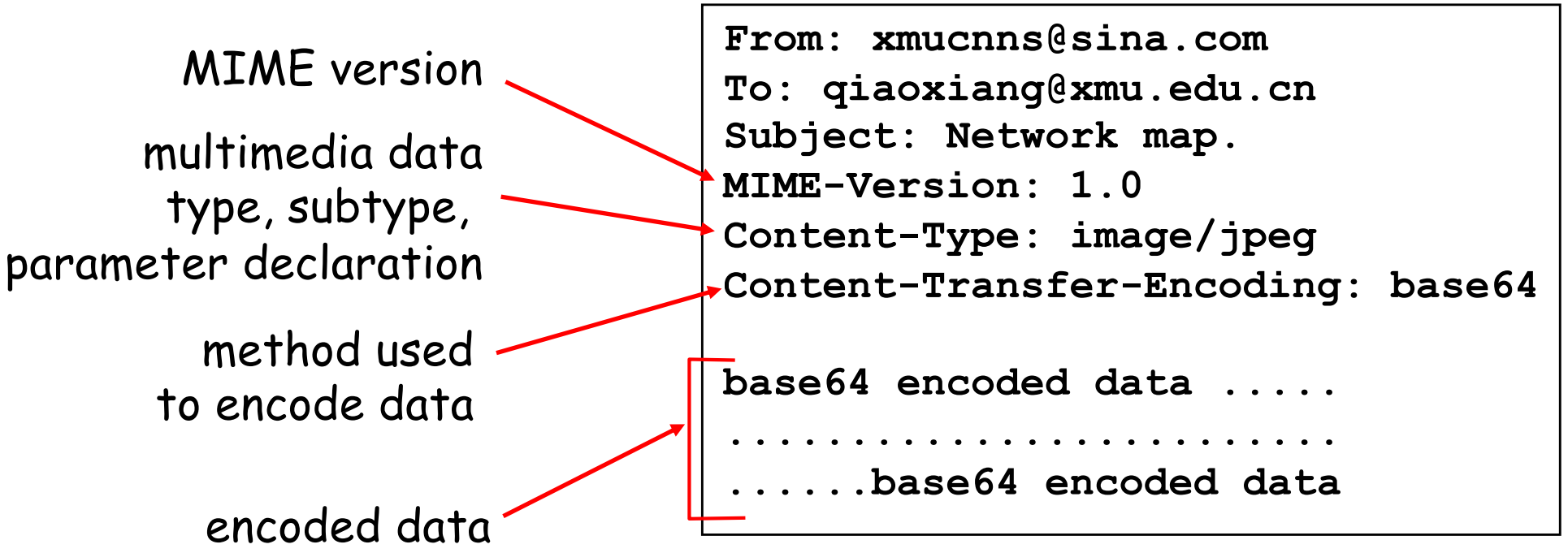
- Header lines, e.g.,
  - To:
  - From:
  - Subject:
- Body
  - the "message", ASCII characters only



Benefit of separating protocol and msg: easier extensibility

Message Format: Multimedia Extensions

- MIME: multimedia mail extension, RFC 2045, 2056
- Additional lines in msg header declare MIME content type



Benefit of MIME type: self describing data type, adding extensibility.

Multipart Type: How Attachment Works

```
From: xmucnns@sina.com
To: qiaoxiang@xmu.edu.cn
Subject: Network map.
MIME-Version: 1.0
Content-Type: multipart/mixed; boundary=98766789

--98766789
Content-Transfer-Encoding: quoted-printable
Content-Type: text/plain

Hi,
Attached is network topology map.
--98766789
Content-Transfer-Encoding: base64
Content-Type: image/jpeg

base64 encoded data .....
.........................
......base64 encoded data
--98766789--
```

POP3 Protocol: Mail Retrieval

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 sina pop3 server ready
C: user xmucnns
S: +OK welcome to sina mail
C: pass 334f5605df1504f9
S: +OK 4 messages (32377 octets)
```

user successfully logged in

```
C: list
S: +OK 4 messages (32377 octets)
S: 1 10410
S: 2 10748
S: 3 7859
S: 4 3360
S: .
C: retr 4
S: +OK 3360 octets
C: dele 2
C: quit
S: +OK
```

POP3 server signing off

`%telnet pop.sina.com 110`

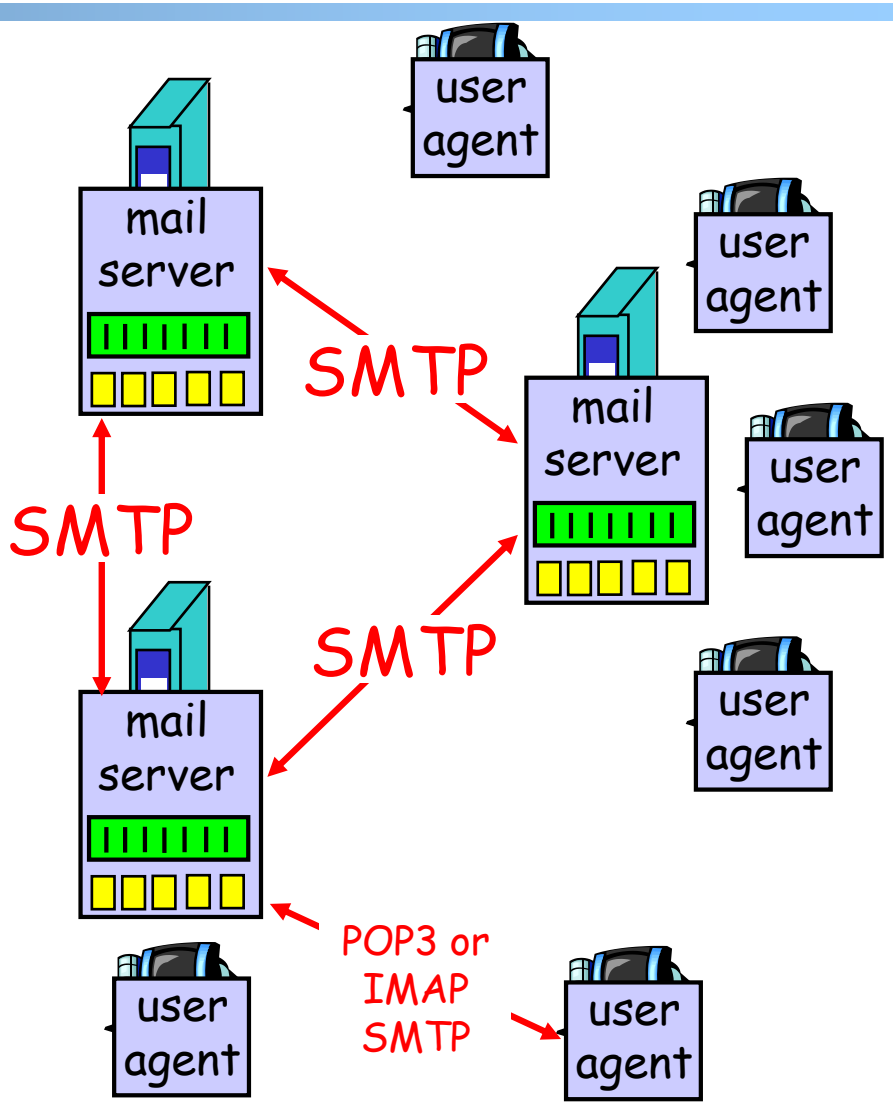
Exercise

- Register an email address at sina.com
- Send an email to the registered email address using smtp
- Retrieve using pop

Evaluation of SMTP/POP/IMAP

Key questions to ask about a C-S application

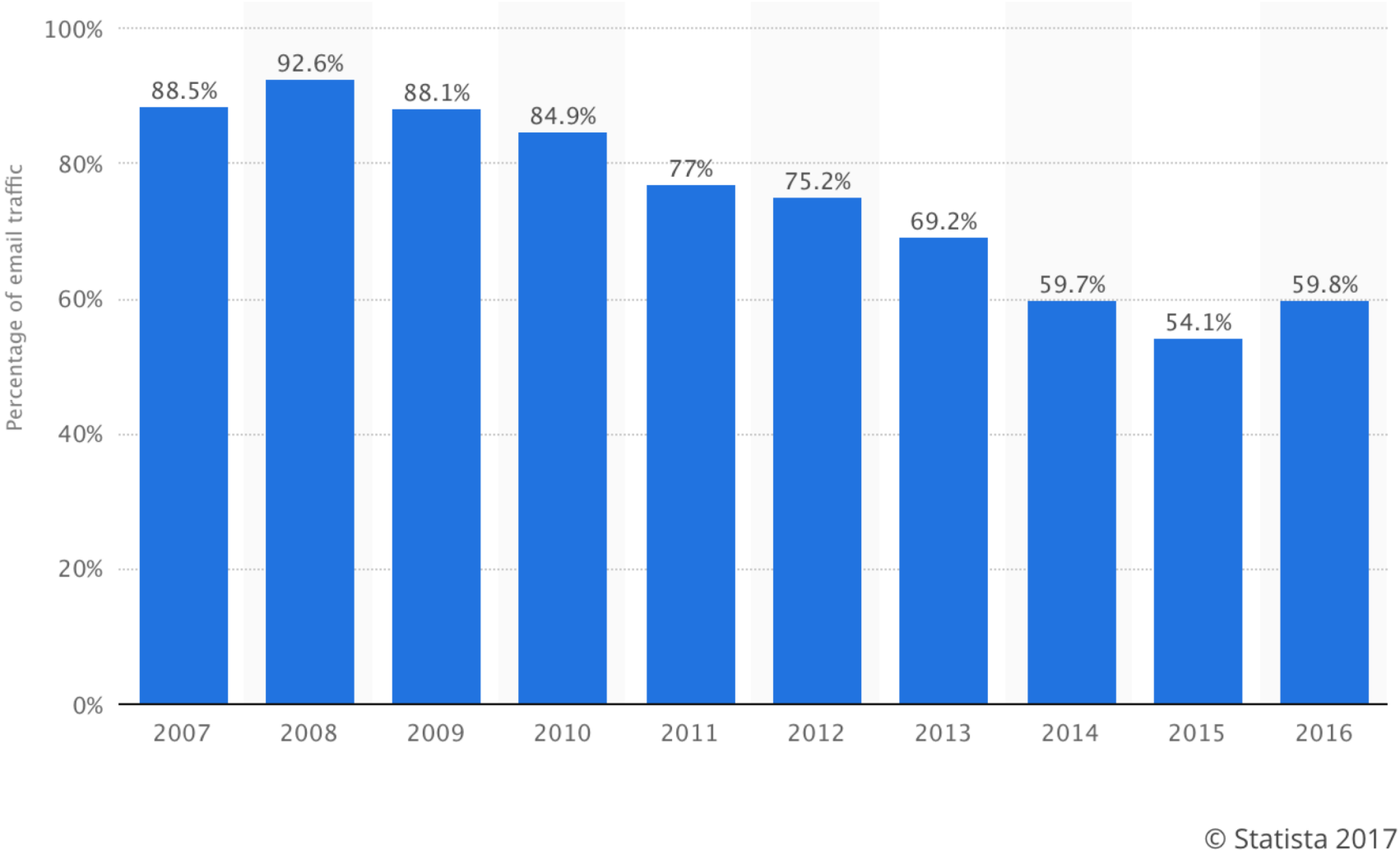
- extensible?
- scalable?
- robust?
- security?



Email Security: Spam

- Spam (Google)

Email Security Issue: Spam



Source: https://www.statista.com/statistics/420400/spam-email-traffic-share-annual/

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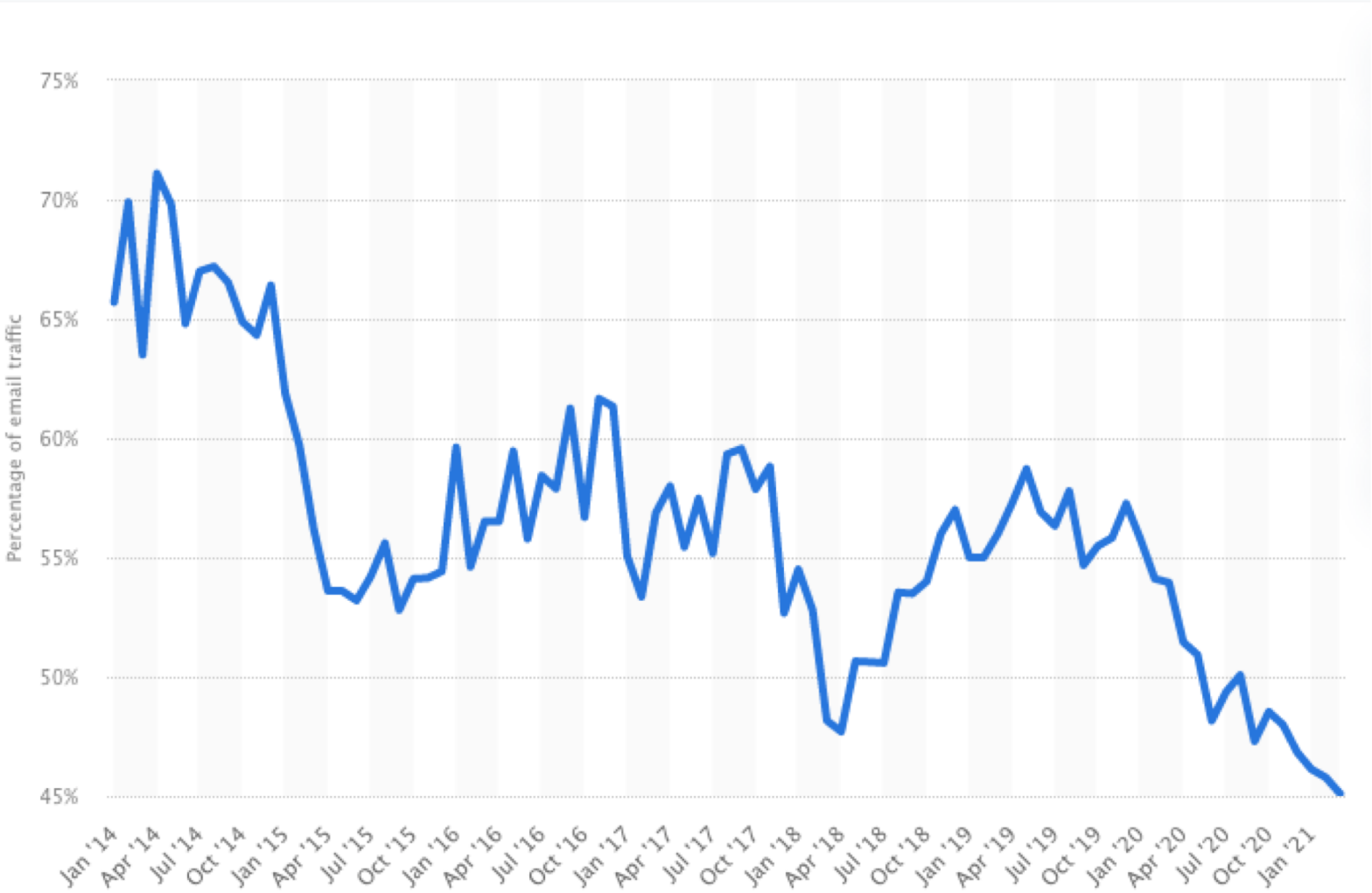


Source: https://www.statista.com/statistics/420391/spam-email-traffic-share/

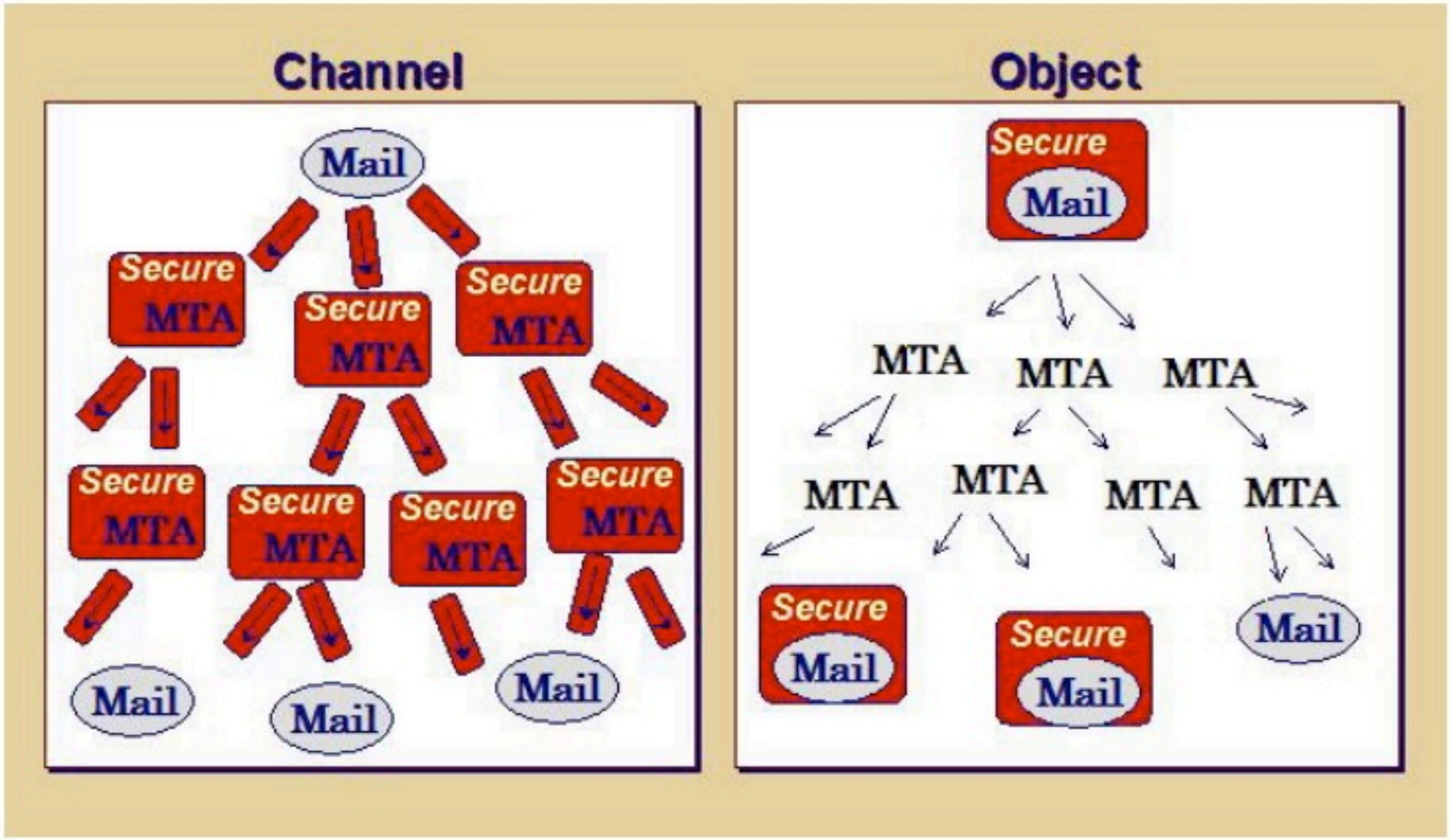
Discussion: How May One Handle Email Spams?

Detection Methods Used by GMail

- Known phishing scams
- Message from unconfirmed sender identity
- Message you sent to Spam/similarity to suspicious messages
- Administrator-set policies

https://support.google.com/mail/answer/1366858?hl=en

Email Authentication Approaches

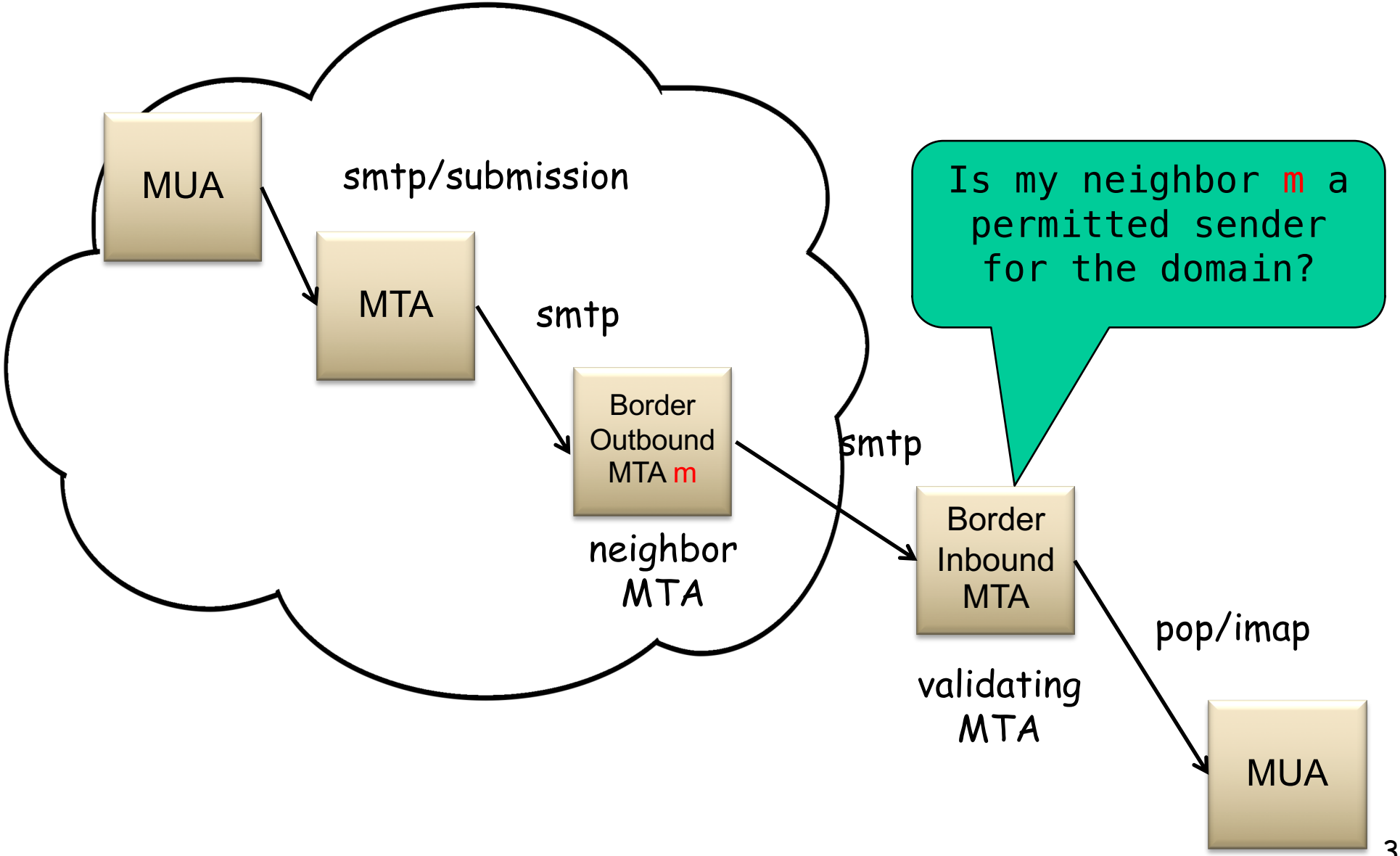


Sender Policy Frame (SPF)

DomainKeys Identified Mail (DKIM)
Authenticated Results Chain (ARC)

https://tools.ietf.org/html/rfc7208

Sender Policy Framework (SPF RFC7208)



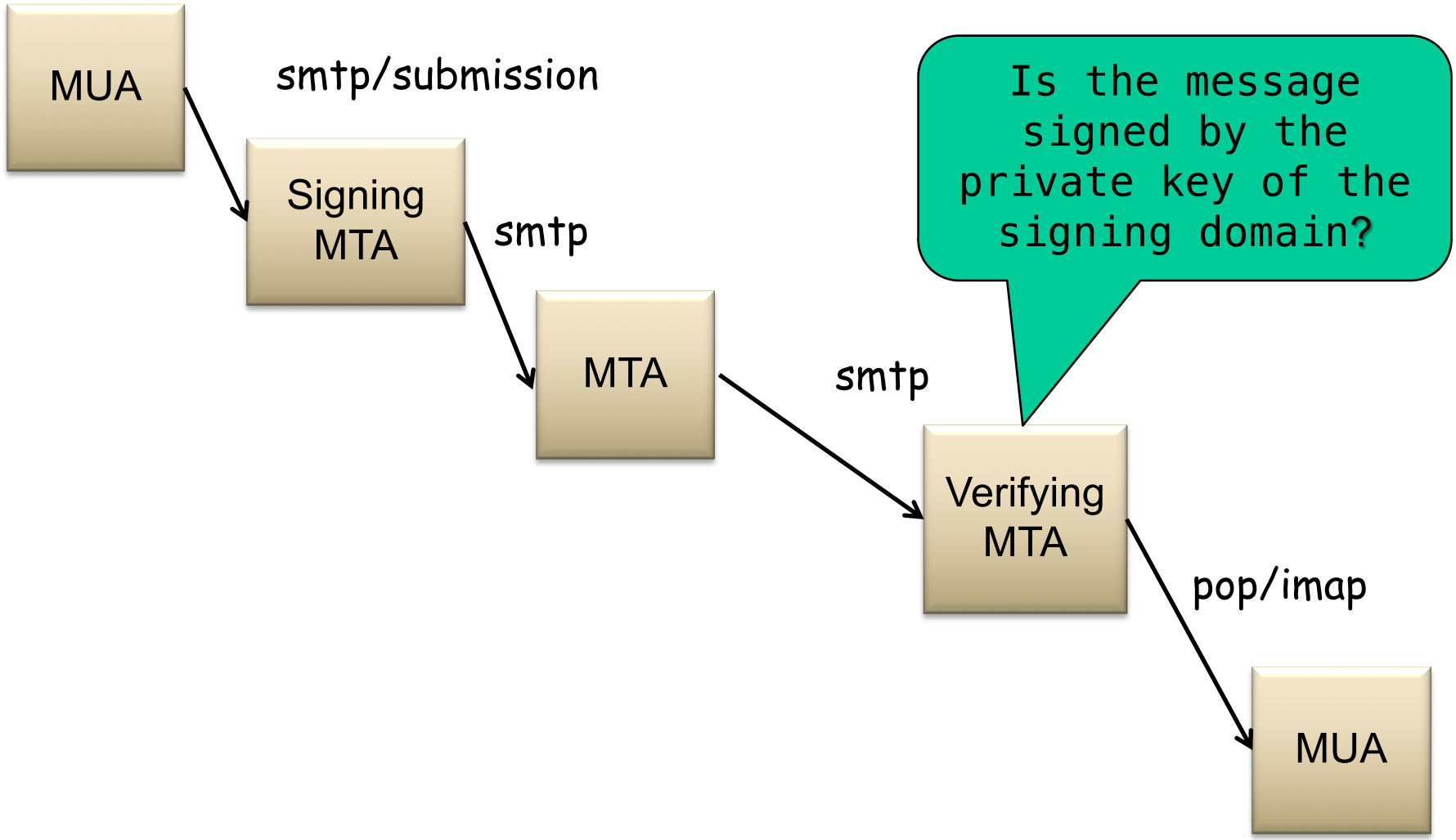
Key Question for SPF?

- How does SPF know if its neighbor MTA is a permitted sender of the domain?

DomainKeys Identified Mail (DKIM; RFC 5585)

- A domain-level digital signature authentication framework for email, using public key crypto
  - E.g., mail.sina.com signs that the message is sent by mail.sina server
- Basic idea of public key signature
  - Owner has both public and private keys
  - Owner uses private key to sign a message to generate a signature
  - Others with public key can verify signature
  - Assumption: difficult to get private key even w/ public key distributed

DomainKeys Identified Mail (DKIM)



Example: RSA

1. Choose two large prime numbers *p*, *q*. (e.g., 1024 bits each)

2. Compute *n* = *pq*, *z* = *(p-1)(q-1)*

3. Choose *e* (with *e* < *n*) that has no common factors with z. (*e*, *z* are "relatively prime").

4. Choose *d* such that *ed-1* is exactly divisible by *z*. (in other words: *ed* mod *z* = *1*).

5. *Public* key is *(n,e)*. *Private* key is *(n,d)*.

RSA: Signing/Verification

0. Given (n,e) and (n,d) as computed above

1. To sign message, m, compute h = hash(m), then sign with private key

   $s = h^d \bmod n$ (i.e., remainder when h^d is divided by n)

2. To verify signature s, compute

   $h' = s^e \bmod n$ (i.e., remainder when s^e is divided by n)

Magic happens! $h = (h^d \bmod n)^e \bmod n$

The magic is a simple application of Euler's generalization of Fermat's little theorem

Key Question about DKIM?

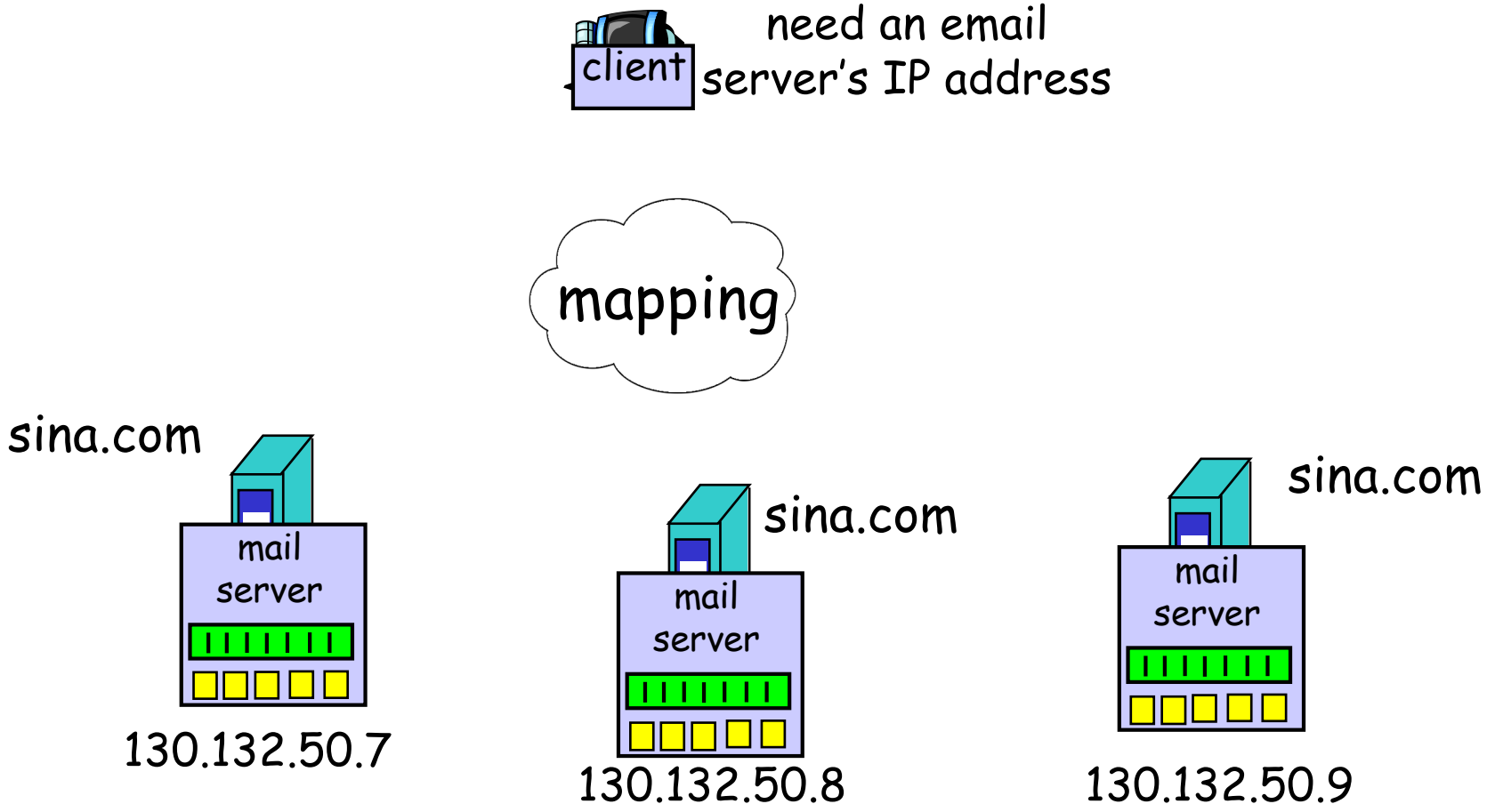
- How does DKIM retrieve the public key of the author domain?

Summary: Some Key Remaining Issues about Email

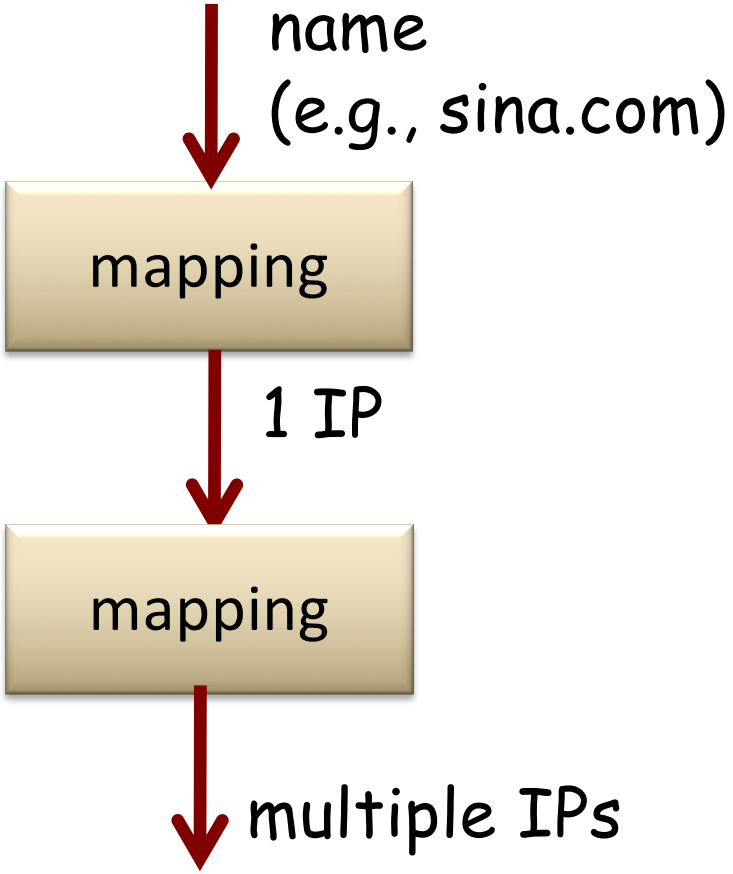
- Basic: How to find the email server of a domain?
- Scalability/robustness: how to find multiple servers for the email domain?
- Security
  - SPF: How does SPF know if its neighbor MTA is a permitted sender of the domain?
  - DKIM: How does DKIM retrieve the public key of the author domain?

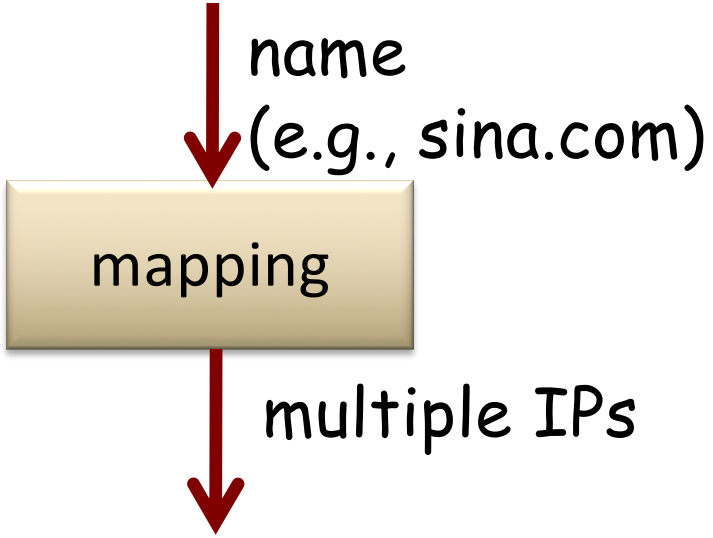
Scalability/Robustness

- Both scalability and robustness require that multiple email servers serve the same email address



Mapping Functions Design Alternatives





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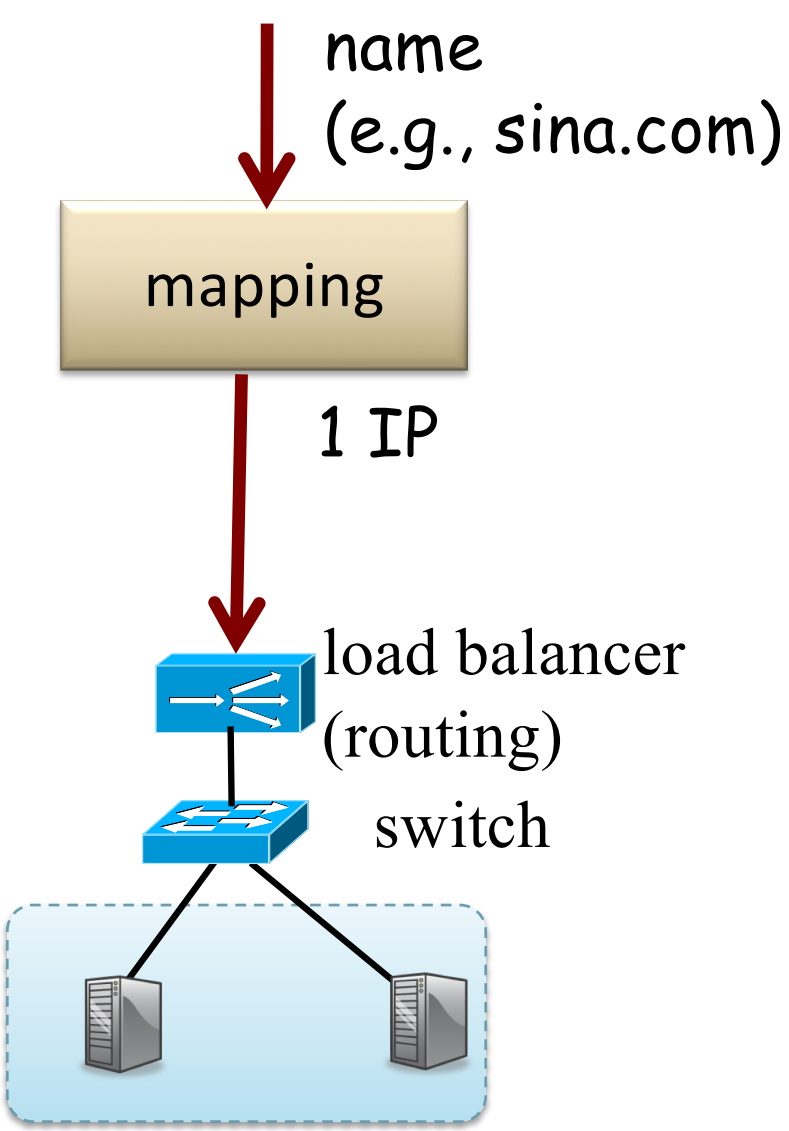
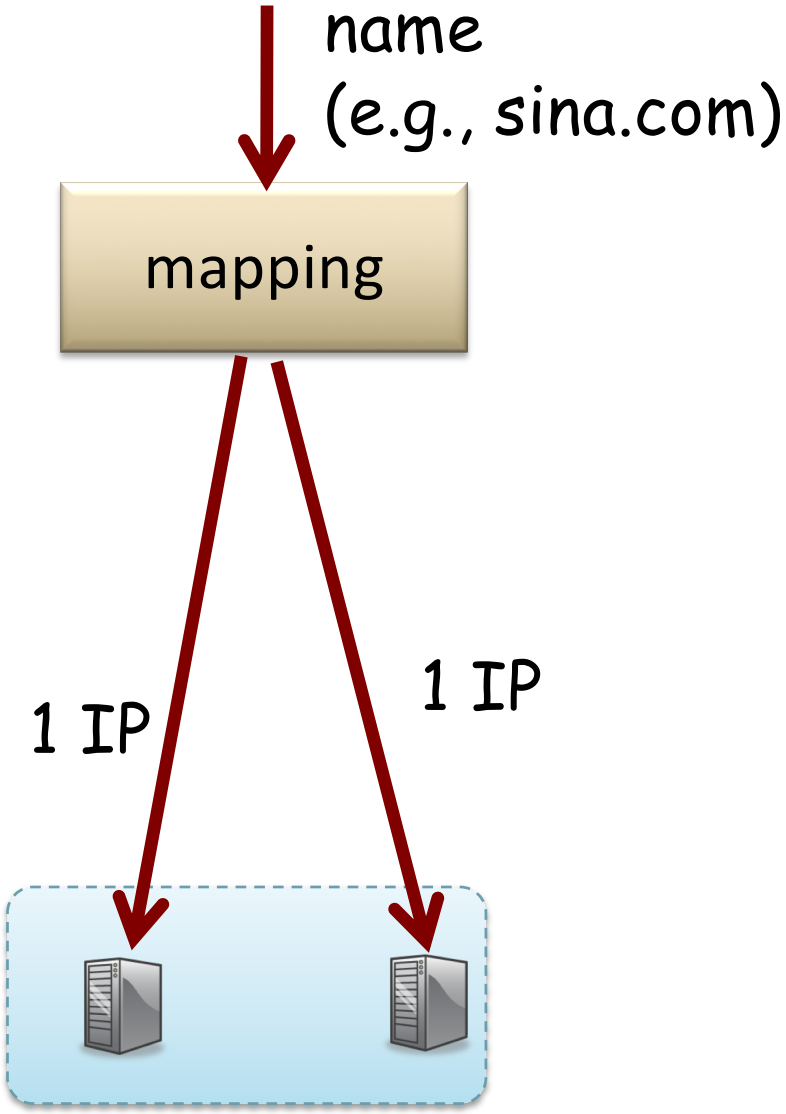


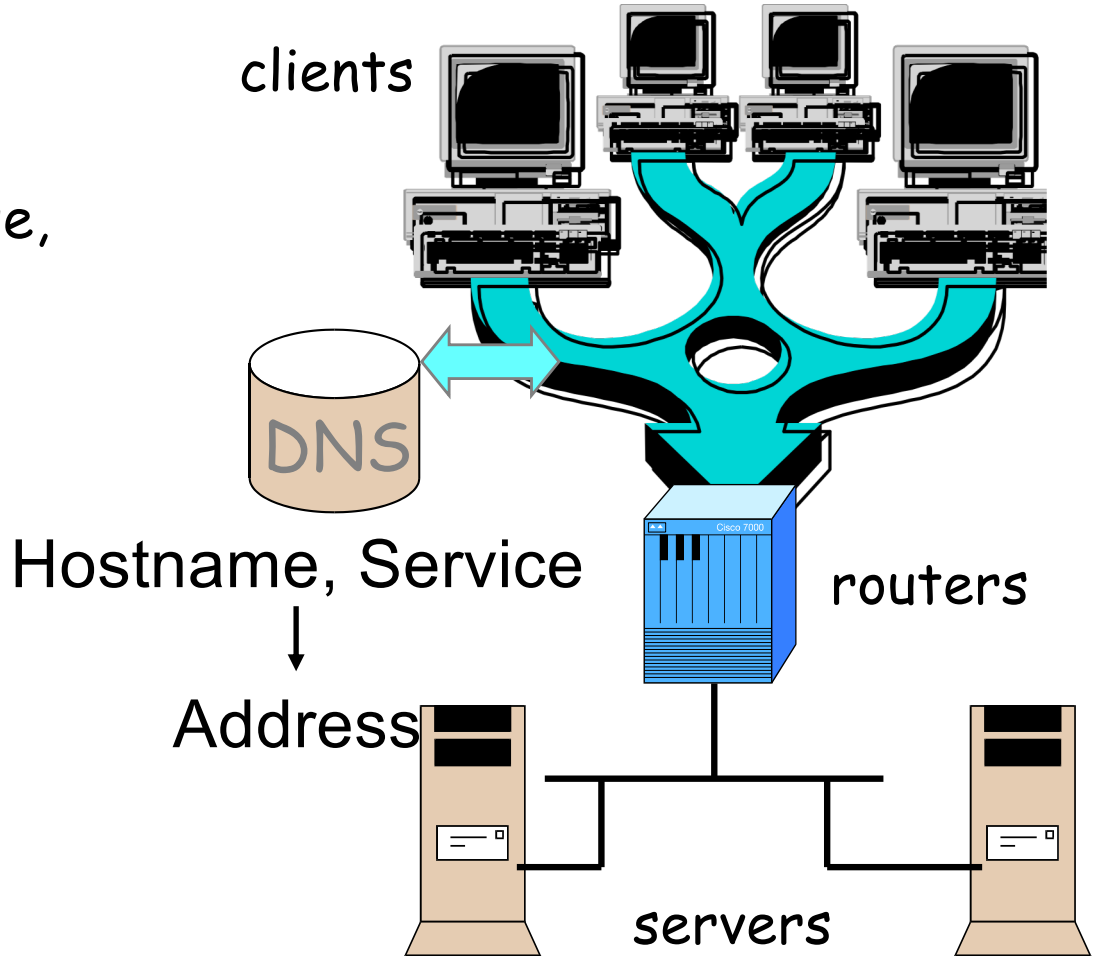


Outline

- Admin. and recap
- Layered network architecture
- Application layer overview
- Network applications
  - Email
  - *DNS*

DNS: Domain Name System

- Function
  - map between (domain name, service) to value, e.g.,
    - (xmu.edu.cn, addr) -> 210.34.0.35
    - (xmu.edu.cn, email) -> cmsn1.xmu.edu.cn



DNS Records

http://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml

DNS: stores resource records (RR)

RR format: **(name, type, value, ttl)**

- Type=A
  - **name** is hostname
  - **value** is IP address
- Type=NS
  - **name** is domain (e.g. xmu.edu.cn)
  - **value** is the name of the authoritative name server for this domain
- Type=TXT
  - general txt
- Type=CNAME
  - **name** is an alias of a "canonical" (real) name
  - **value** is canonical name
- Type=MX
  - **value** is hostname of mail server associated with **name**
- Type=SRV
  - general extension for services
- Type=PTR
  - a pointer to another name