Network Applications: Email; DNS;

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https://qiaoxiang.me/courses/cnns-xmuf22/index.shtml

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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
- Email
  - How to handle spam
- DNS
  - High-level design
  - Details
  - Extensions/alternatives

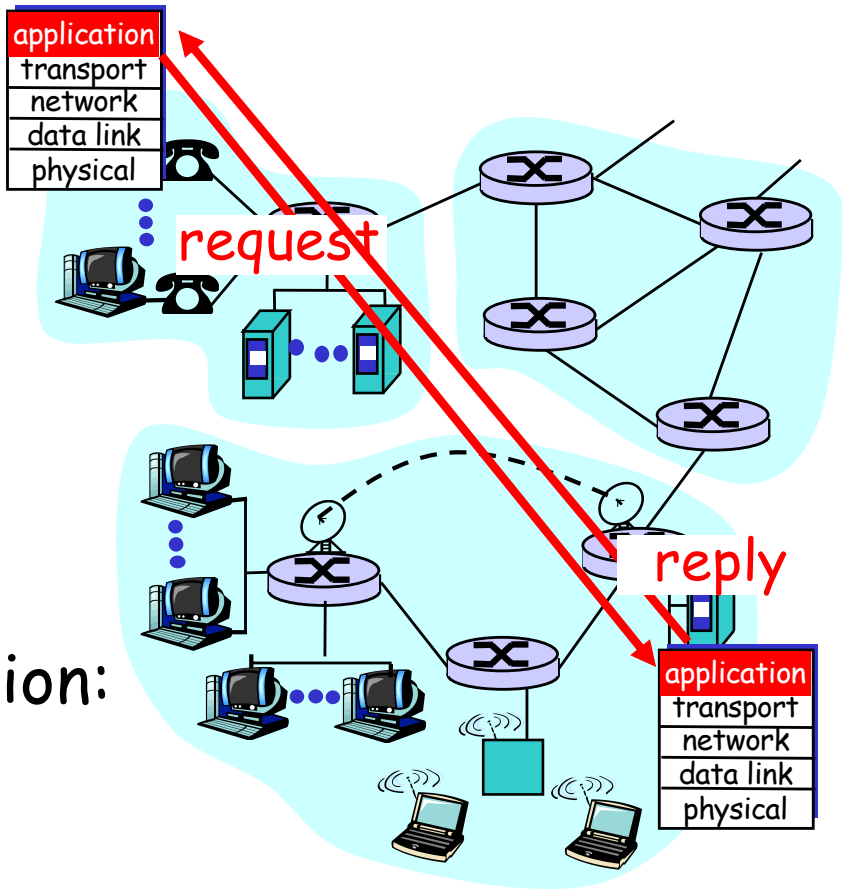
Admin

- Assignment One due on Sep. 29
- List of suggested projects to be posted on Sep. 29

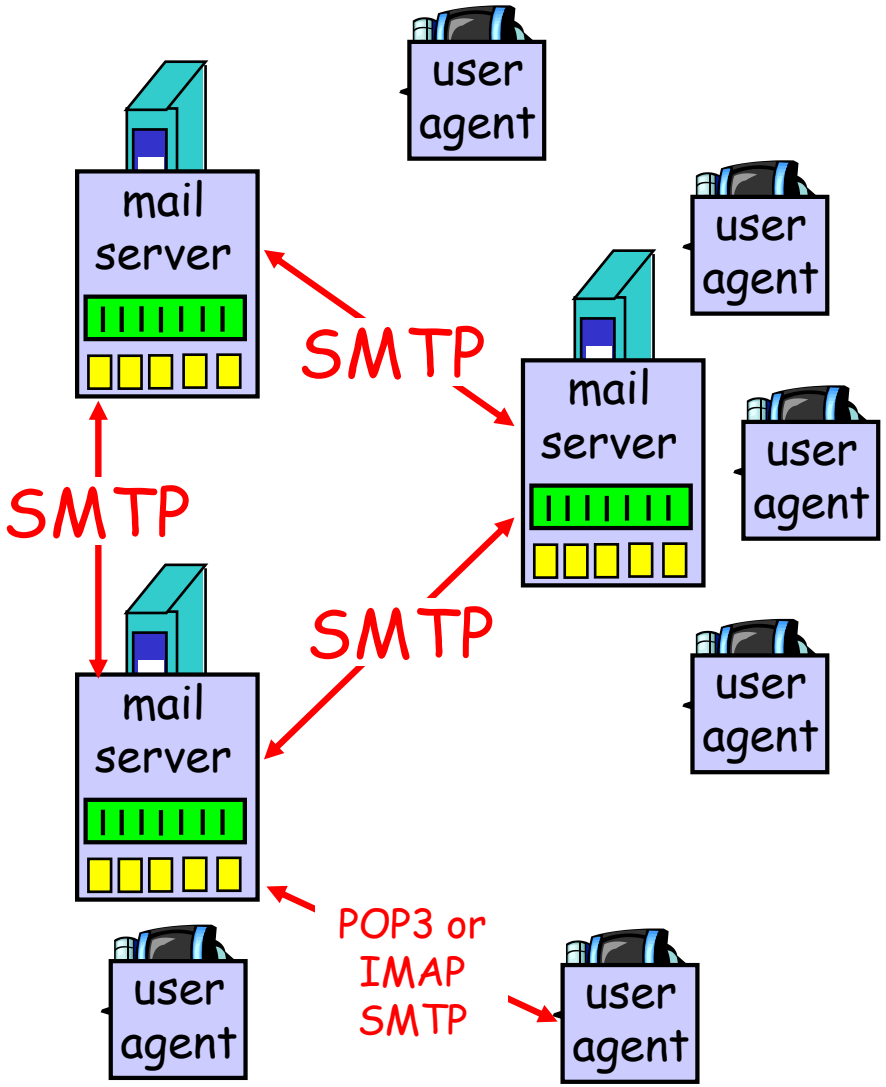
Recap: Client-Server Paradigm

- The basic paradigm of network applications is the client-server (C-S) paradigm

- Some key design questions to ask about a C-S application:
  - extensibility
  - scalability
  - robustness
  - security



Recap: Email App



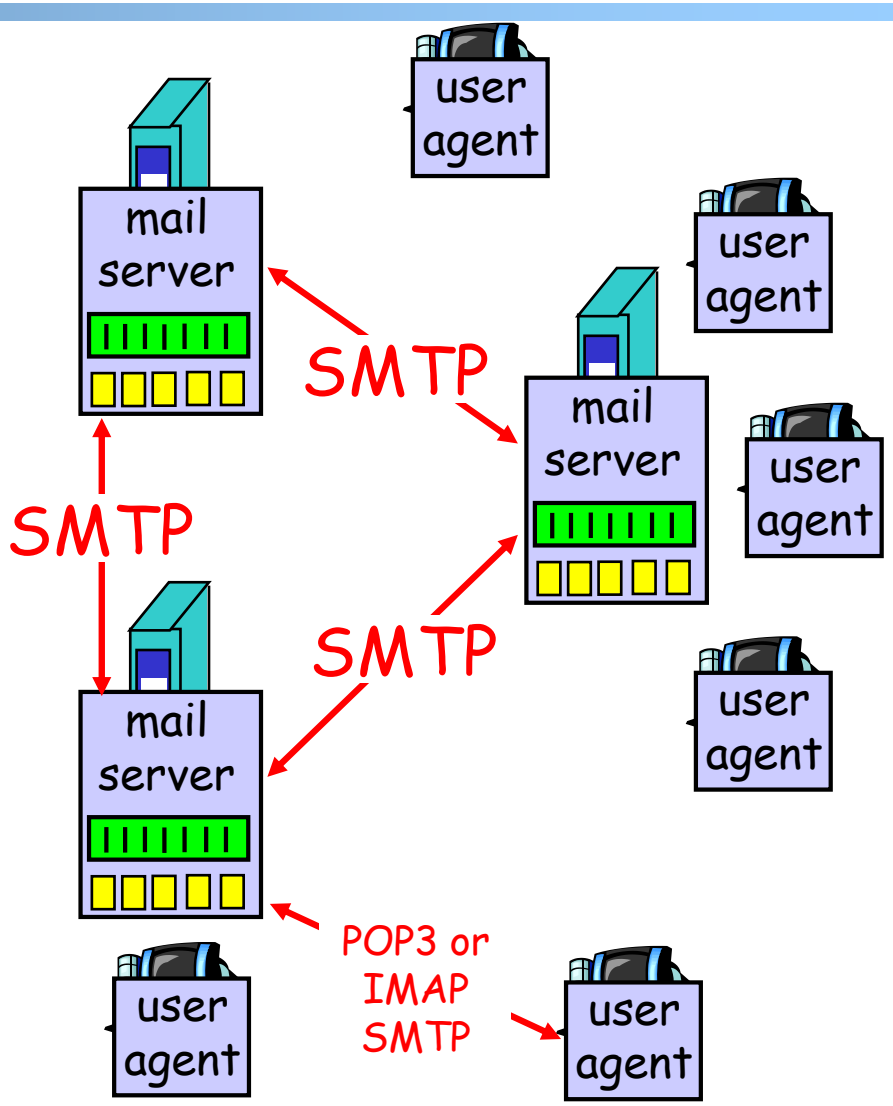
Some key design features of Email

- Separate protocols for different functions
  - email access (e.g., POP3, IMAP)
  - email transport (SMTP)
- Separation of envelop and message body (end-to-end arguments)
  - envelop: simple/basic requests to implement transport control;
  - message body: fine-grain control through ASCII header and message body
    - MIME type as self-describing data type
- Status code in response makes message easy to parse

Evaluation of SMTP/POP/IMAP

Key questions to ask about a C-S application

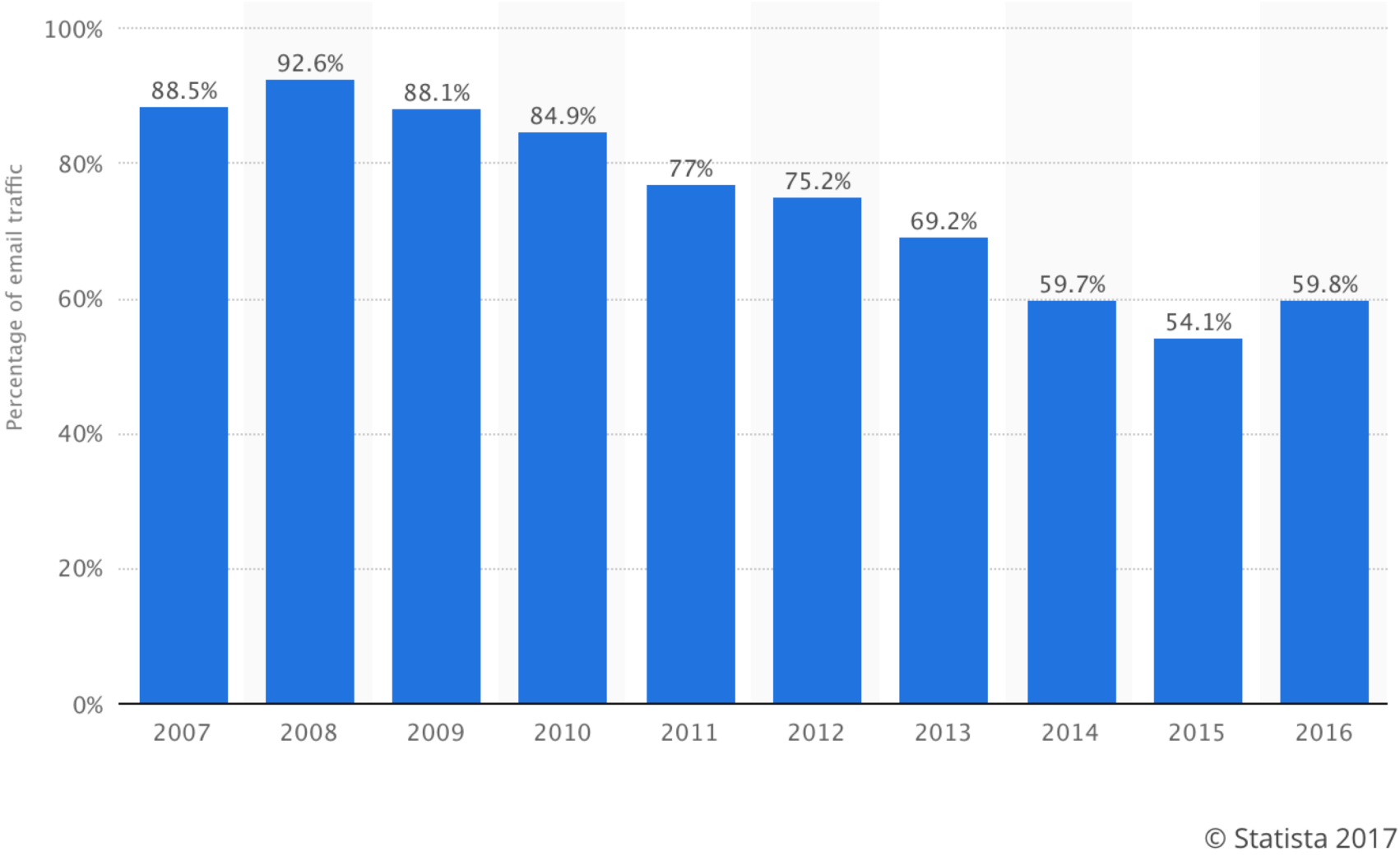
- extensible?
- scalable?
- robust?
- security?



Email Security: Spam

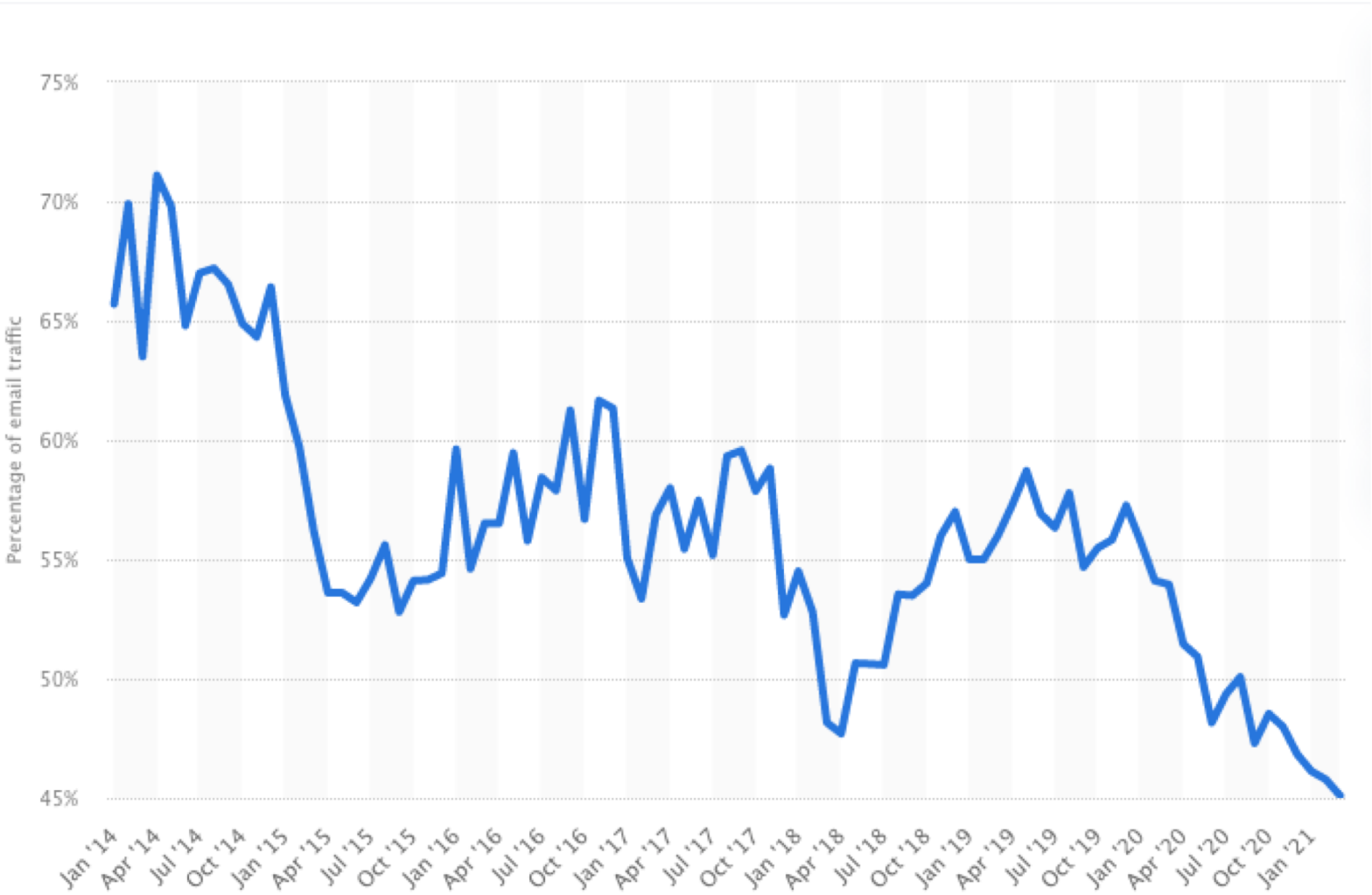
- Spam (Google)

Email Security Issue: Spam



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

Email Security Issue: Spam



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

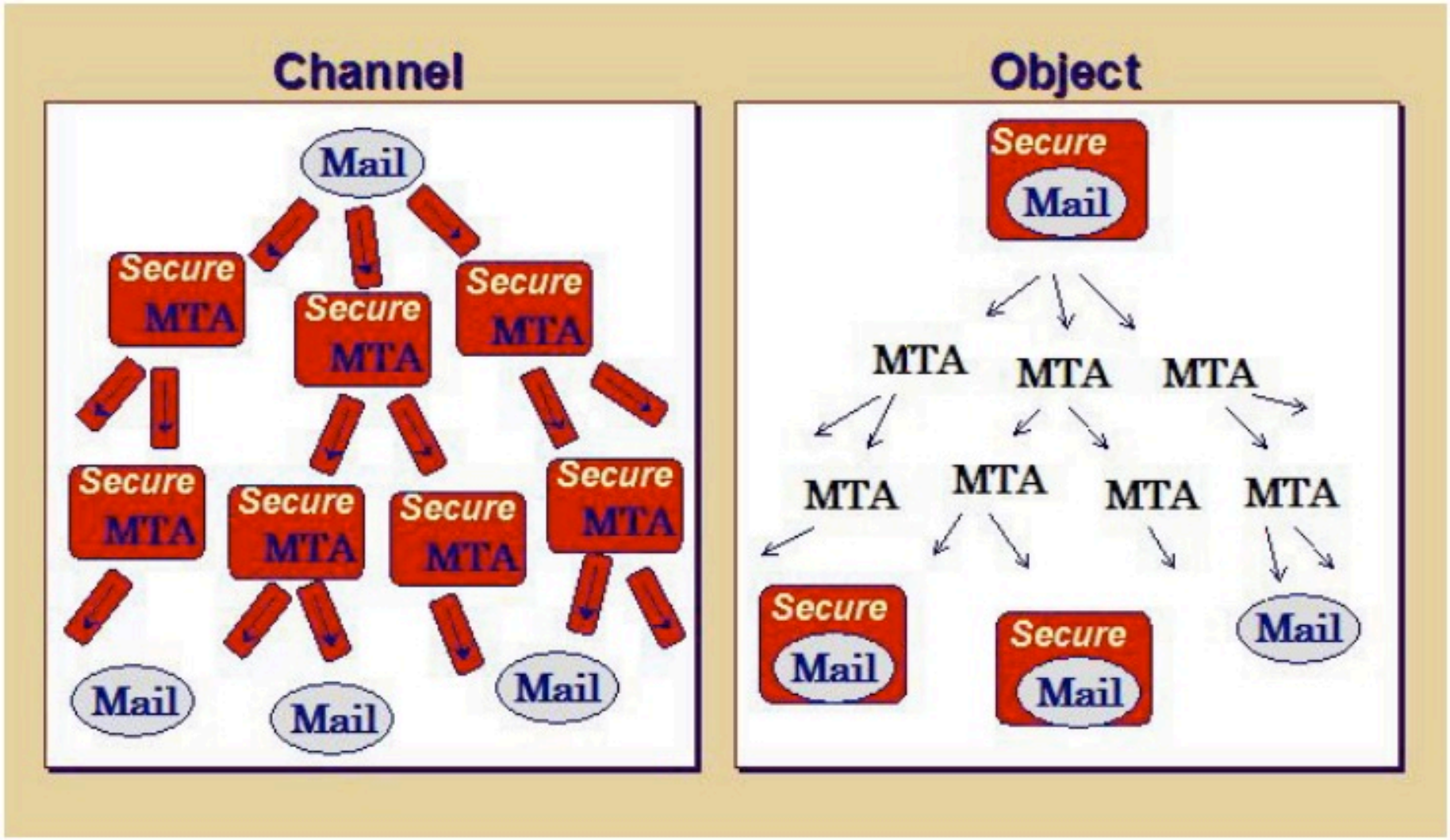
Discussion: How May One Handle Email Spams?

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

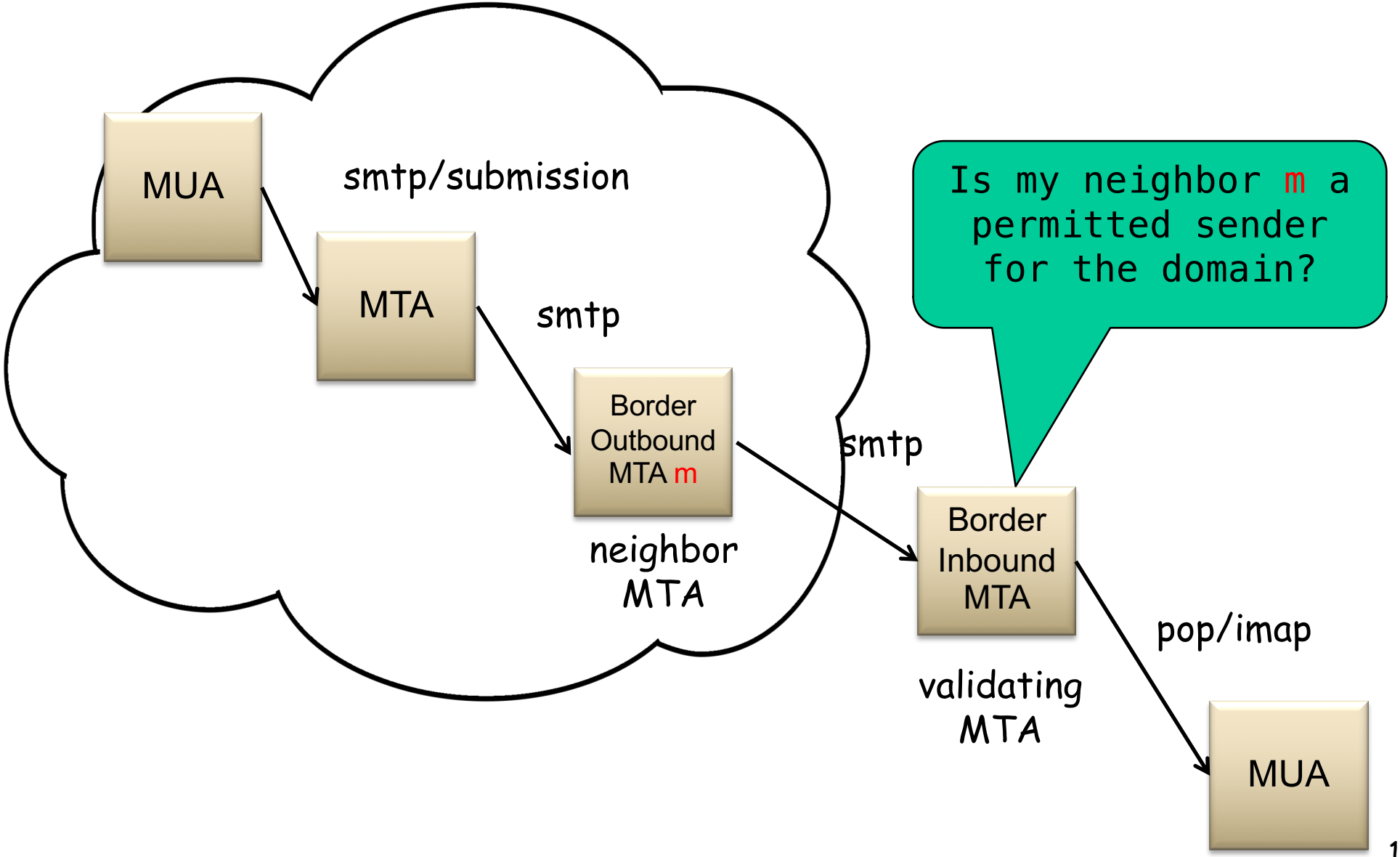


Sender Policy Frame (SPF)

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

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

Sender Policy Framework (SPF RFC7208)



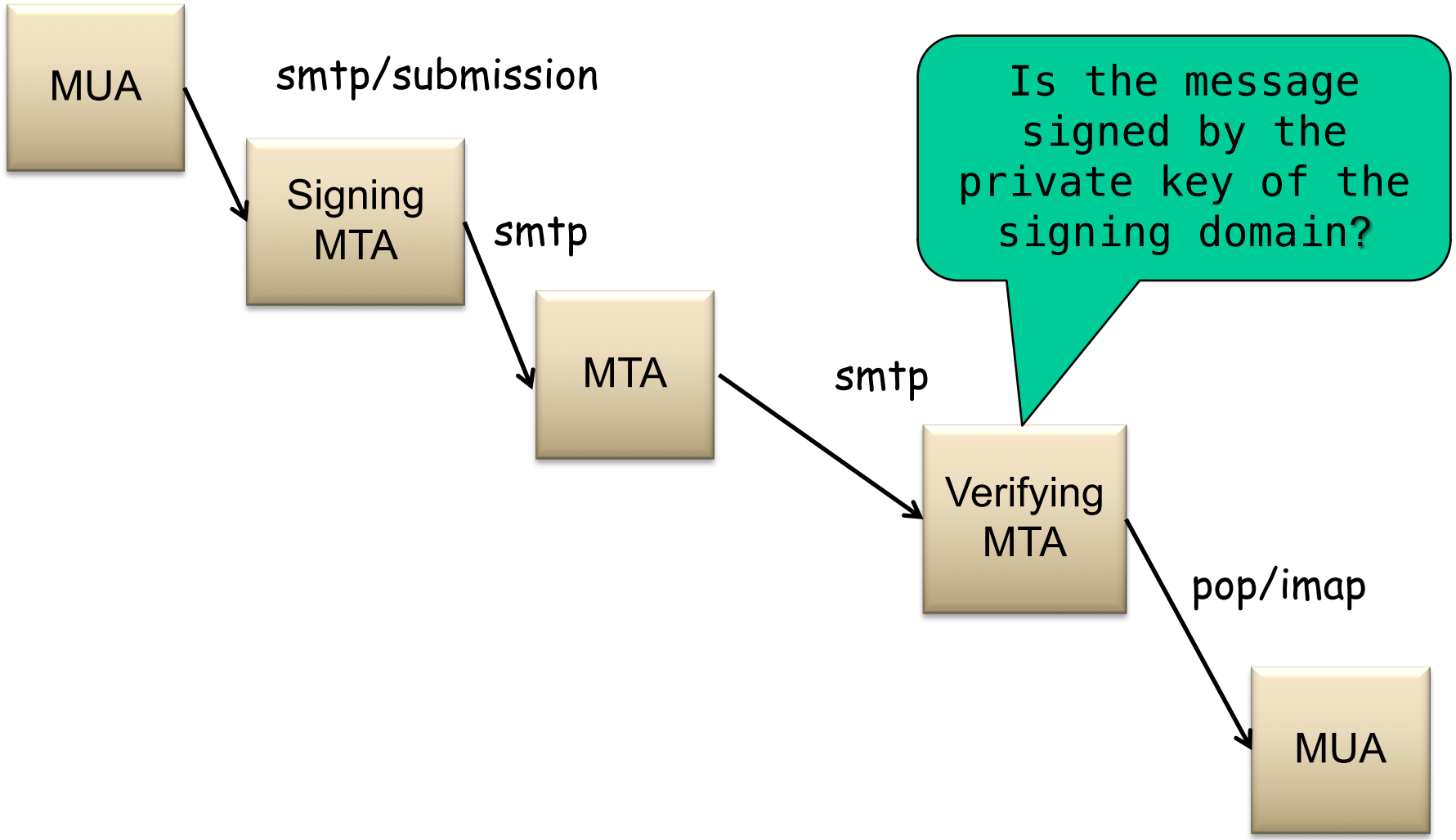
Key Question for SPF?

- 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?

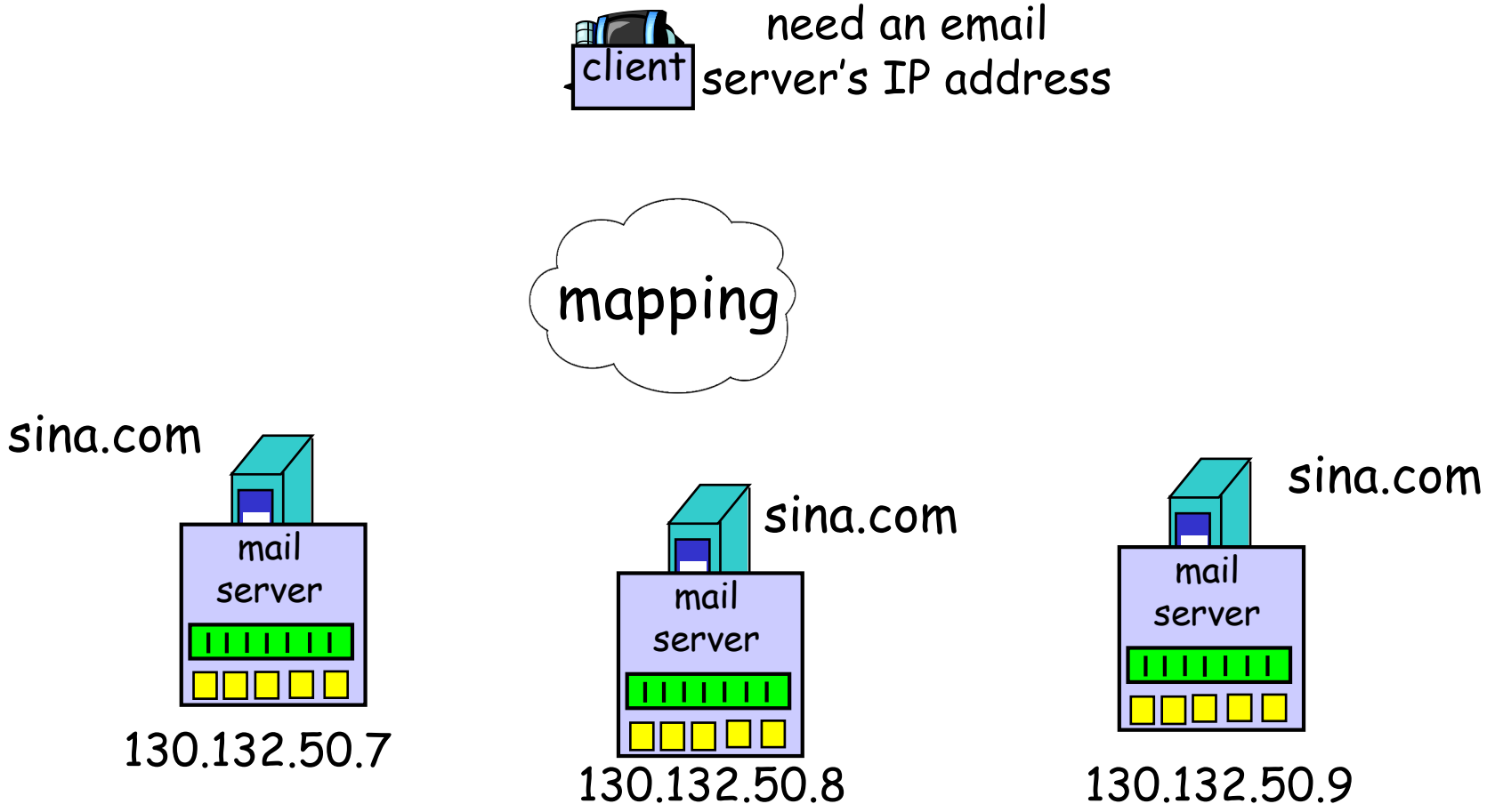
- How does DKIM retrieve the public key of the author domain?

Summary: Some Key Remaining Issues about Email

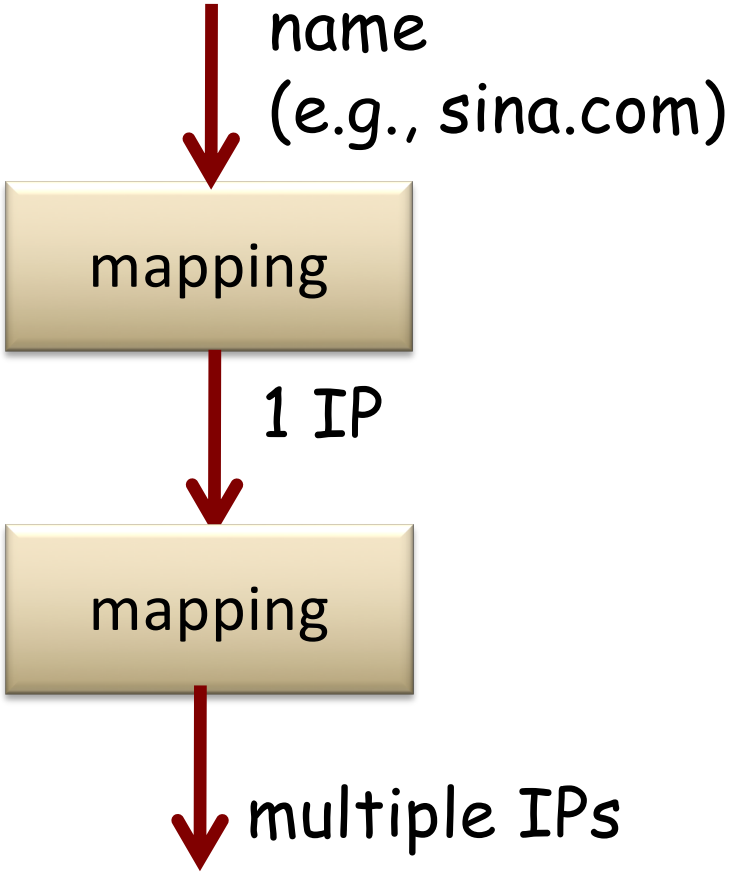
- Basic: How to find the email server of a domain?
- Scalability/robustness: how to find multiple servers for the email domain?
- Security
  - SPF: How does SPF know if its neighbor MTA is a permitted sender of the domain?
  - DKIM: How does DKIM retrieve the public key of the author domain?

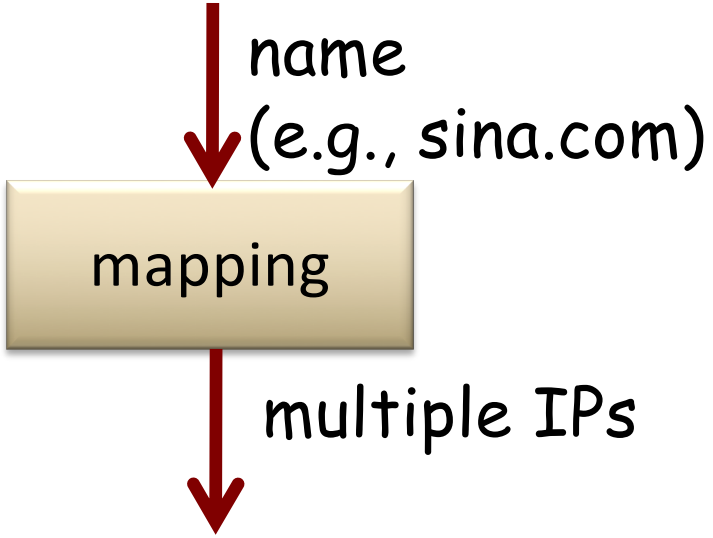
Scalability/Robustness

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



Mapping Functions Design Alternatives





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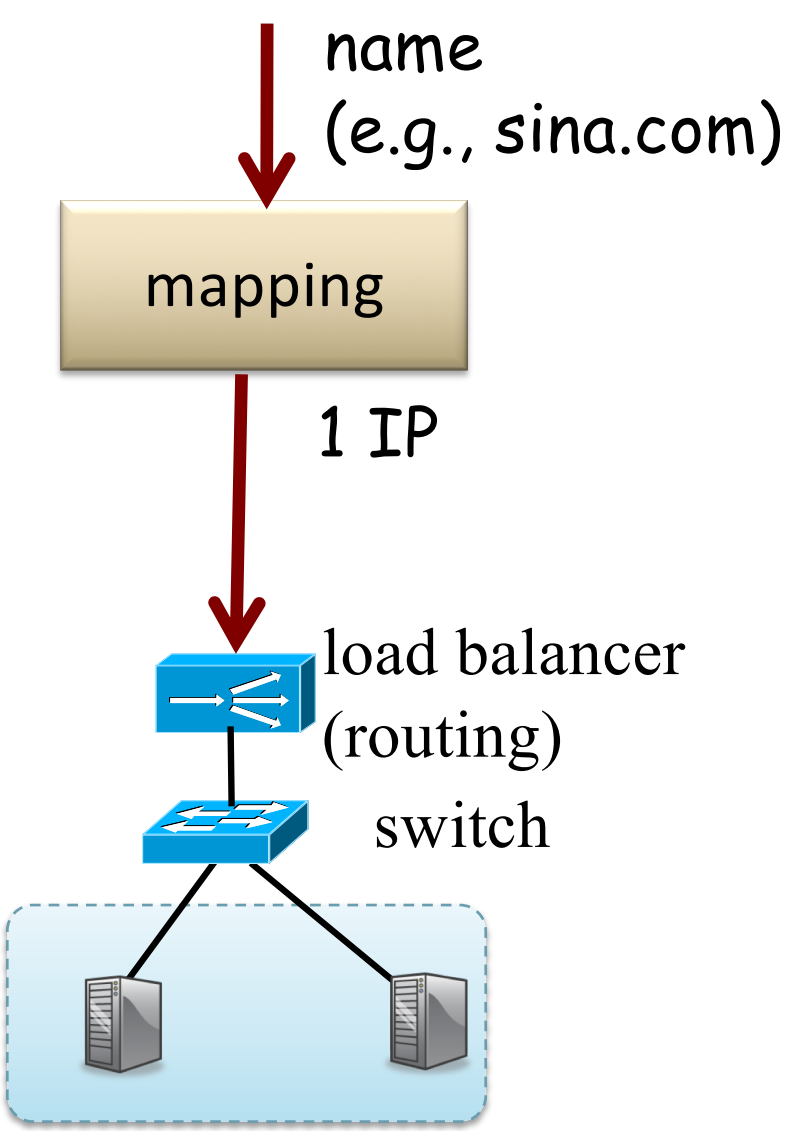
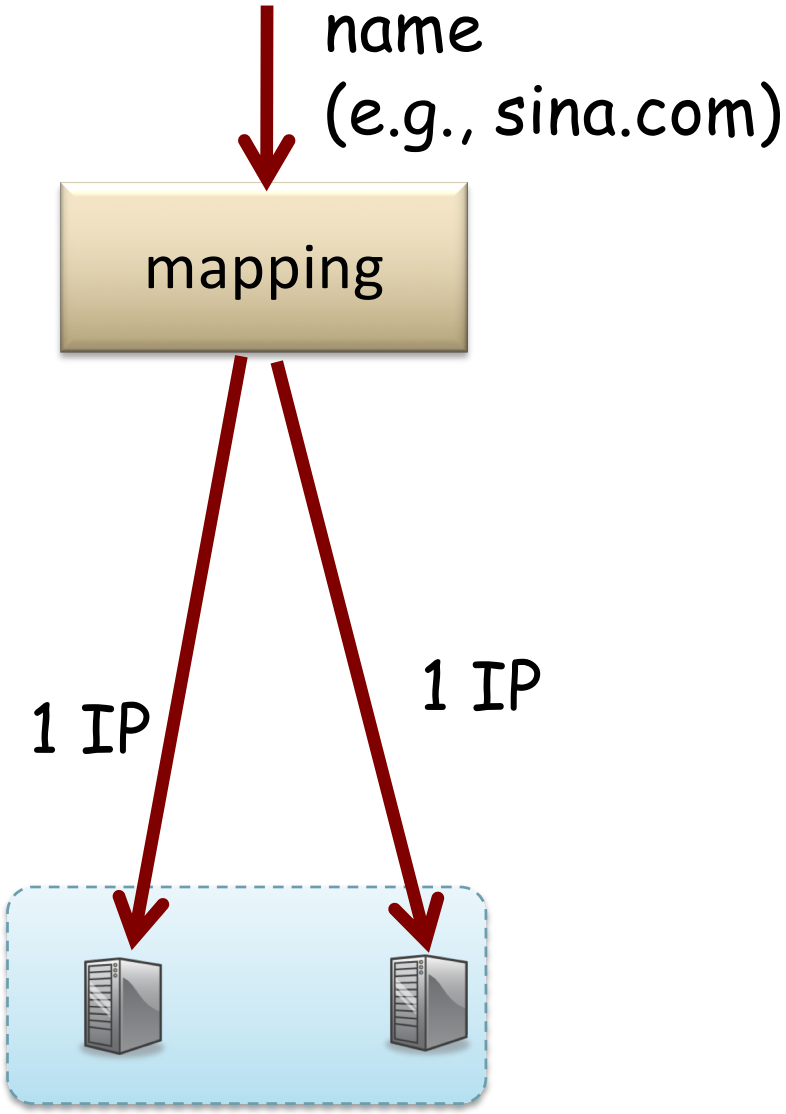


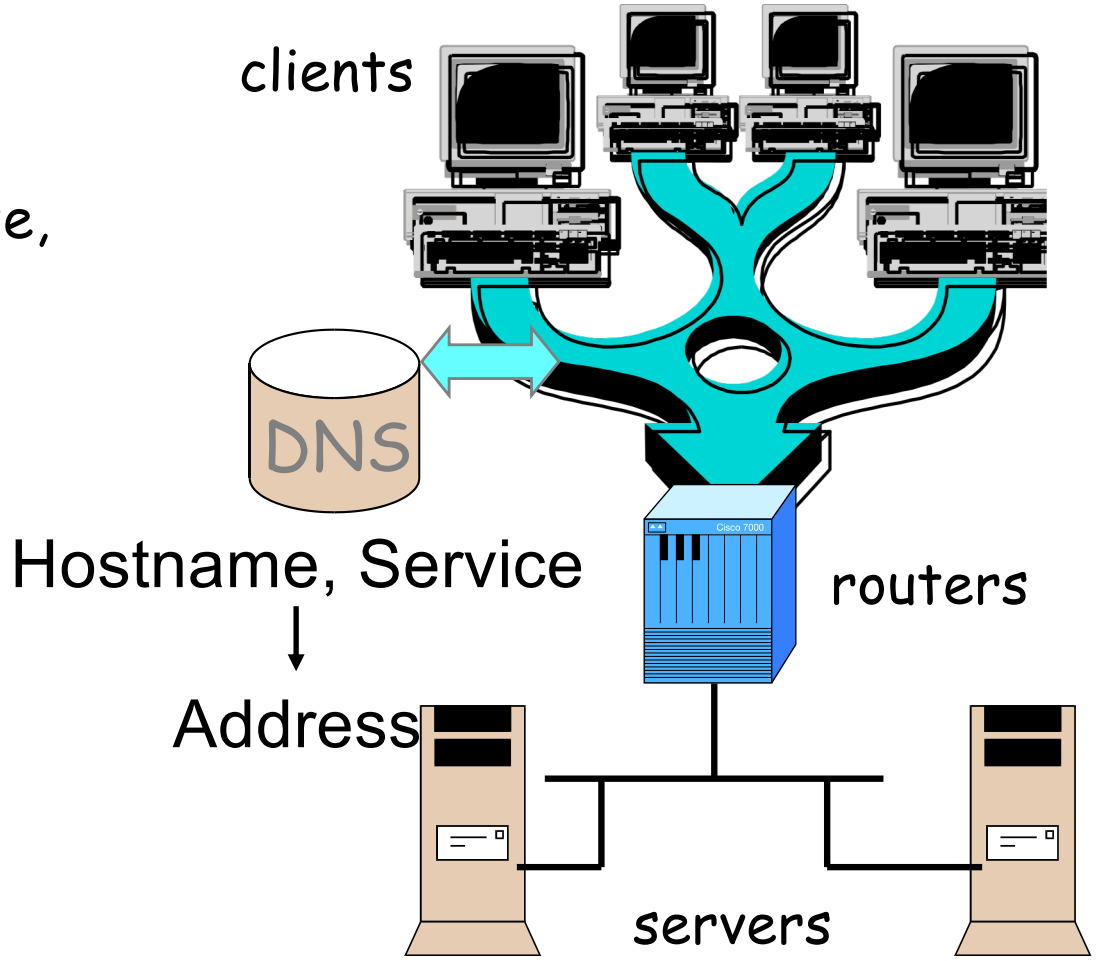


Outline

- 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

Discussion

- Can DNS handle multiple values for the same (name, service)?

Try DNS: Examples

- dig <name> <type>
  - Try xmu.edu.cn / others and various types

- dig <domain> txt to retrieve spf

http://www.zytrax.com/books/dns/ch9/spf.html

Observations

- MX can return multiple servers
- DNS may rotate the servers in answer
- Address can also return multiple addresses
- SPF is encoded as the txt type

Outline

- Admin. and recap
- DNS
  - High-level design
  - *Details*

DKIM Example

- Send email from hotmail and check message

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

DKIM Example

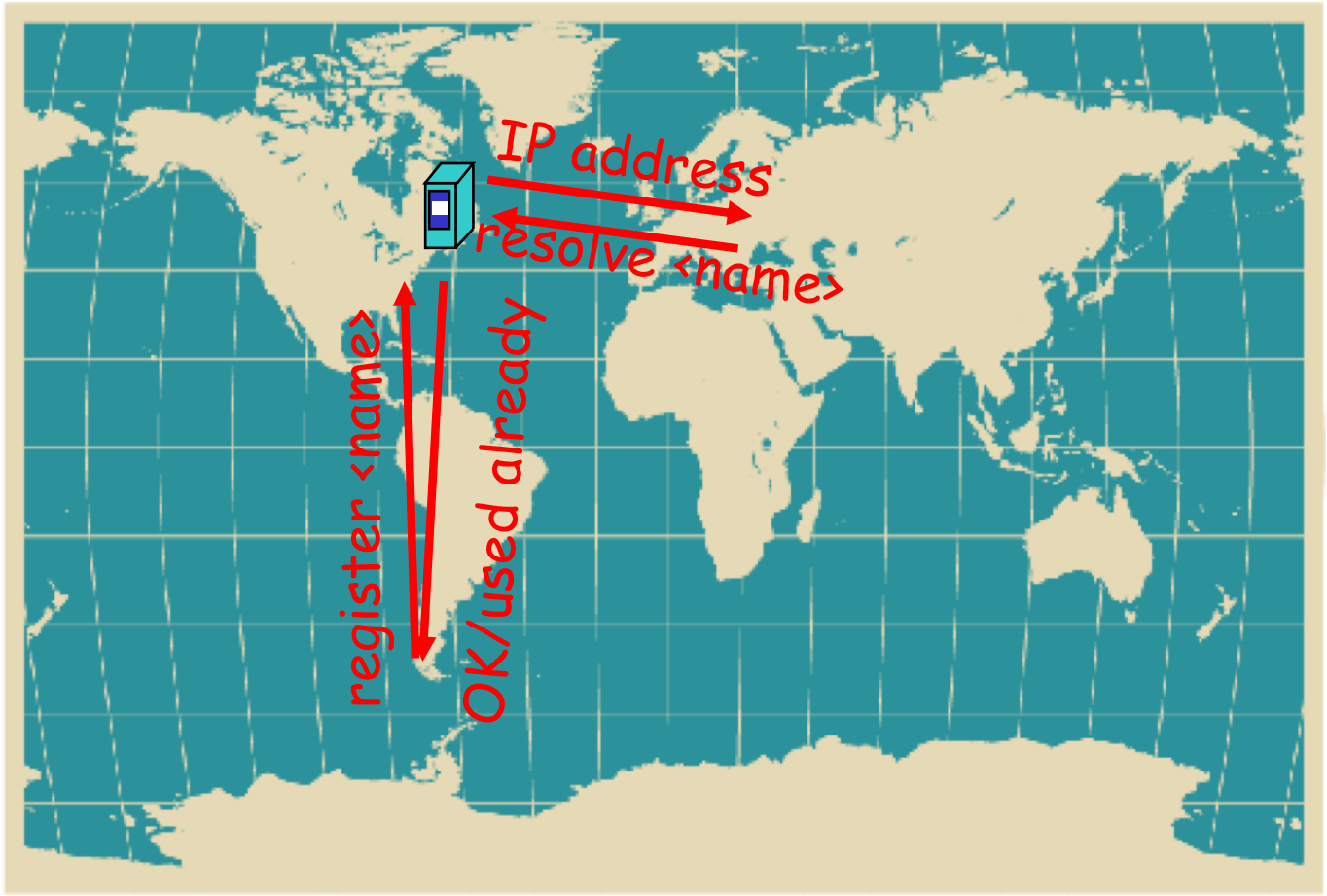
- DKIM / ARC:
  Msg: ARC-Message-Signature: i=1; a=rsa-sha256; c=relaxed/relaxed; d=microsoft.com; s=arcselector9901; h=From:Date:Subject:Message-ID:Content-Type:MIME-Version; bh=bO91TxHI+4MjgAusrfg0EWGiDmvQ5hZRZ/aqb1MKLY8=; …

  DKIM-Signature: v=1; a=rsa-sha256; c=relaxed/relaxed; d=hotmail.com; s=selector1; h=From:Date:Subject:Message-ID:Content-Type:MIME-Version:X-MS-Exchange-SenderADCheck;…
- Query: dig arcselector9901._domainkey.microsoft.com txt
- DKIM introduces a session key to allow multiple public keys
  - <session>._domainkey.<domain>

DNS Design: Dummy Design

- DNS itself can be considered as a client-server system as well
- How about a dummy design: introducing one super Internet DNS server?

THE DNS server of the Internet

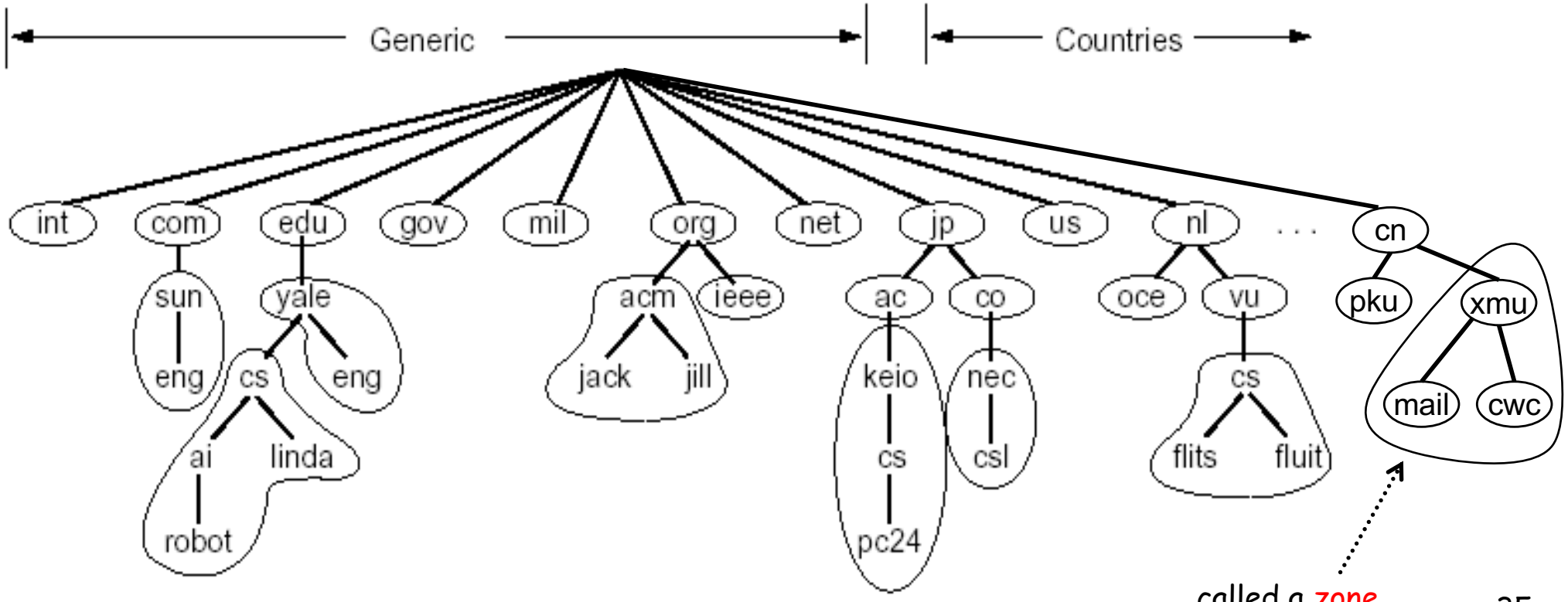


Problems of a Single DNS Server

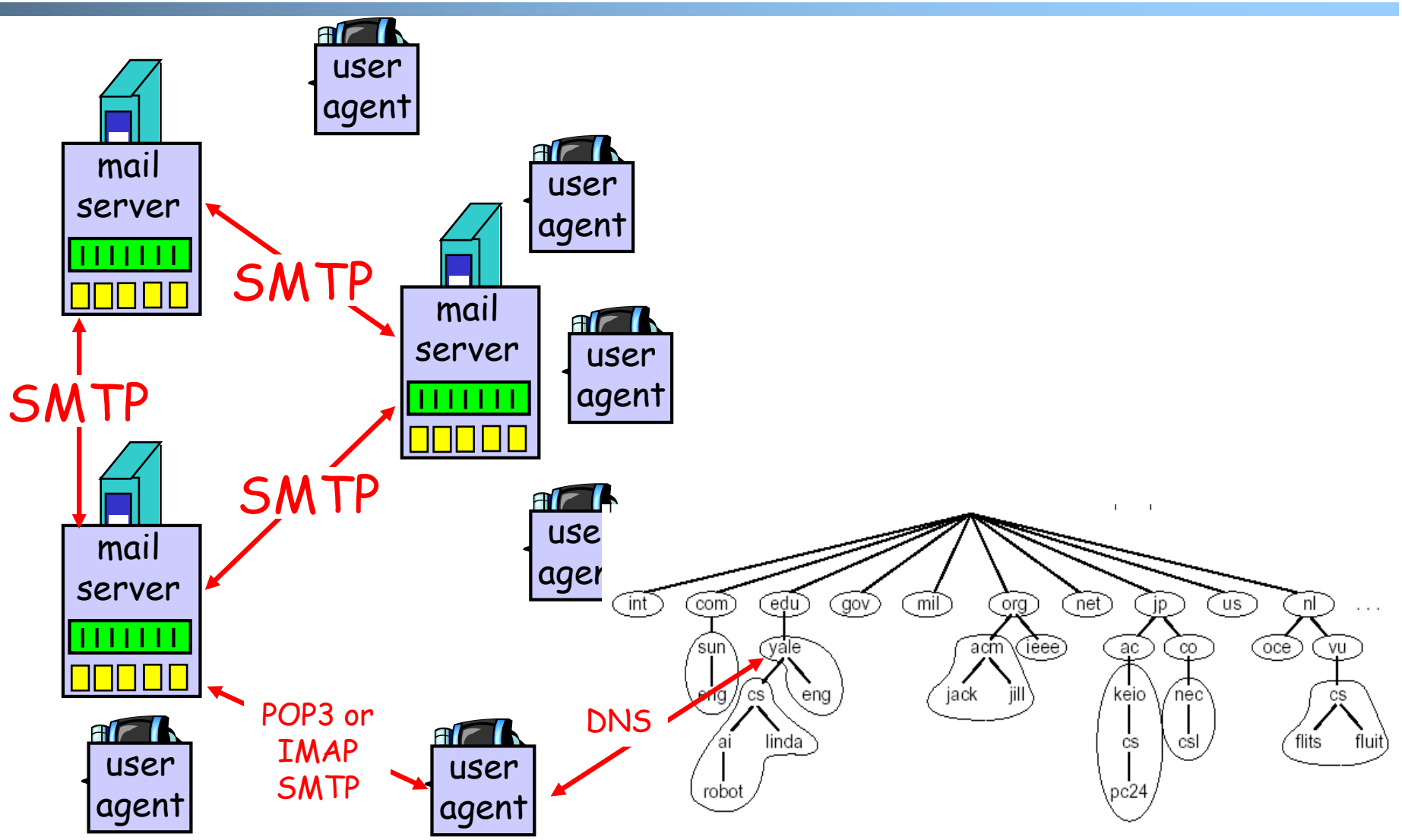
- Scalability and robustness bottleneck
- Administrative bottleneck

DNS: Distributed Management of the Domain Name Space

- A distributed database managed by authoritative name servers
  - divided into zones, where each zone is a sub-tree of the global tree
  - each zone has its own **authoritative name servers**
  - an authoritative name server of a zone may delegate a subset (i.e. a sub-tree) of its zone to another name server



Email Architecture + DNS



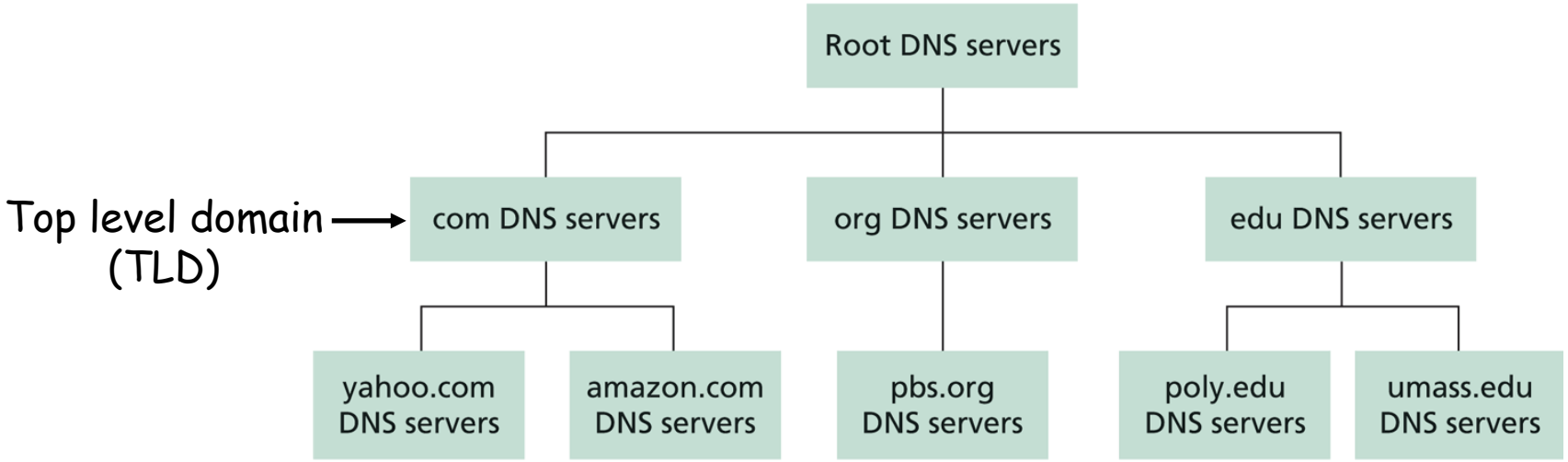
Root Zone and Root Servers

- The root zone is managed by the root name servers
  - 13 root name servers worldwide

See http://root-servers.org/ for more details

Linking the Name Servers

- Each name server knows the addresses of the root servers
- Each name server knows the addresses of its immediate children (i.e., those it delegates)



Q: how to query a hierarchy?

DNS Message Flow: Two Types of Queries

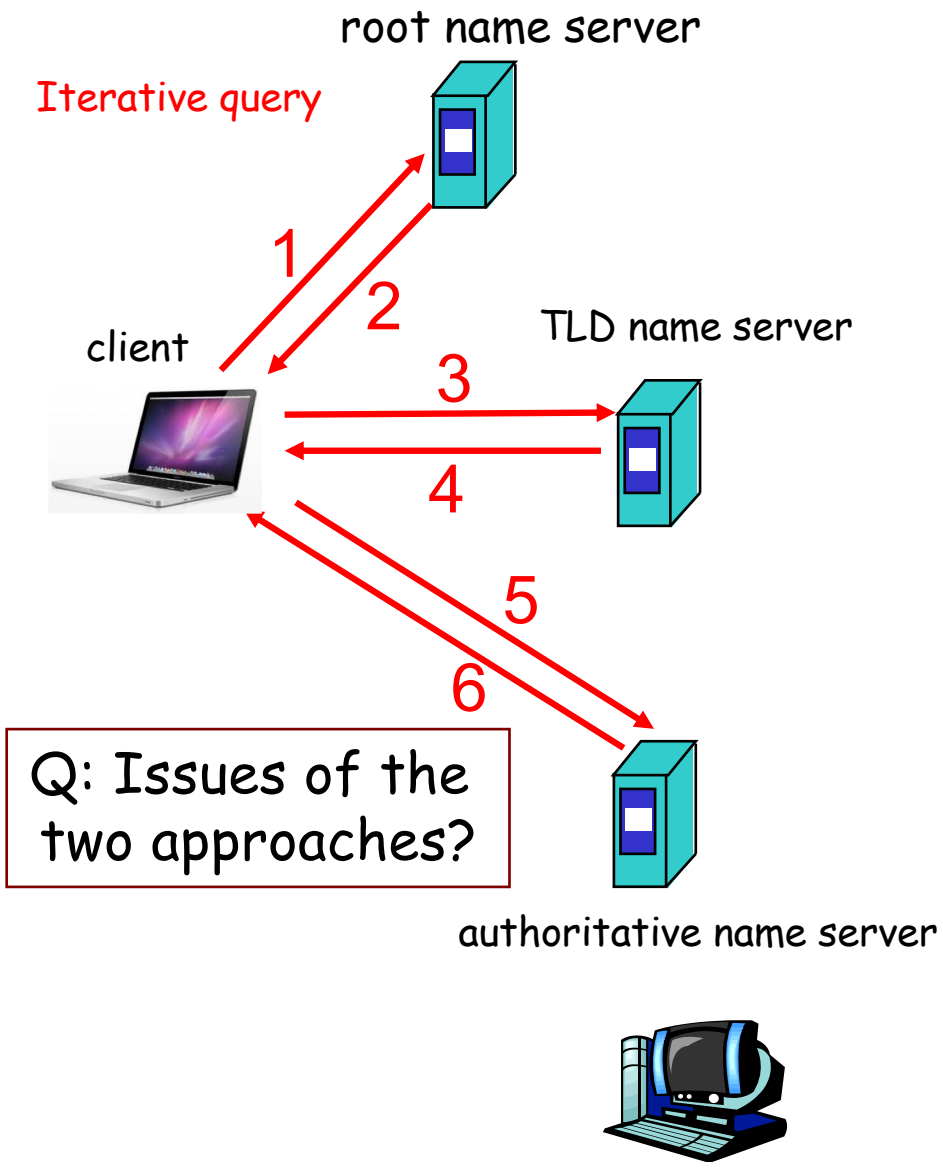
Recursive query:

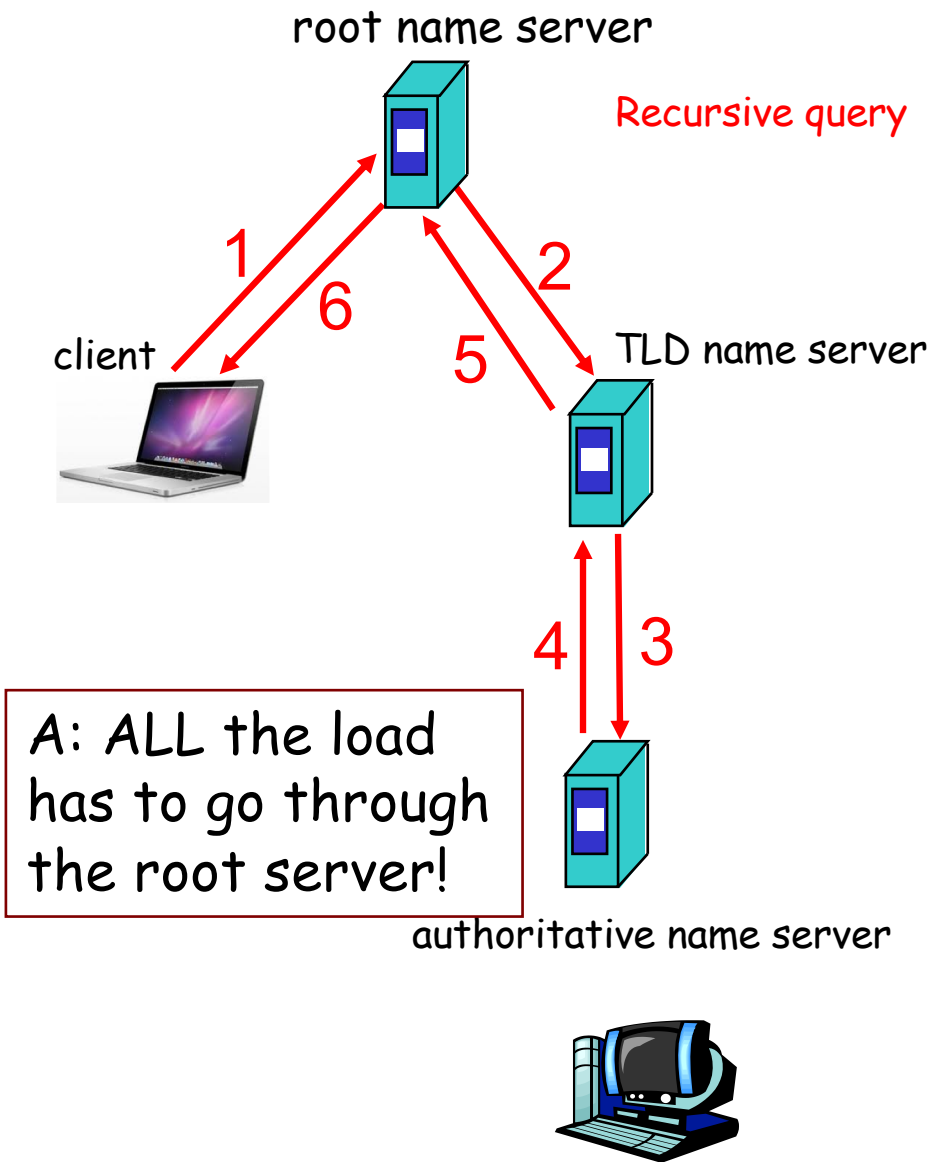
- The contacted name server resolves the name completely

Iterated query:

- Contacted server replies with name of server to contact
  - "I don't know this name, but ask this server"

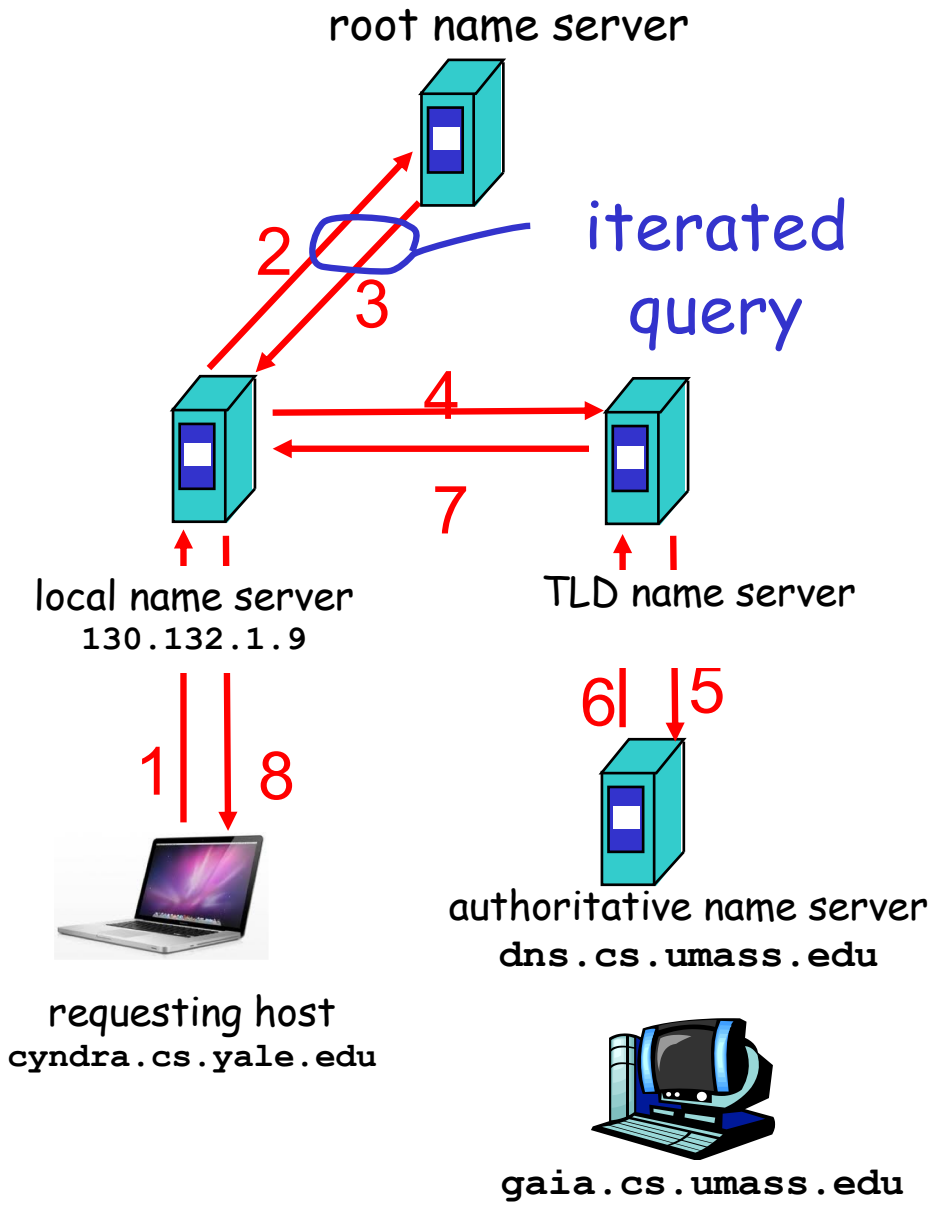
Two Extreme DNS Message Flows





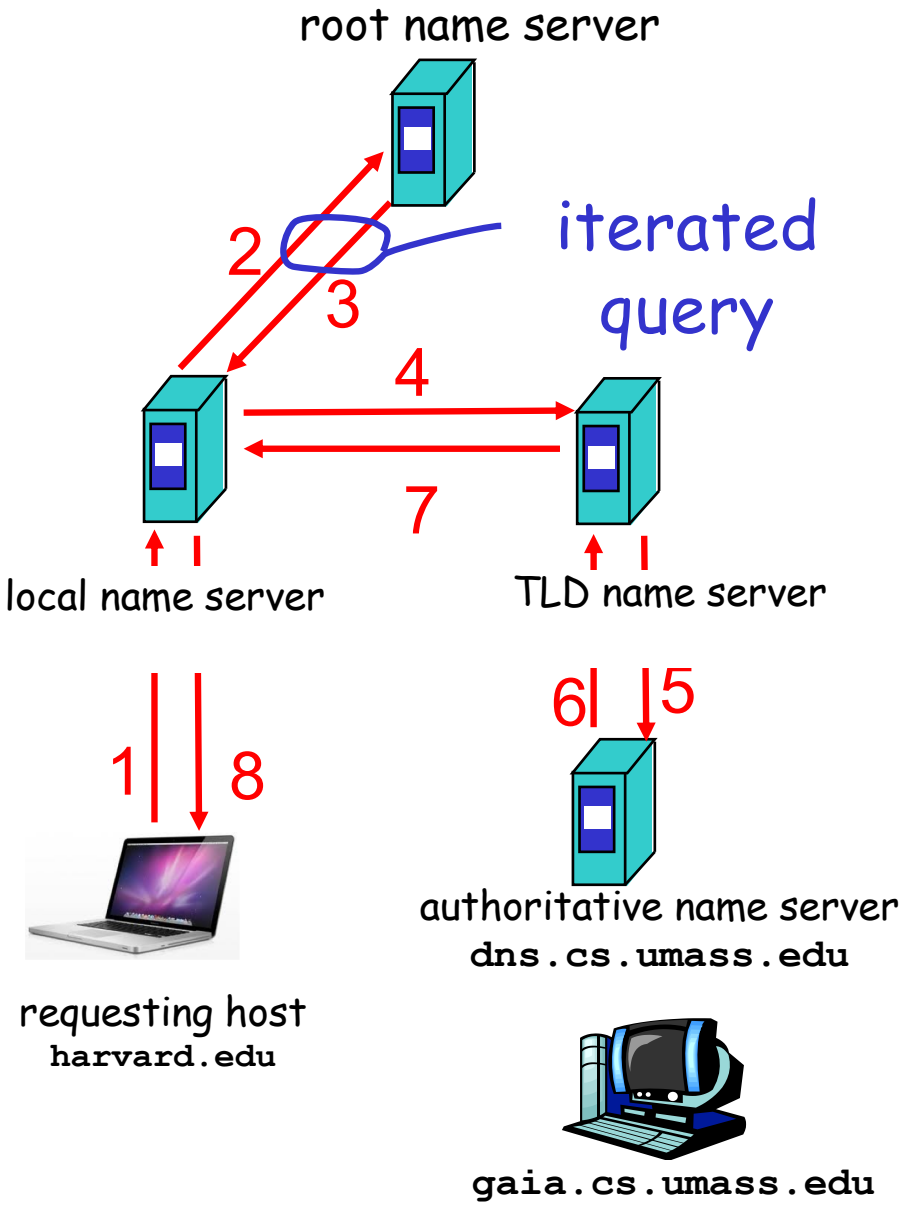
Typical DNS Message Flow: The Hybrid Case

- Host knows only local name server
- Local name server is learned from DHCP, or configured, e.g. /etc/resolv.conf
- Local DNS server helps clients resolve DNS names



Typical DNS Message Flow: The Hybrid Case

- Host knows only local name server
- Local name server is learned from DHCP, or configured, e.g. /etc/resolv.conf
- Local DNS server helps clients resolve DNS names
- Benefits of local name servers (often called **resolvers**)
  - simplifies client
  - caches/reuses results



Outline

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- *DNS*
  - High-level design
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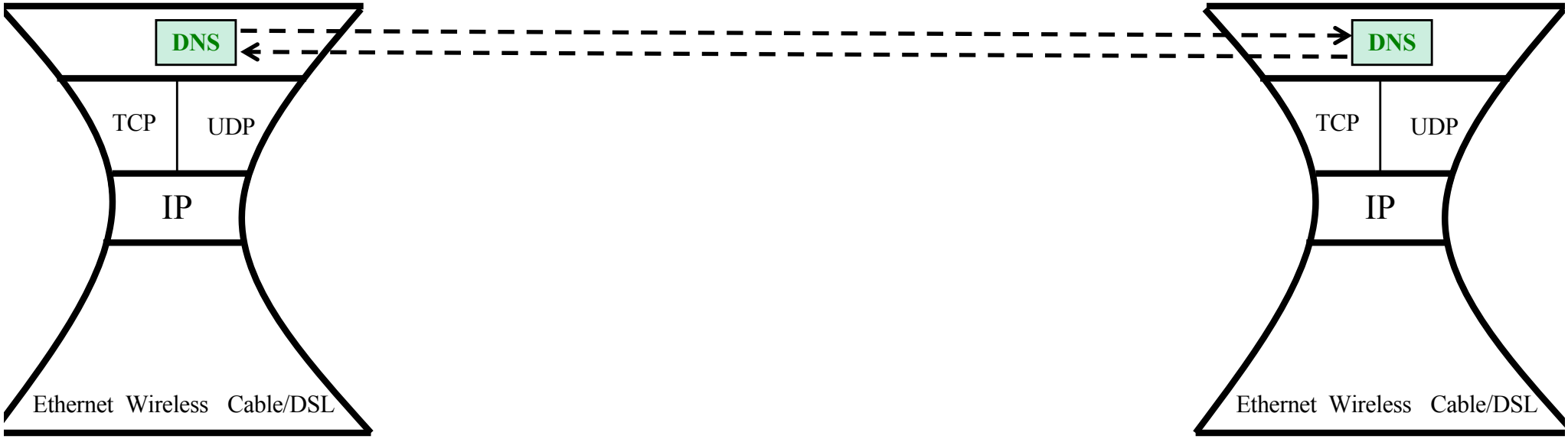
DNS Message Format?

Basic encoding decisions: UDP/TCP, how to encode domain name, how to encode answers…



Observing DNS Messages

- Capture the messages
  - DNS server is at port 53
    - Display and clear DNS cache
      - MacOS: https://support.apple.com/en-us/HT202516
        sudo killall -HUP mDNSResponder
      - Ubuntu:

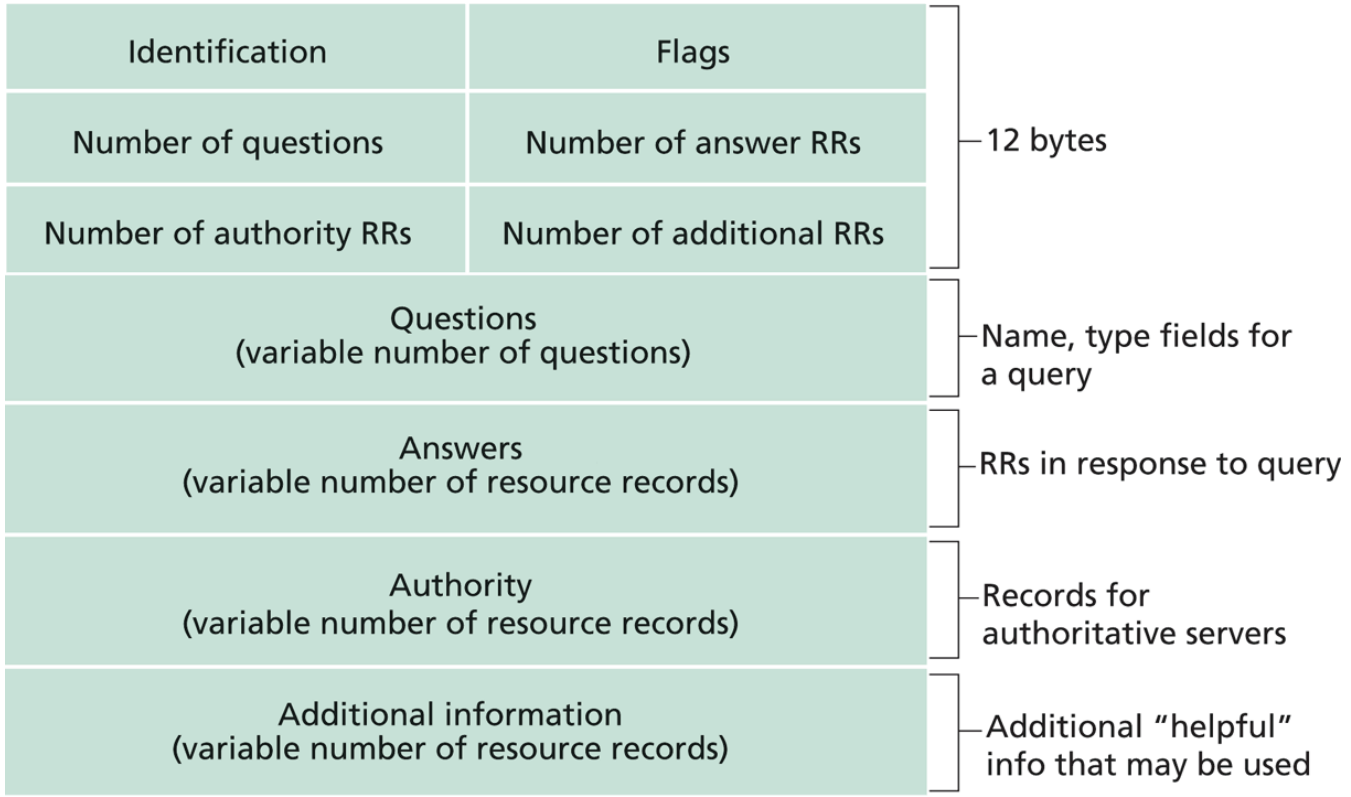
        sudo systemd-resolve --flush-caches

        sudo systemd-resolve --statistics
  - Try to load the dns-capture file from class Schedule page, if you do not want live capture

https://www.ietf.org/rfc/rfc1035.txt

DNS Protocol, Messages

DNS protocol : typically over UDP (can use TCP): *query* and *reply* messages, both with the same *message format*



DNS Details

- Header (Sec. 4.1.1 of https://www.ietf.org/rfc/rfc1035.txt)
- Encoding of questions (Sec. 4.1.2):
  - [Label-length label-chars]
- Encoding of answers (Sec. 4.1.3)
  - Pointer format (http://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml)
- See example DNS packets

Name Encoding

```
▼ Queries
  ▼ xmu.edu.cn: type A, class IN
      Name: xmu.edu.cn
      [Name Length: 10]
      [Label Count: 3]
      Type: A (Host Address) (1)
      Class: IN (0x0001)
    [Response In: 3]
```

```
0000  34 71 46 af 81 aa 08 00  27 ba b3 67 08 00 45 00   4qF····· '··g··E·
0010  00 38 02 d4 40 00 40 11  b0 5b c0 a8 03 34 c0 a8   ·8··@·@· ·[···4··
0020  03 01 9b 8f 00 35 00 24  87 bb ed 00 01 00 00 01   ·····5·$ ········
0030  00 00 00 00 00 00 03 78  6d 75 03 65 64 75 02 63   ·······x mu·edu·c
0040  6e 00 00 01 00 01                                 n·····
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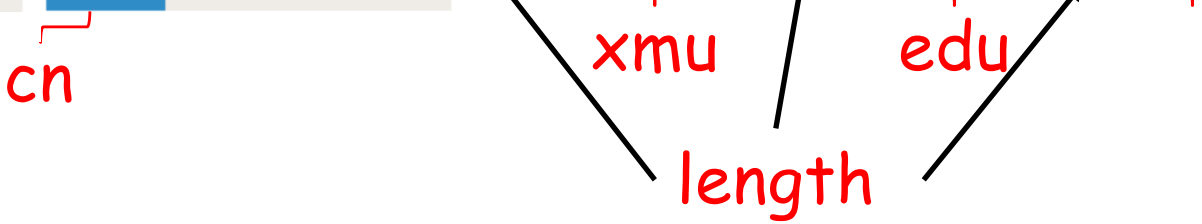
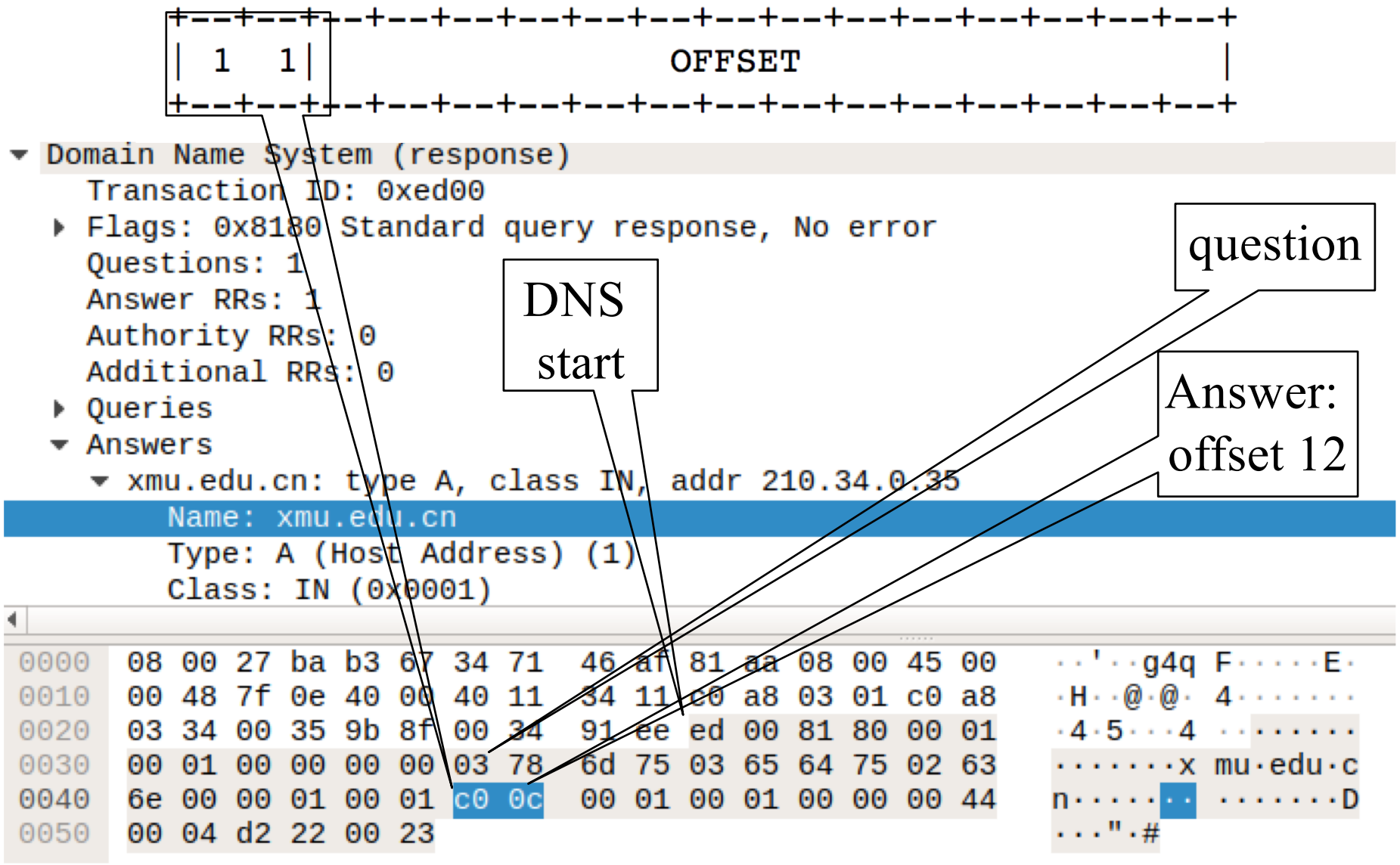


Message Compression (Label Pointer)



https://www.ietf.org/rfc/rfc1035.txt

Recap: DNS Protocol, Messages

Many features: typically over UDP (can use TCP); *query* and *reply* messages with the same *message format*; *length/content encoding* of names; simple *compression*; additional info as *server push*