Network Applications: Email, DNS

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

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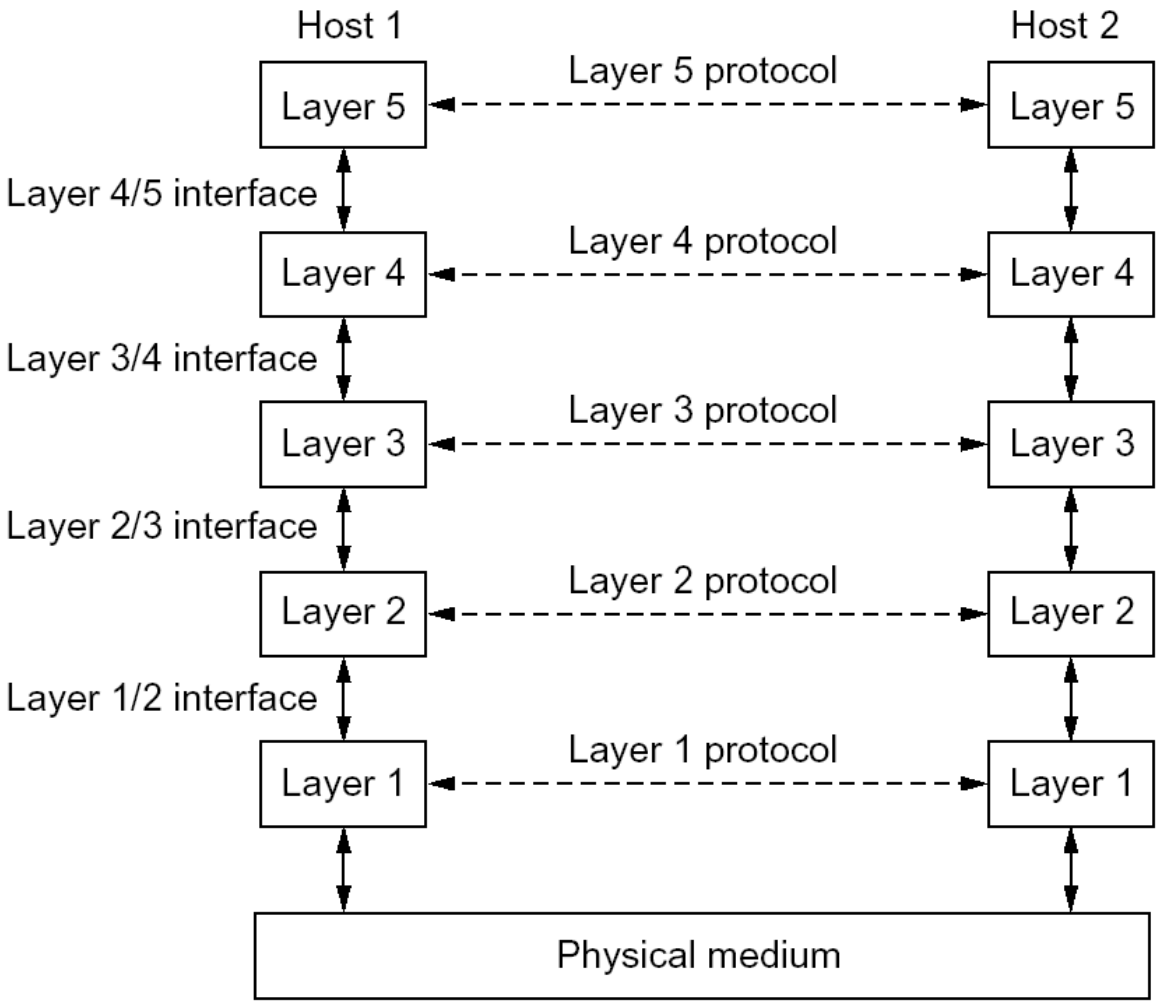
This deck of slides are heavily based on CPSC 433/533 at Yale University, by courtesy of Dr. Y. Richard Yang.

Outline

- Admin. and recap
- Layered architecture
  - Internet layering
- Application layer overview
- Network applications
  - Email
  - DNS

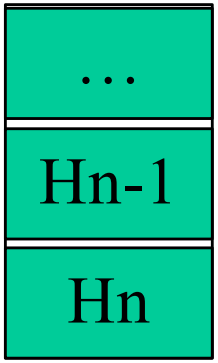
Recap: Layering

- 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

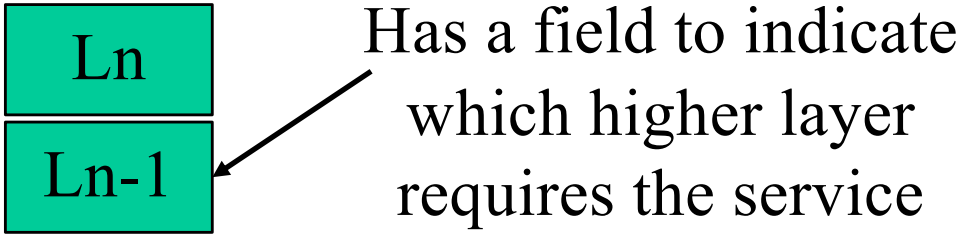


Some Implications of Layered Architecture

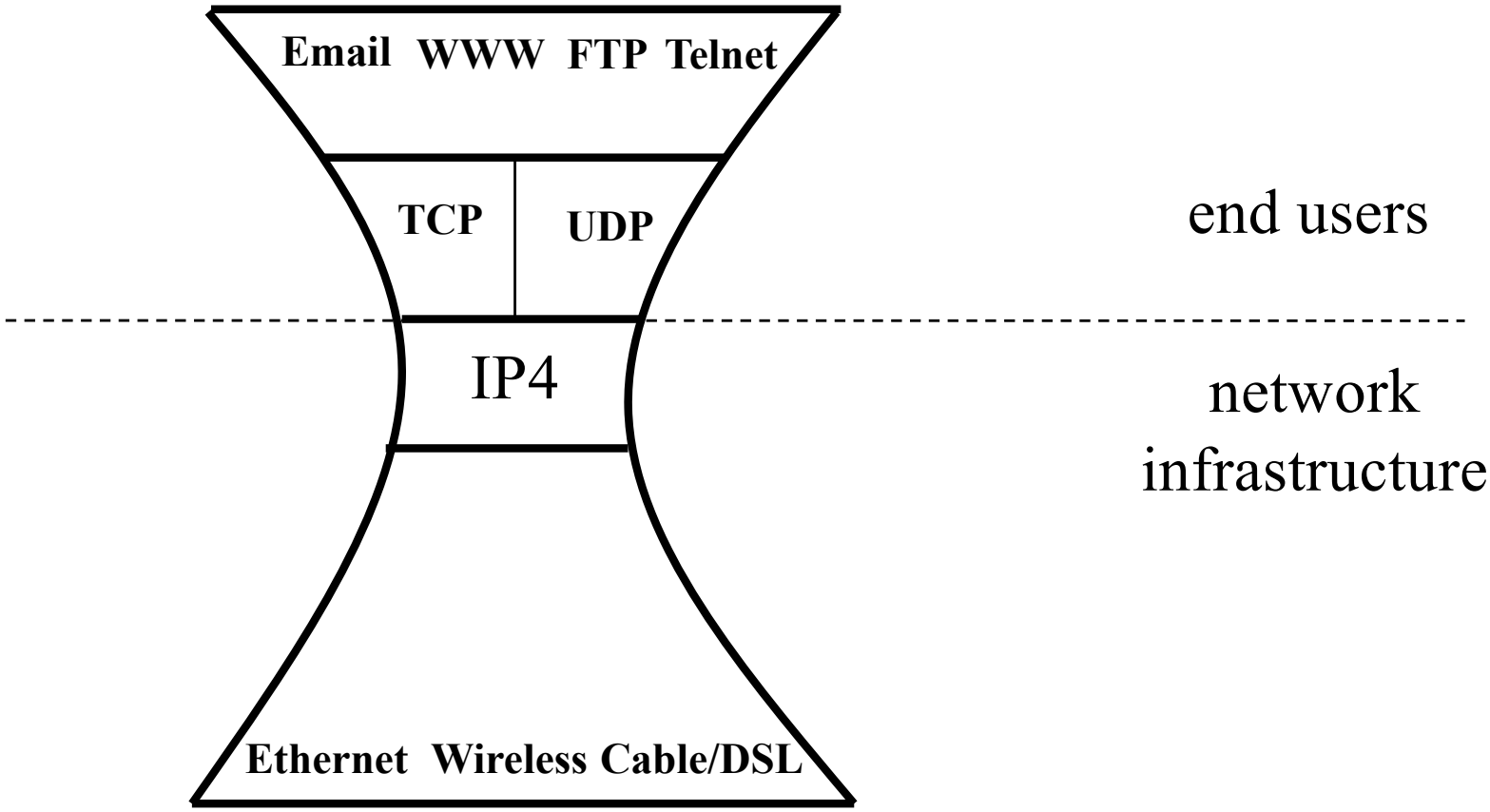
- A packet as a stack container



- Each layer needs multiplexing and demultiplexing to serve layer above

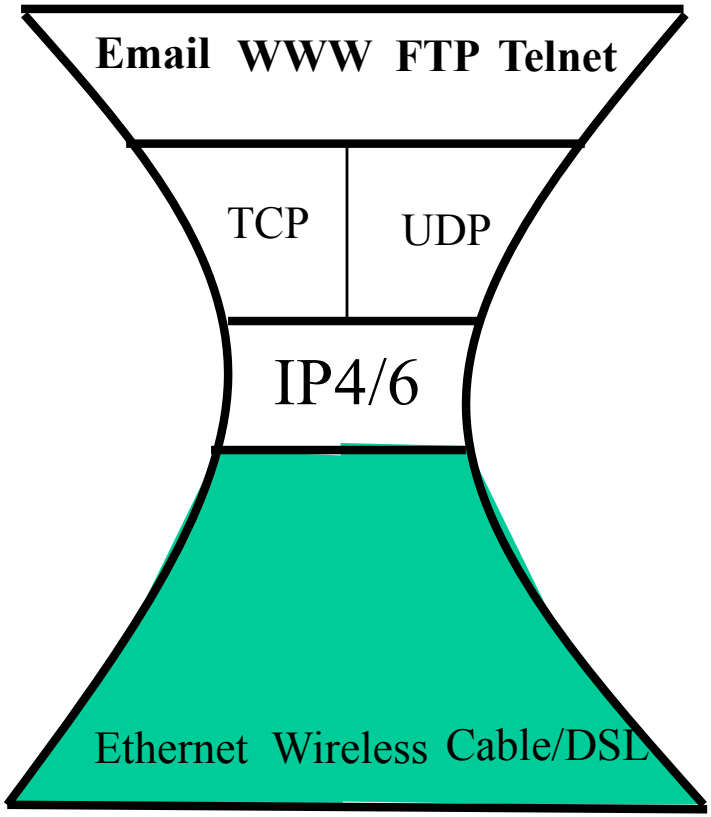


The Hourglass Architecture of the Internet

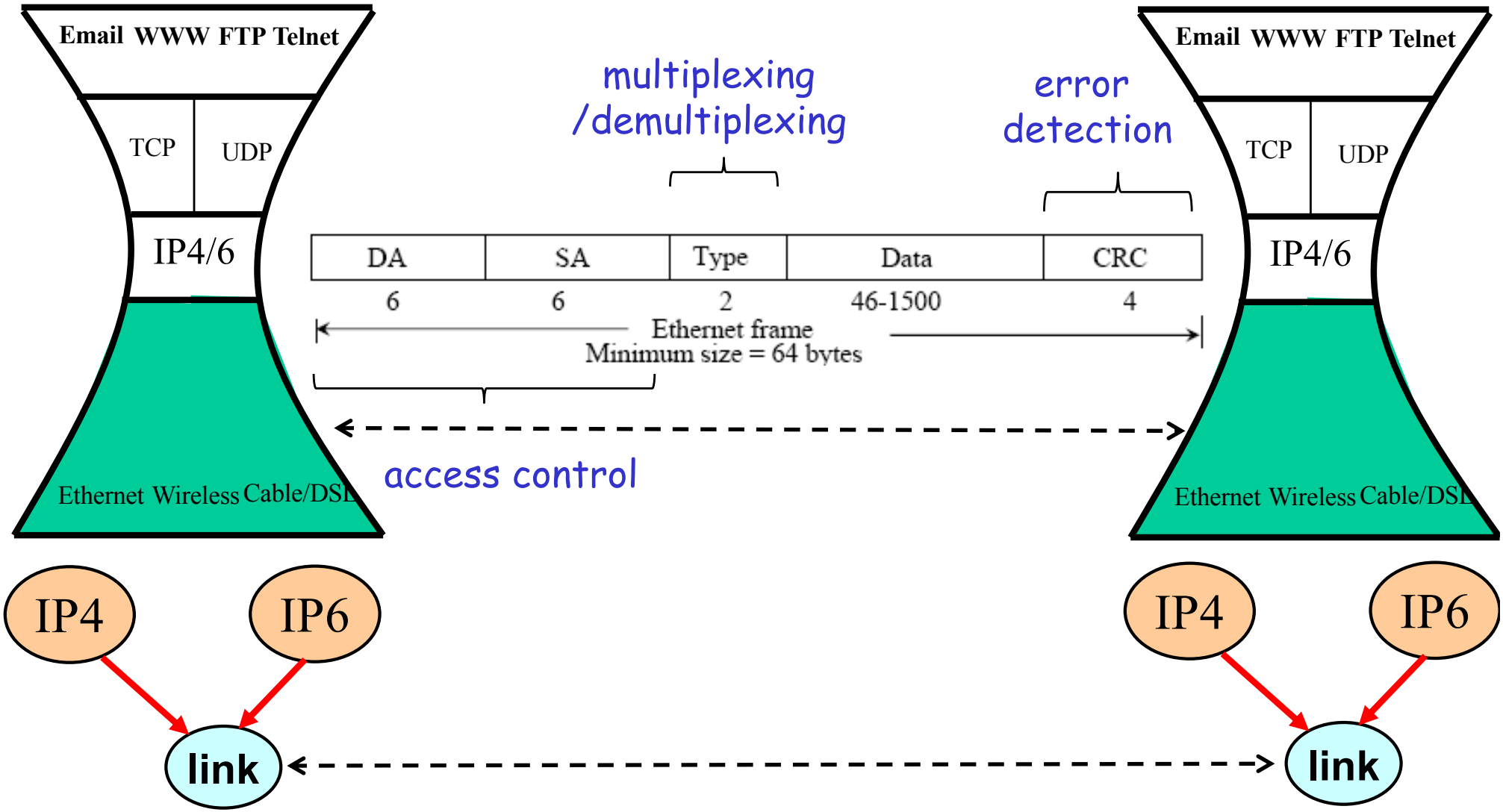


Link Layer (Ethernet)

- Services (to network layer)
  - multiplexing/demultiplexing
    - from/to the network layer
  - error detection
  - multiple access control
    - arbitrate access to shared medium
- Interface
  - send frames to a directly reachable peer

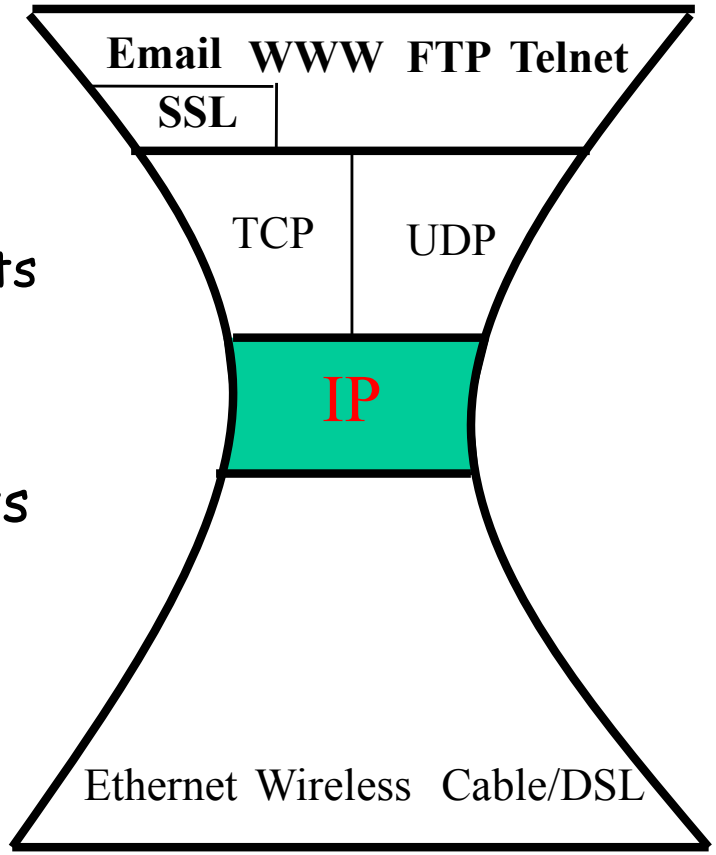


Link Layer: Protocol Header (Ethernet)

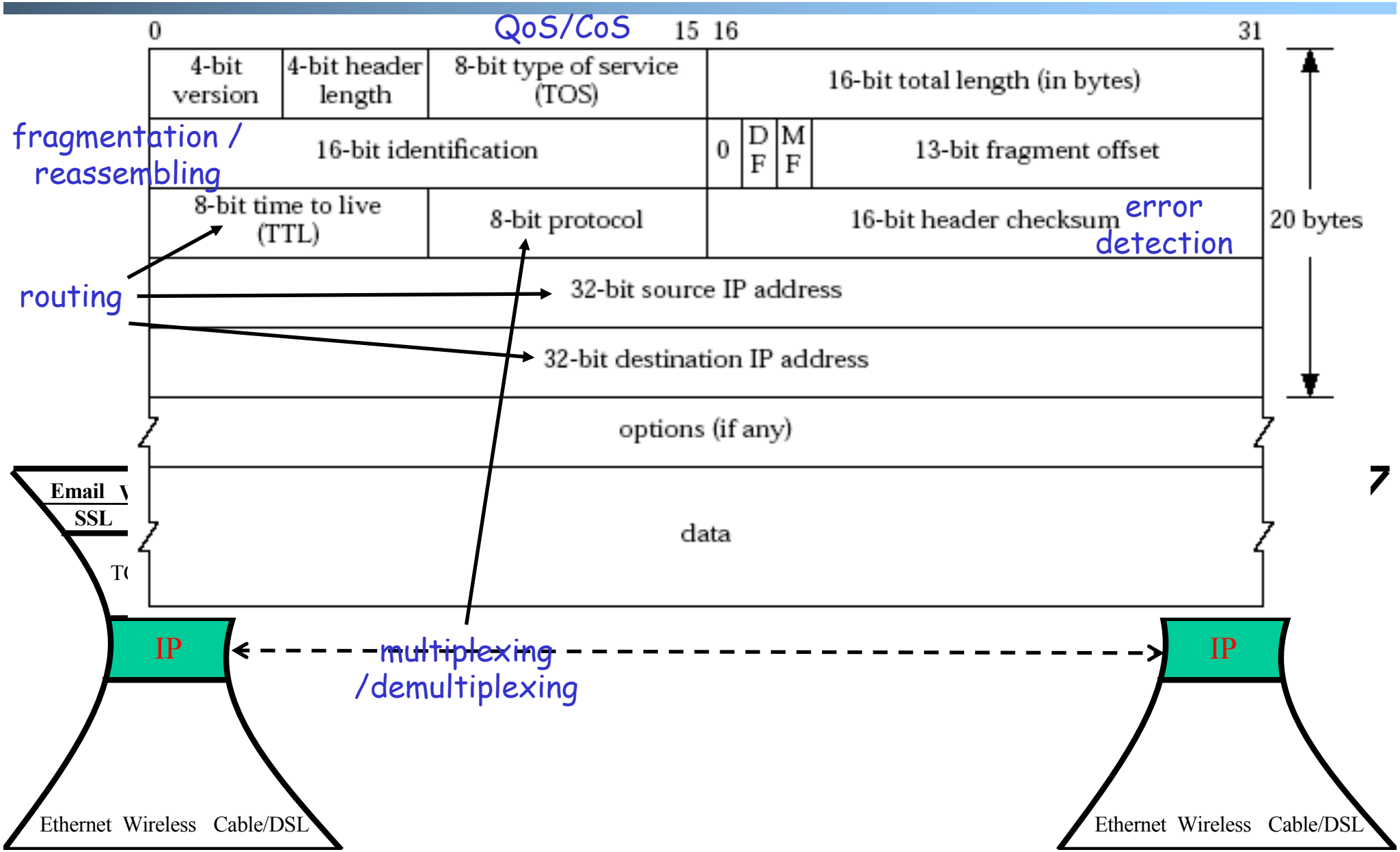


Network Layer: IP

- Services (to transport layer)
  - multiplexing/demultiplexing from/to the transport
  - fragmentation and reassembling: partition a fragment into smaller packets
    - removed in IPv6
  - error detection
  - routing: best-effort to send packets from source to destination
  - certain QoS/CoS
  - does not provide reliability or reservation
- Interface:
  - send a packet to a (transport-layer) peer at a specified global destination, with certain QoS/CoS

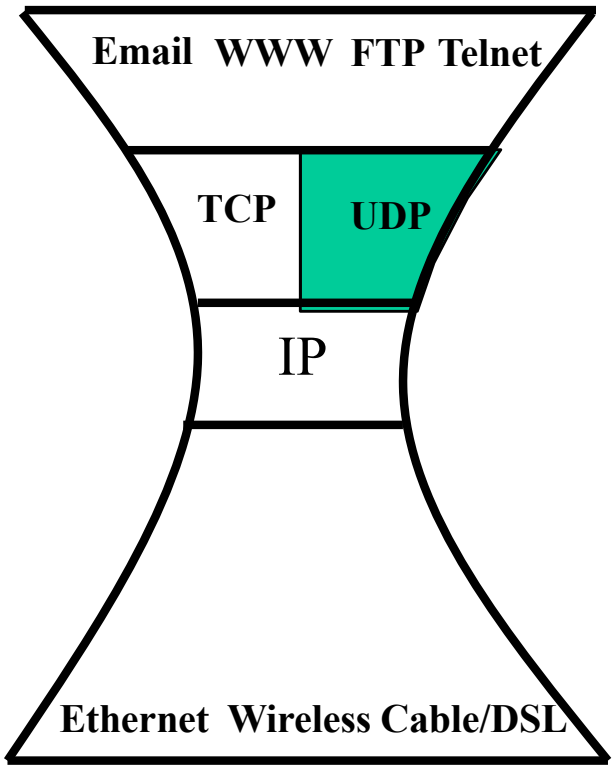


Network Layer: IPv4 Header



Transport Layer: UDP

- A connectionless service
- Does not provide: connection setup, reliability, flow control, congestion control, timing, or bandwidth guarantee
  - why is there a UDP?

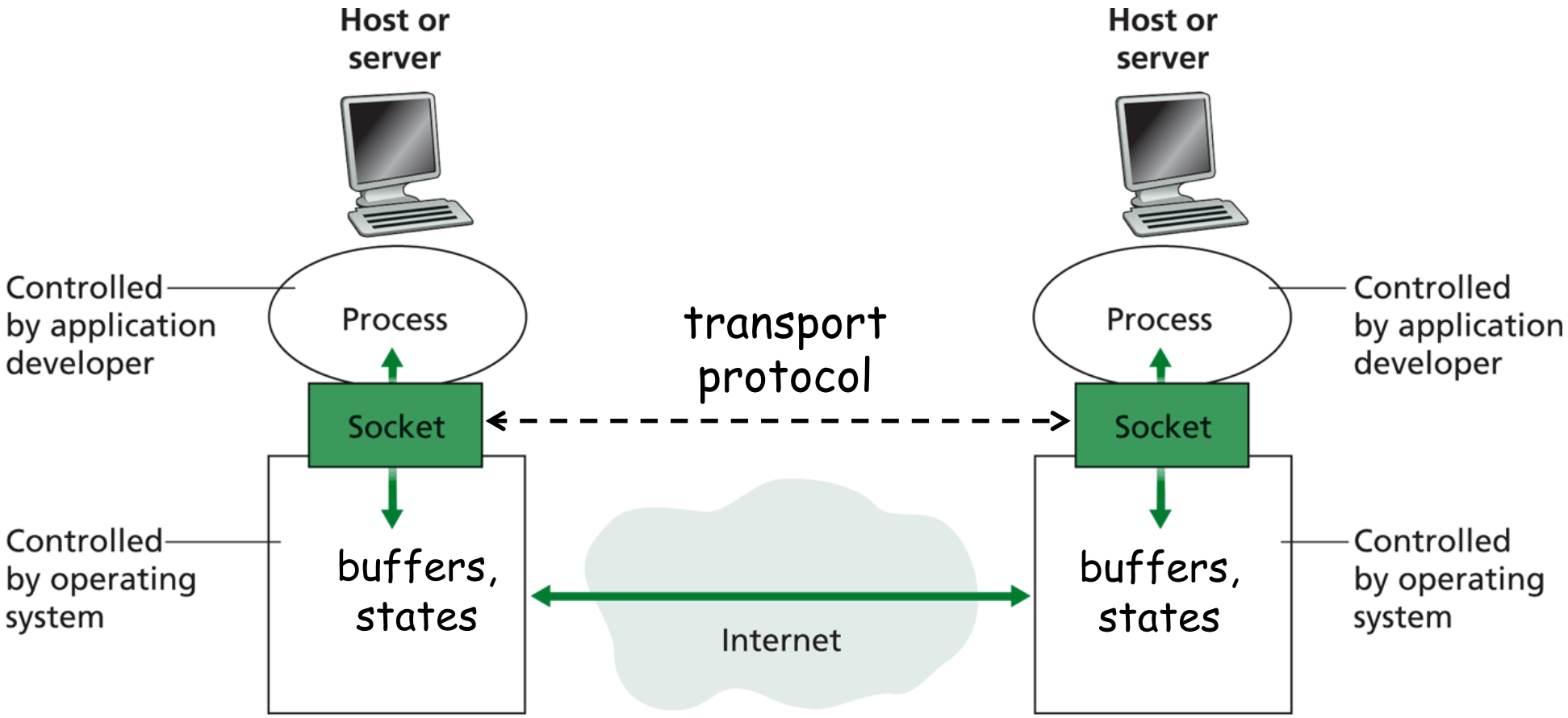


Transport Services and APIs

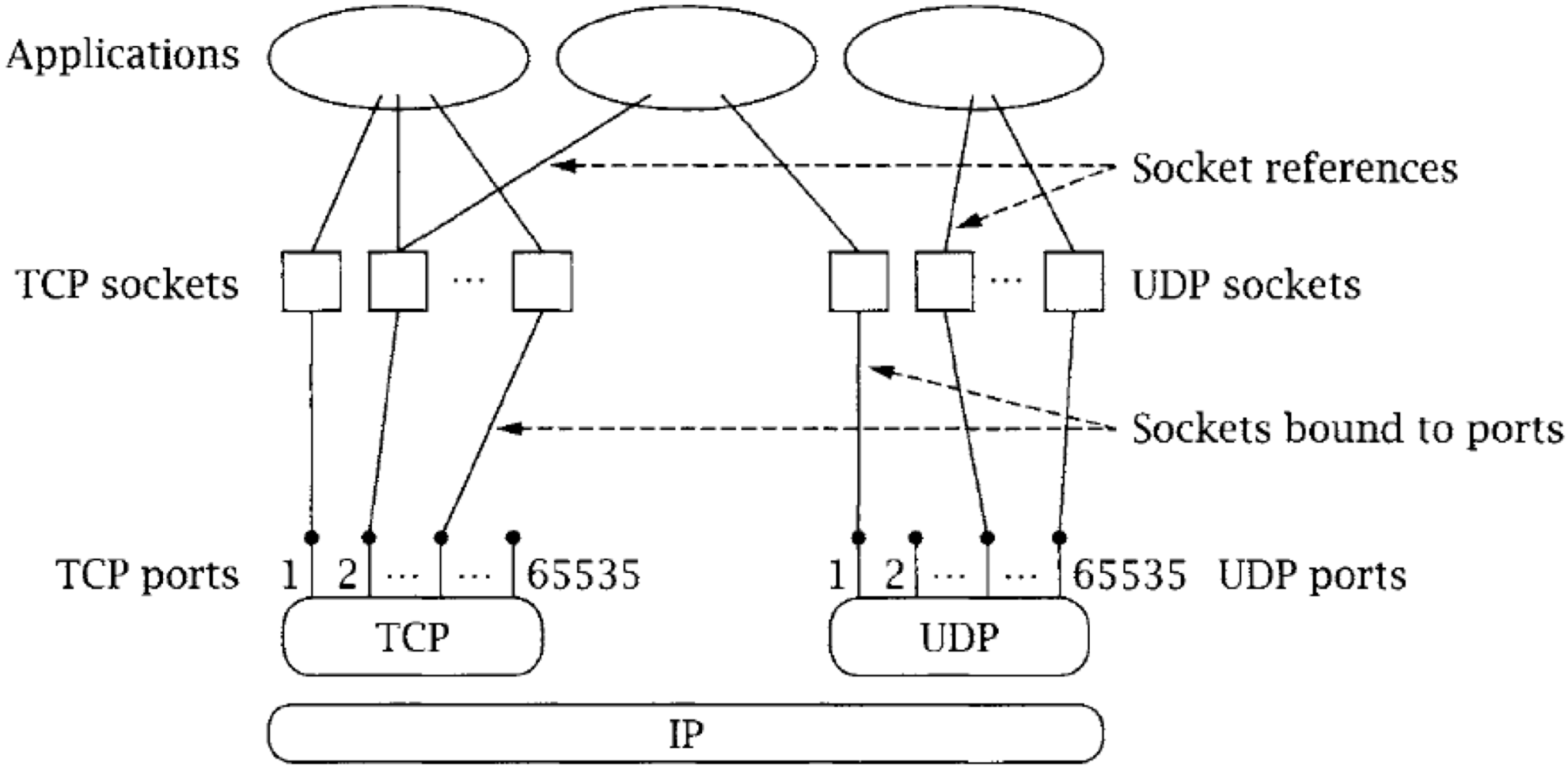
- Multiple services and APIs proposed in history
  - XTI (X/Open Transport Interface), a slight modification of the Transport Layer Interface (TLI) developed by AT&T.

- Commonly used transport-layer service model and API: Socket
  - sometimes called "Berkeley sockets" acknowledging their heritage from Berkeley Unix
  - a socket has a transport-layer local port number
    - e.g., email (SMTP) port number 25, web port number 80
  - Application can send data into socket, read data out of socket
  - an application process binds to a socket (-a all; -u udp; -n number)
    - %netstat -aun

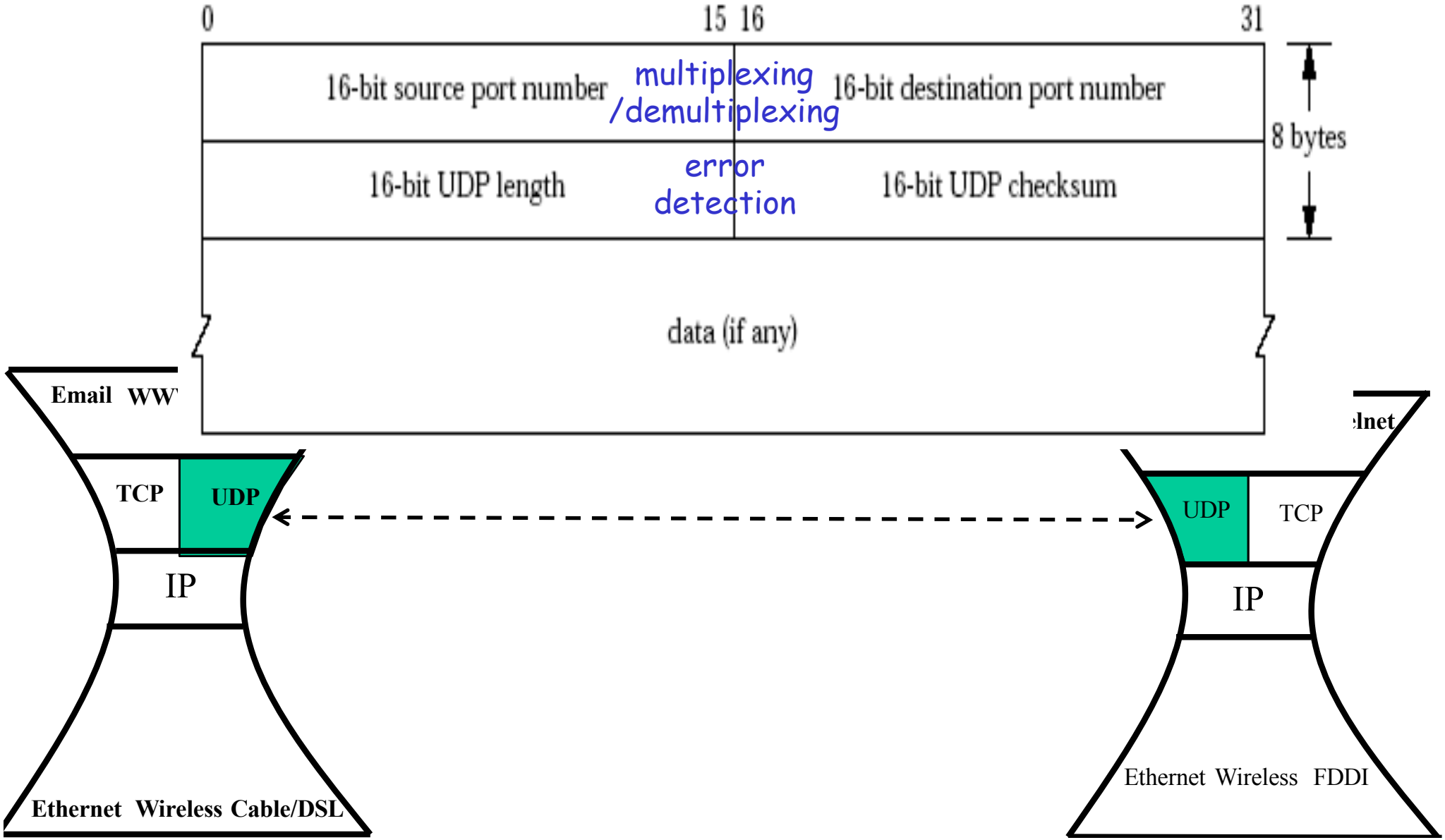
Socket Service Model and API



Multiplexing/Demultiplexing

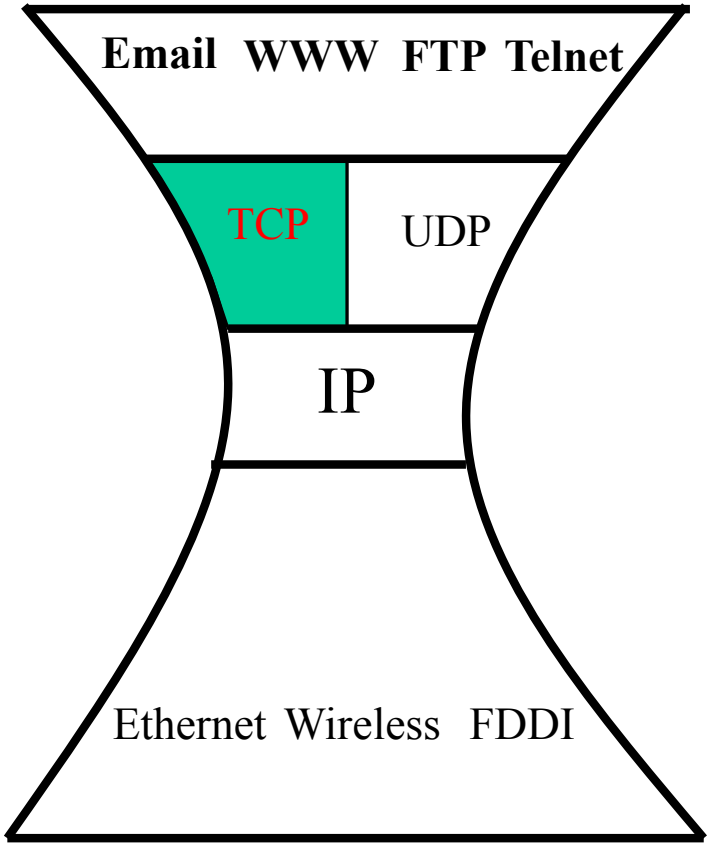


Transport Layer: UDP Header

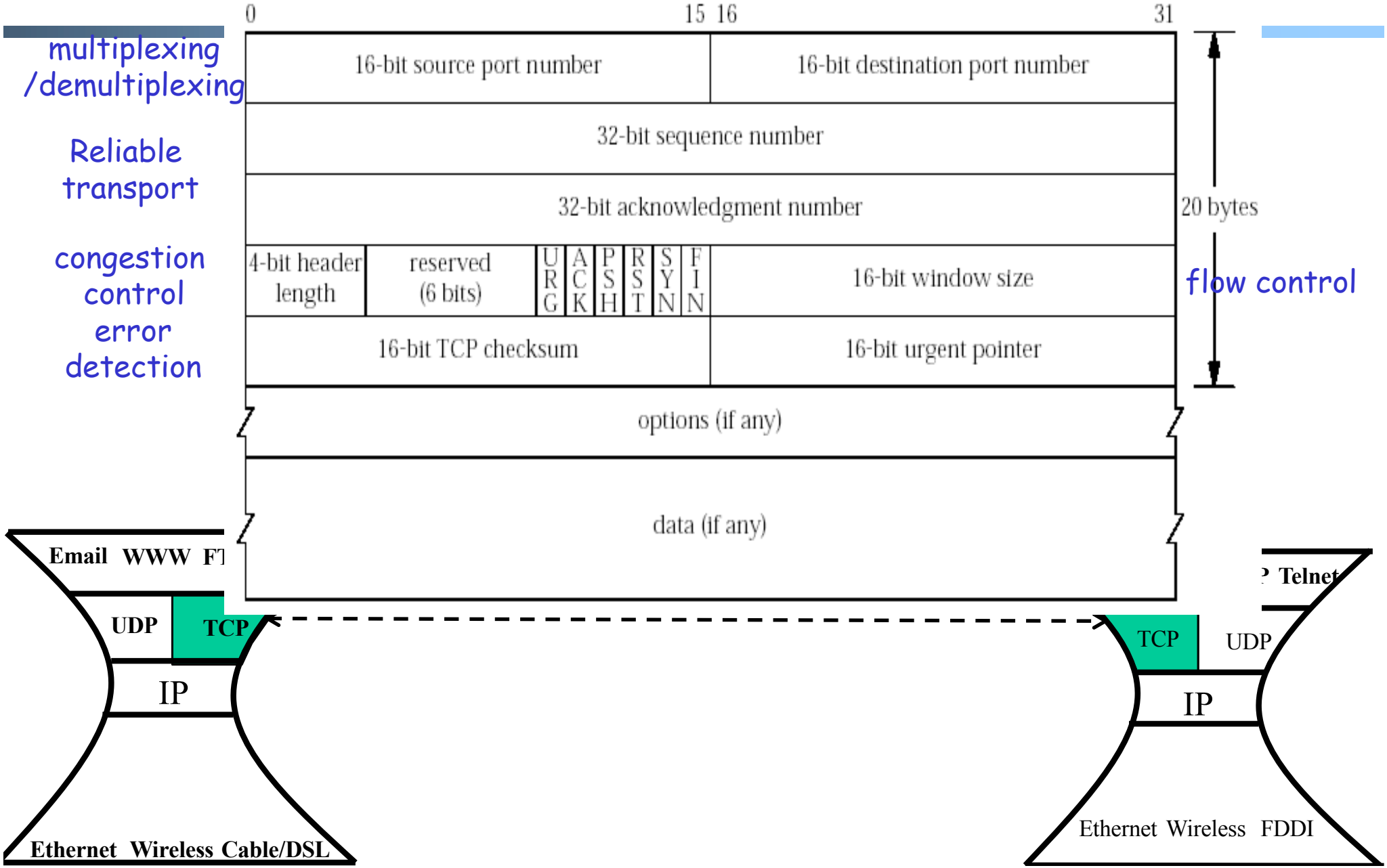


Transport Layer: TCP

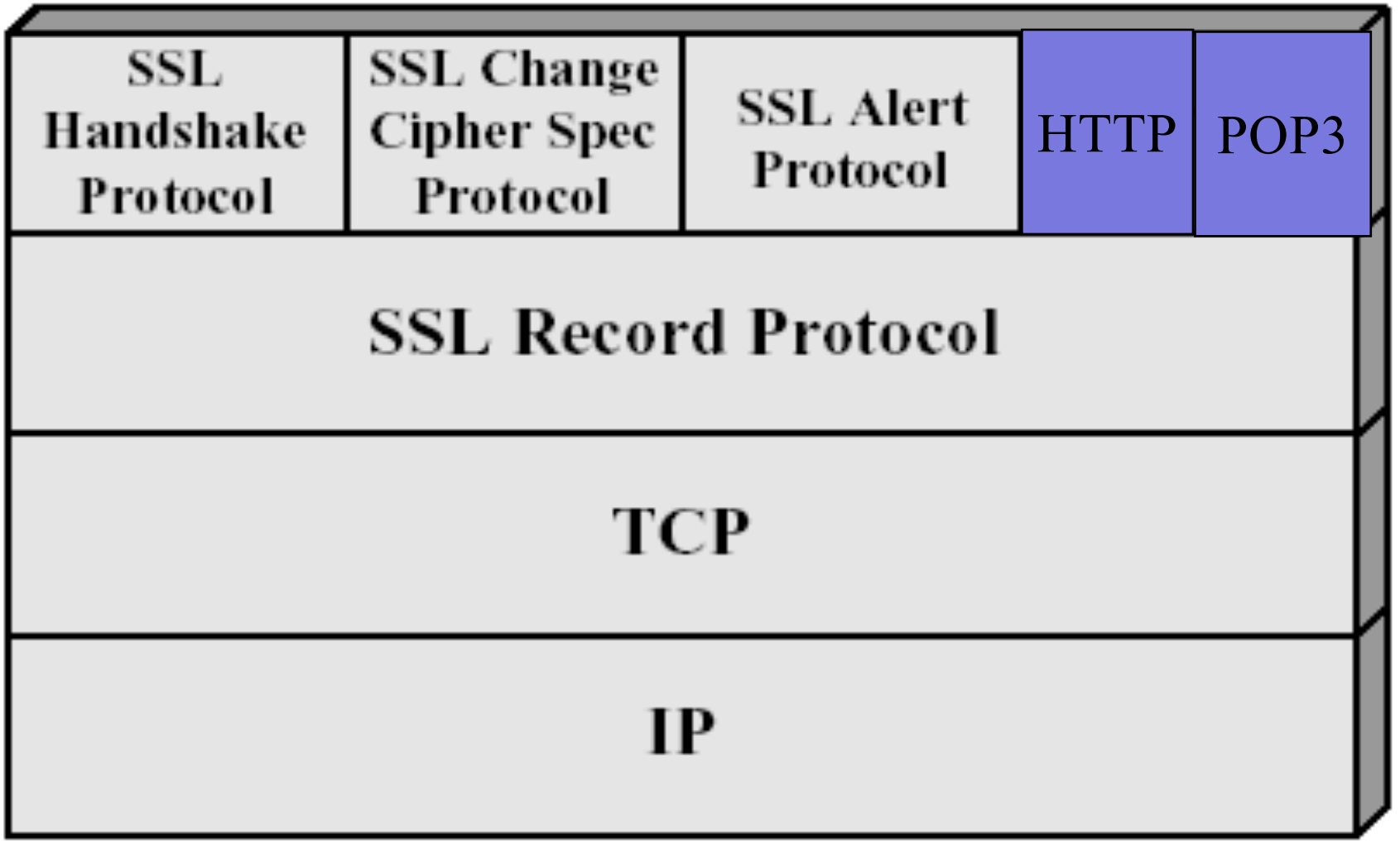
- Services
  - multiplexing/demultiplexing
  - reliable transport
    - between sending and receiving processes
    - setup required between sender and receiver: a connection-oriented service
  - flow control: sender won't overwhelm receiver
  - congestion control: throttle sender when network overloaded
  - error detection
  - does not provide timing, minimum bandwidth guarantees
- Interface:
  - send a packet to a (app-layer) peer



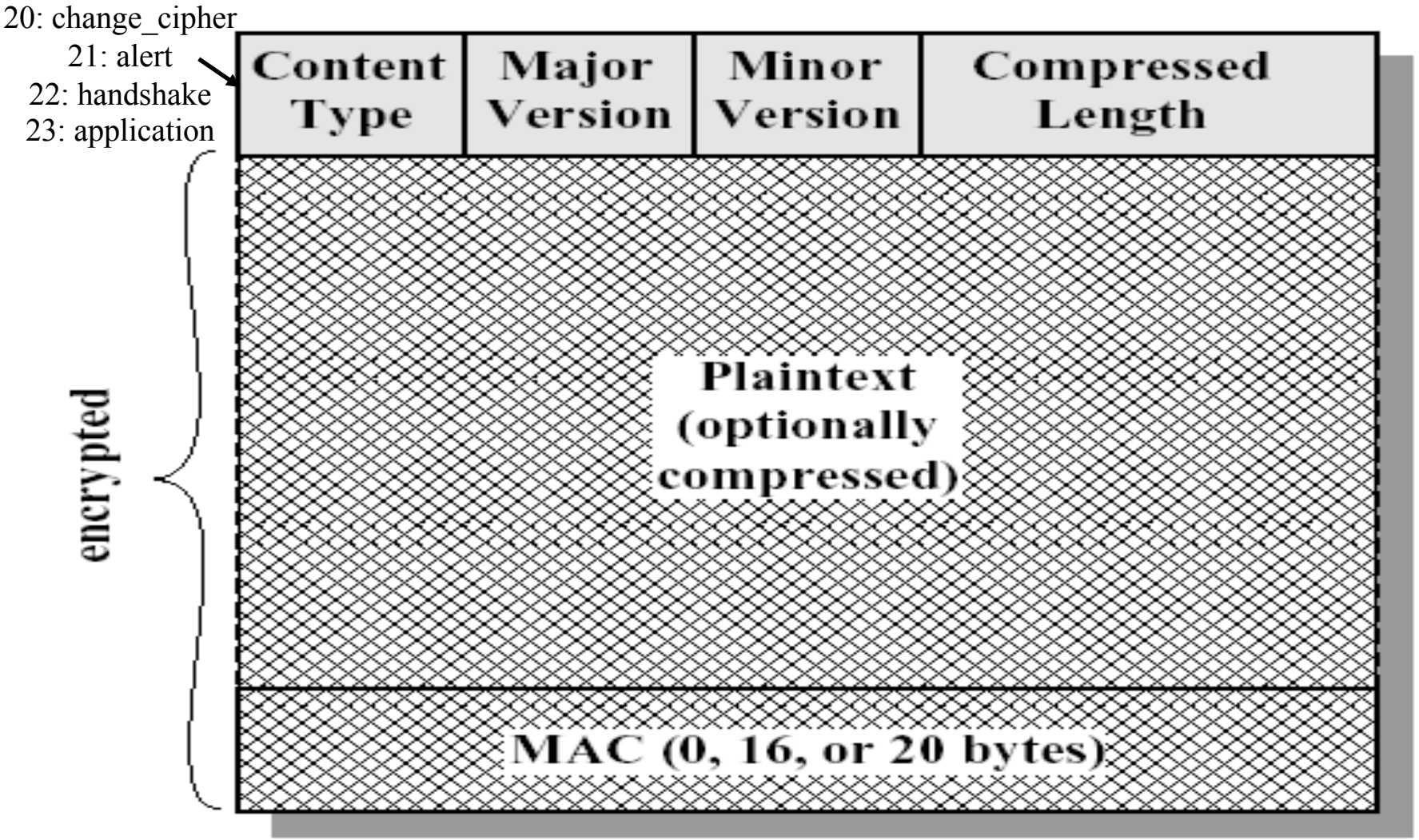
Transport Layer: TCP Header



Secure Socket Layer Architecture



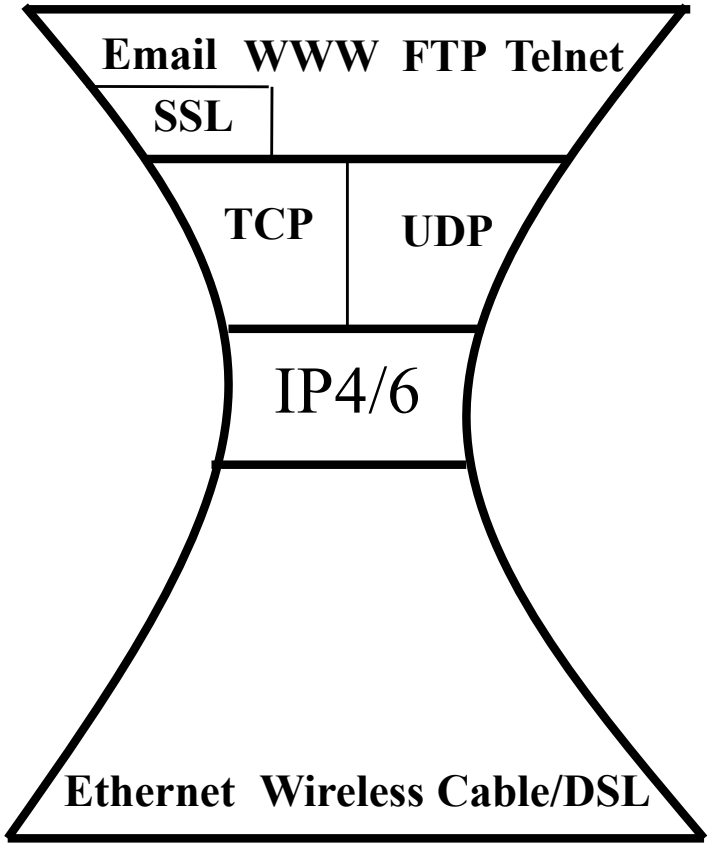
SSL Record-Layer Packet Format



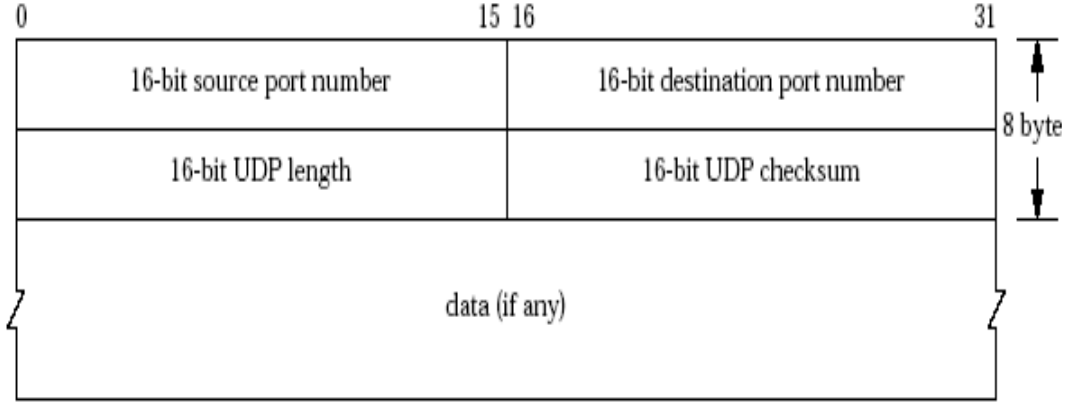
Summary: The Big Picture of the Internet

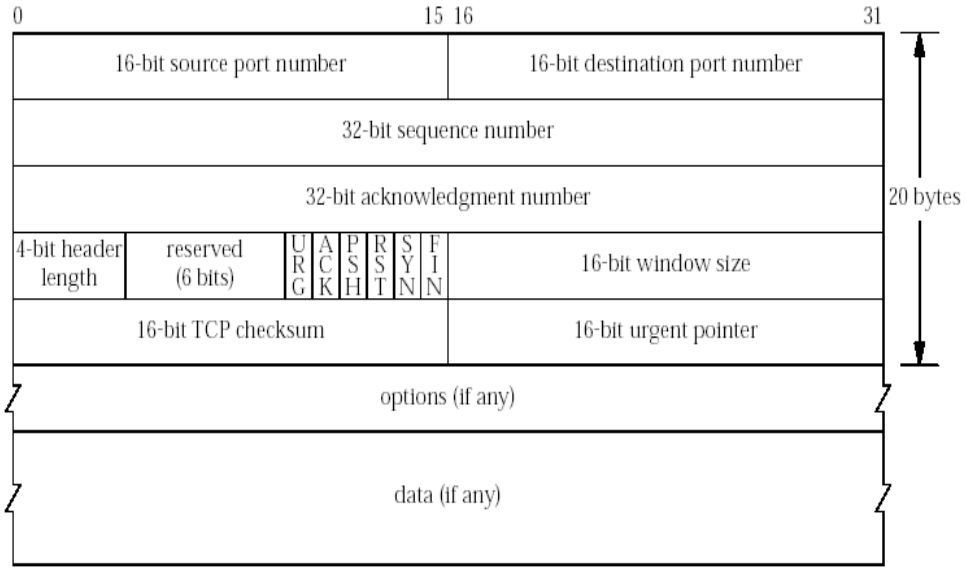
- Hosts and routers:
  - ~ 1 bil. hosts
  - autonomous systems organized roughly hierarchical
  - backbone links at 100 Gbps

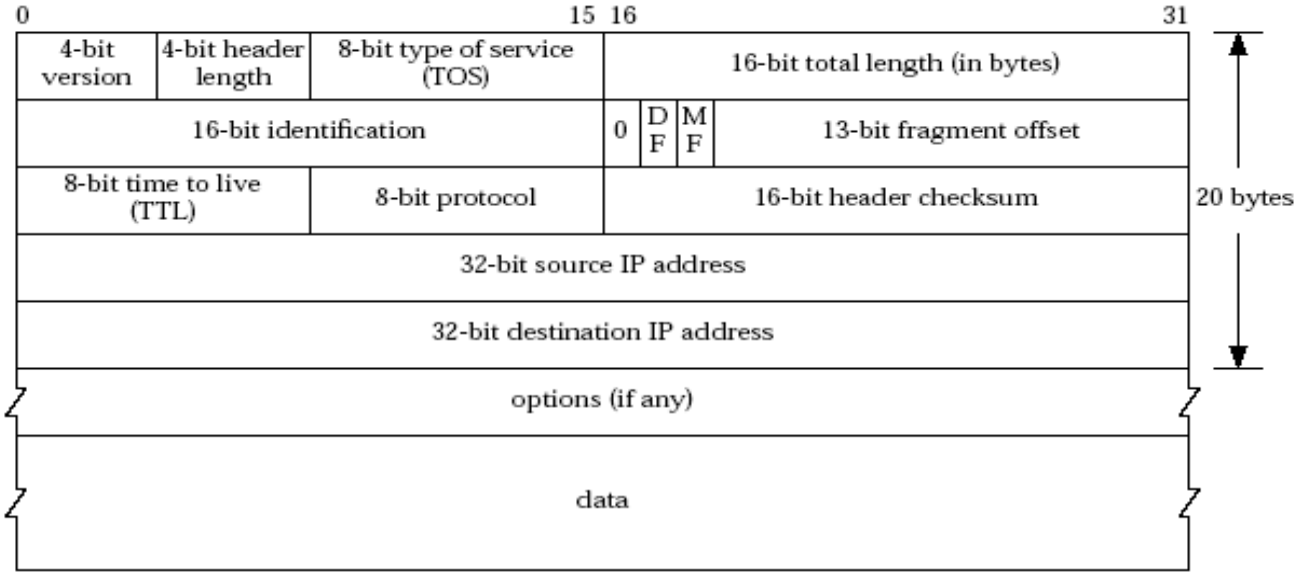
- Software:
  - datagram switching with virtual circuit support at backbone
  - layered network architecture
    - use end-to-end arguments to determine the services provided by each layer
  - the hourglass architecture of the Internet

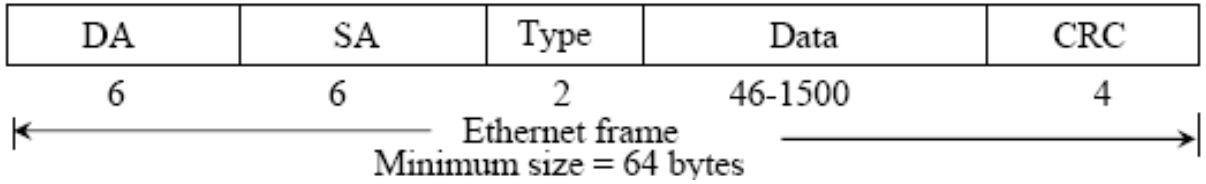


Protocol Formats









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

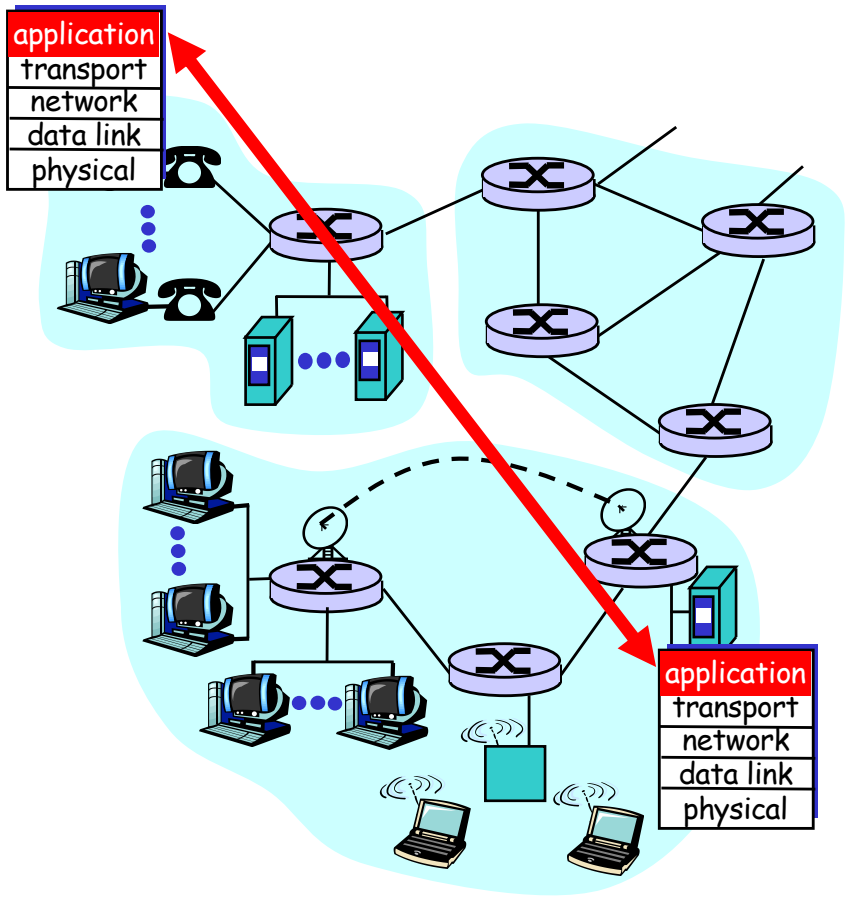
Network Applications vs. Application-layer Protocols

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

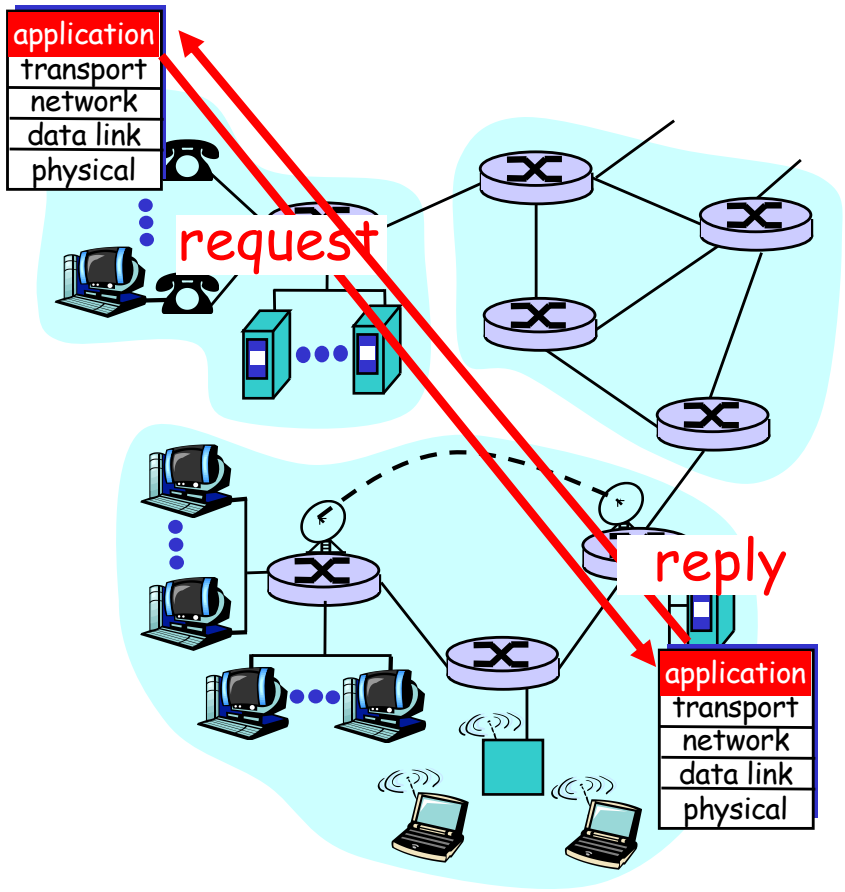
Typical network app has two pieces: *client* and *server*

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):

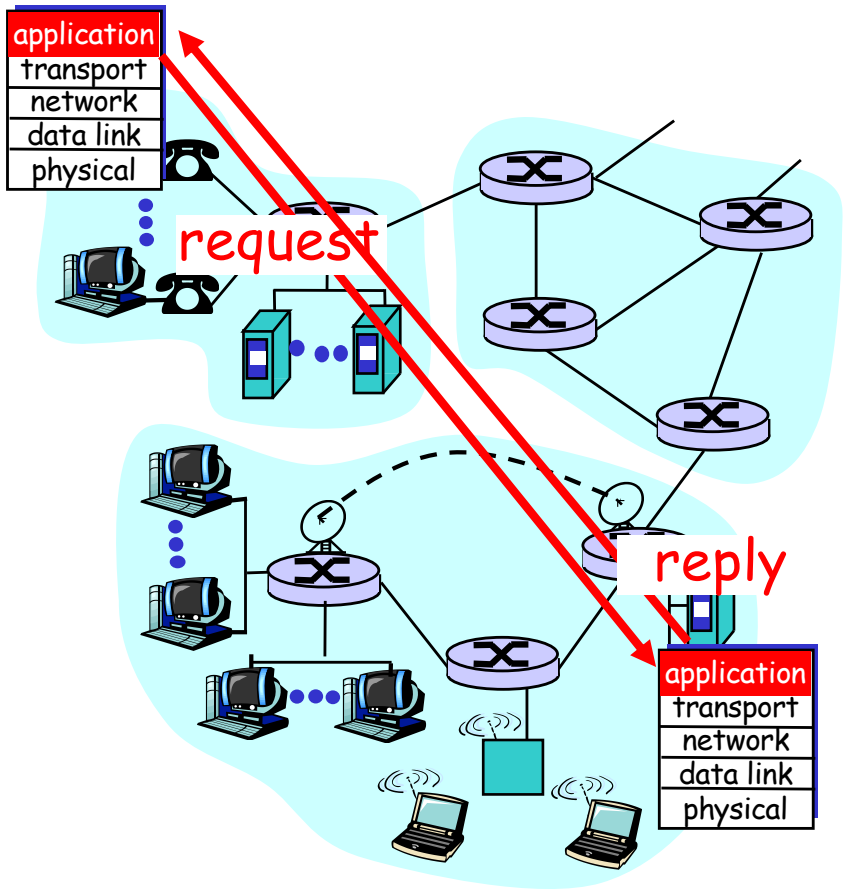
- provides requested service to client
- e.g., Web server sends requested Web page; mail server delivers e-mail



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

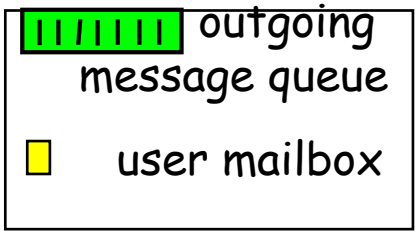
- Still active
  - 80B emails/day
  - 3.9B active email boxes

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

Demo: SMTP

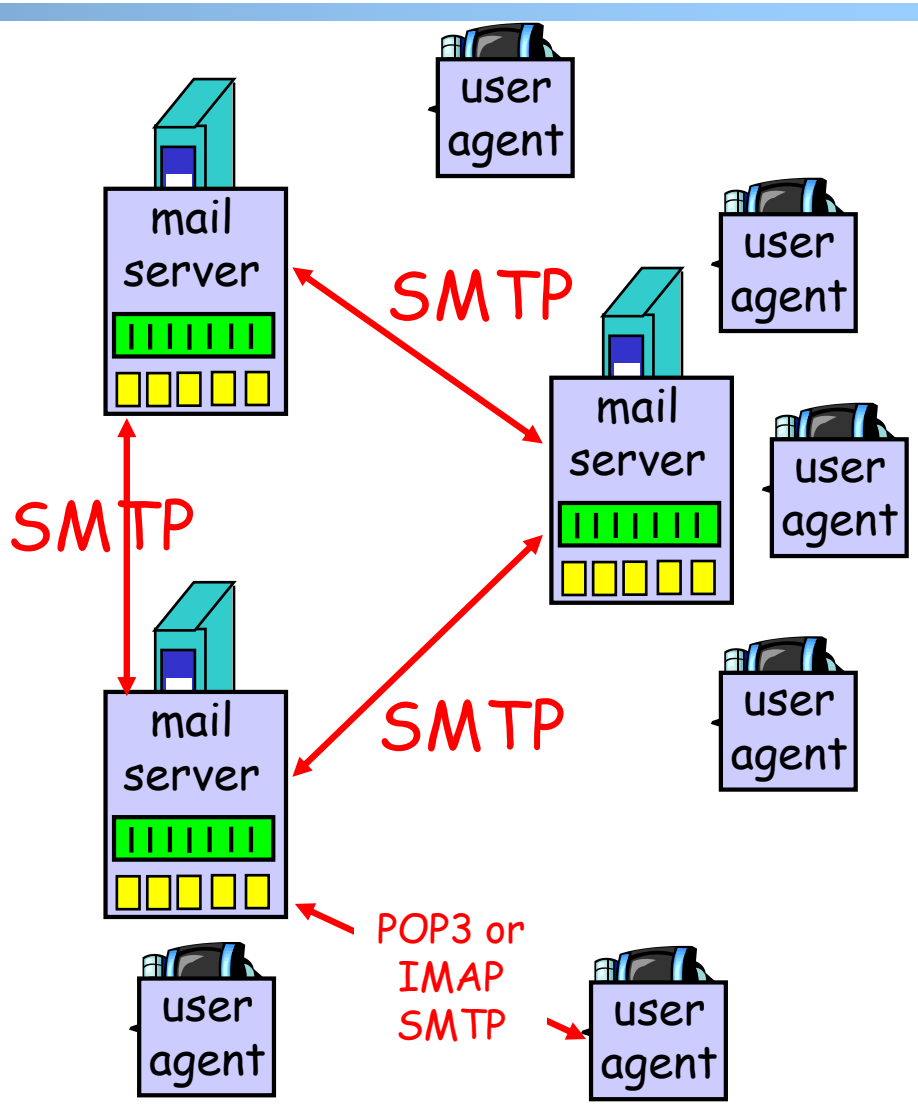
C: auth login
S: 334 VXNlcm5hbWU6
C: eG11Y25ucw==
S: 334 UGFzc3dvcmQ6
C: MzM0ZjU2MDVkZjE1MDRmOQ==
S: 235 OK Authenticated
C: mail from:xmucnns@sina.com
S: 250 ok
C: rcpt to:qiaoxiang@xmu.edu.cn
S: 250 ok
C: data
S: 354 End data with <CR><LF>.<CR><LF>
C: Date:2022-9-22 12:36
C: From:xmucnns@sina.com
C: 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

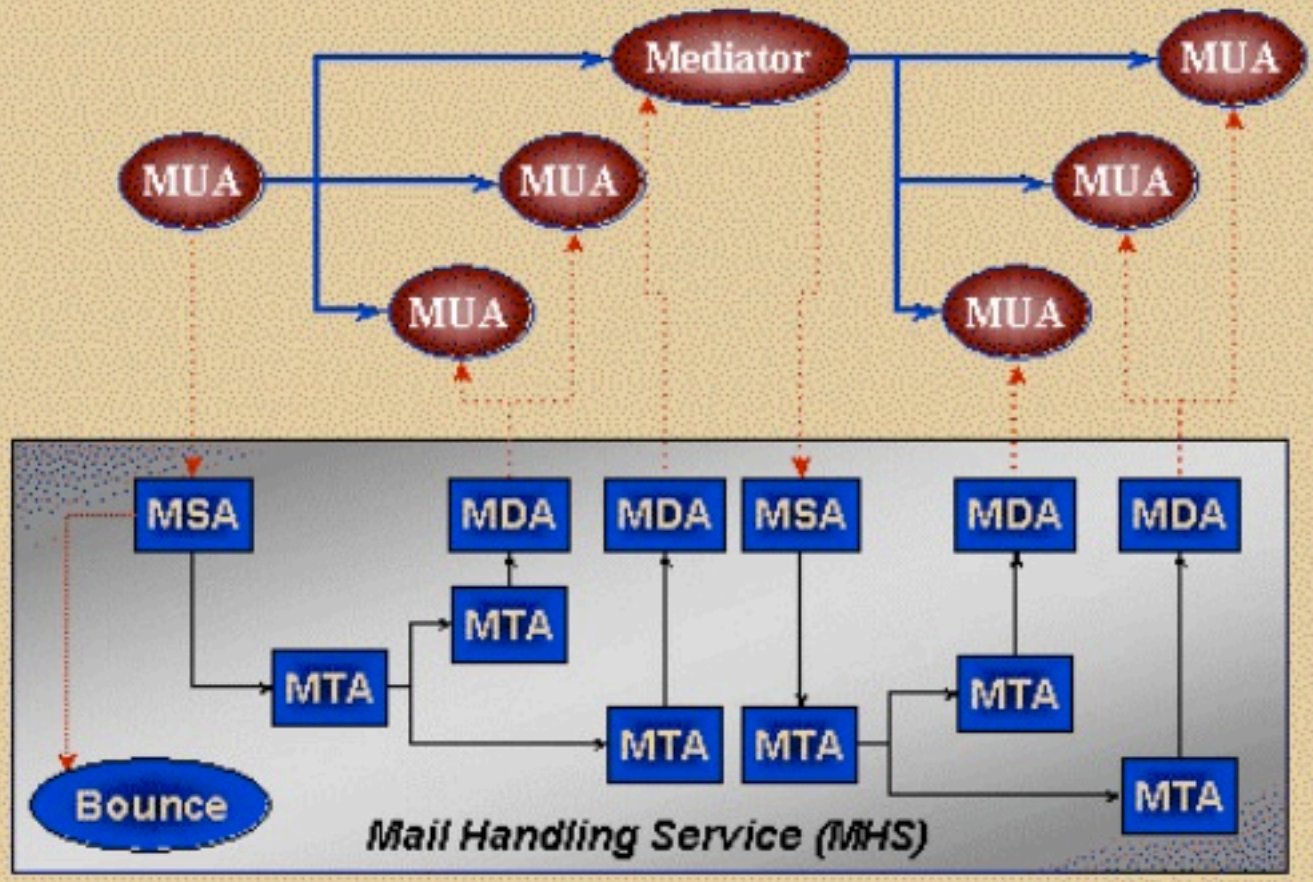
MHS: Mail Handling (transit) Service

MSA: Submission

MTA: Transfer

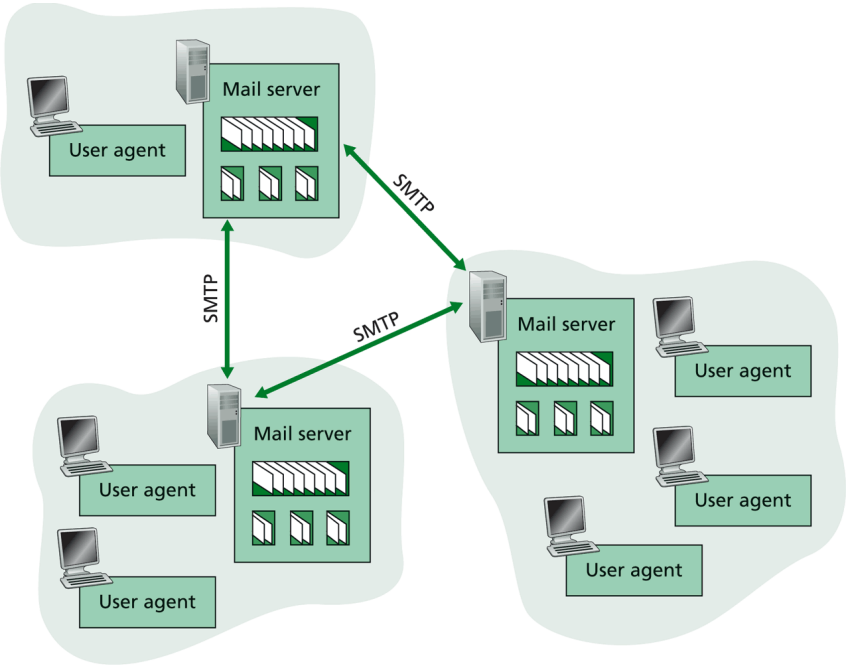
MDA: Delivery

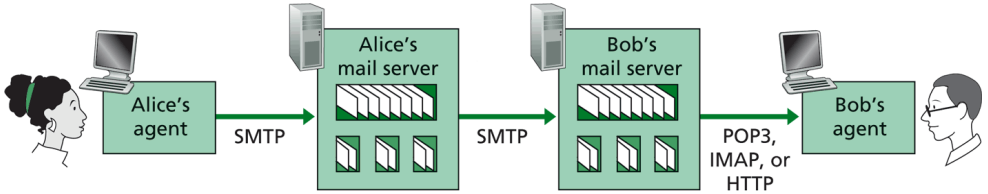
Bounce: Returns



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:2021-9-22 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

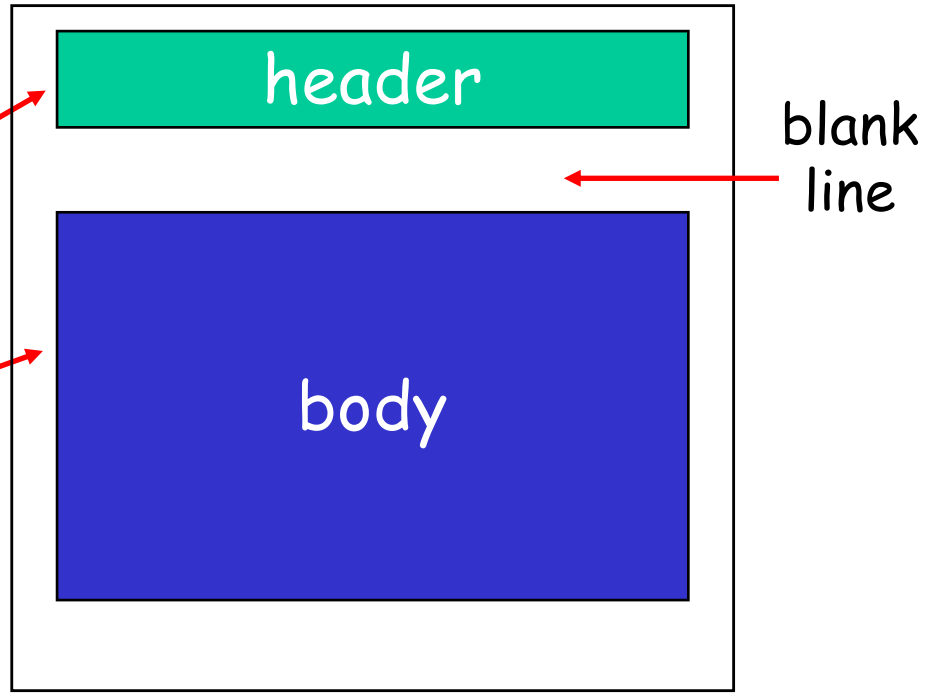
%telnet smtp.sina.com 25

Mail Message Data

SMTP: protocol for exchanging email msgs

RFC 822: standard for text message format:

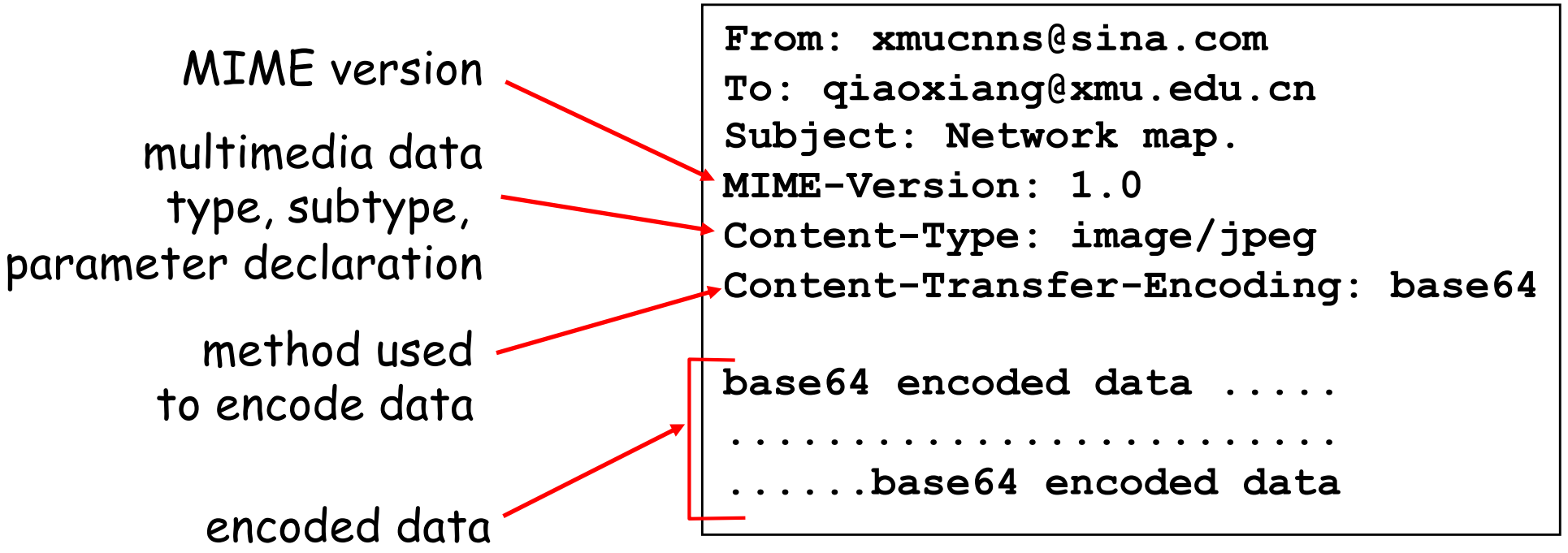
- Header lines, e.g.,
  - To:
  - From:
  - Subject:
- Body
  - the "message", ASCII characters only



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`

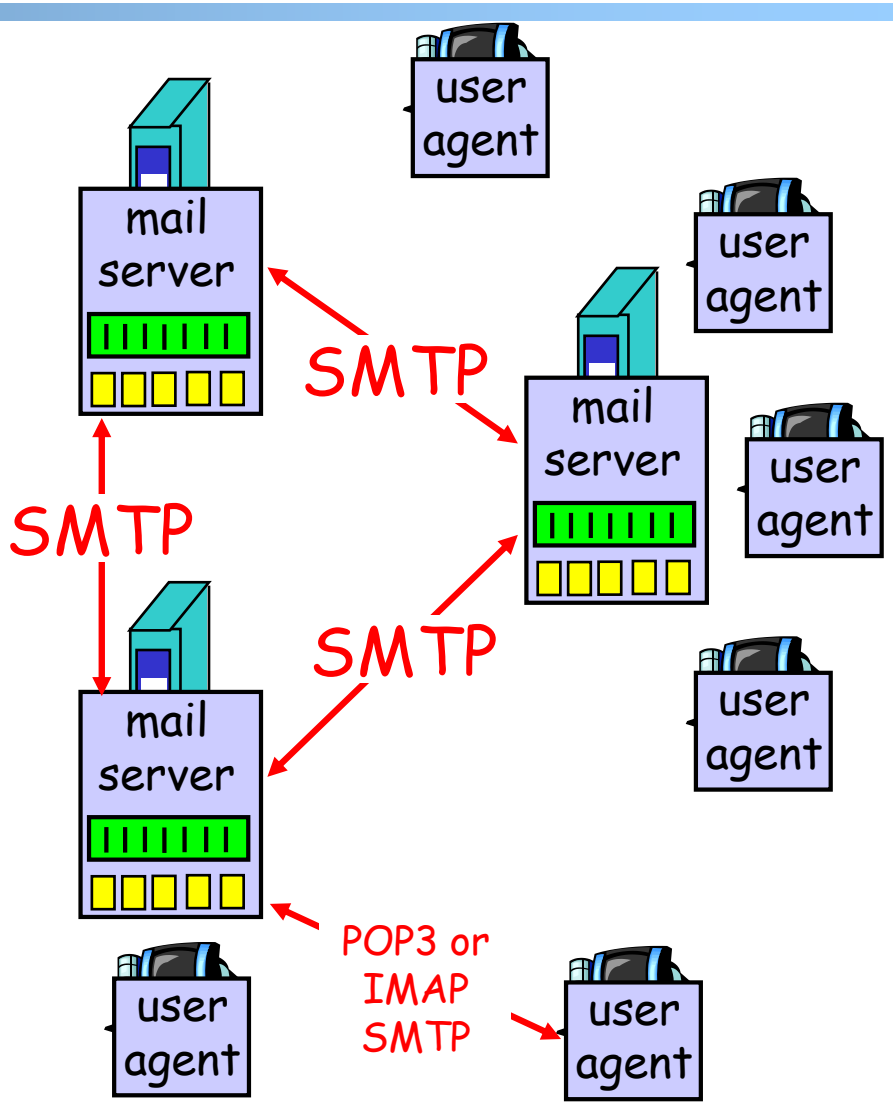
Exercise

- 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

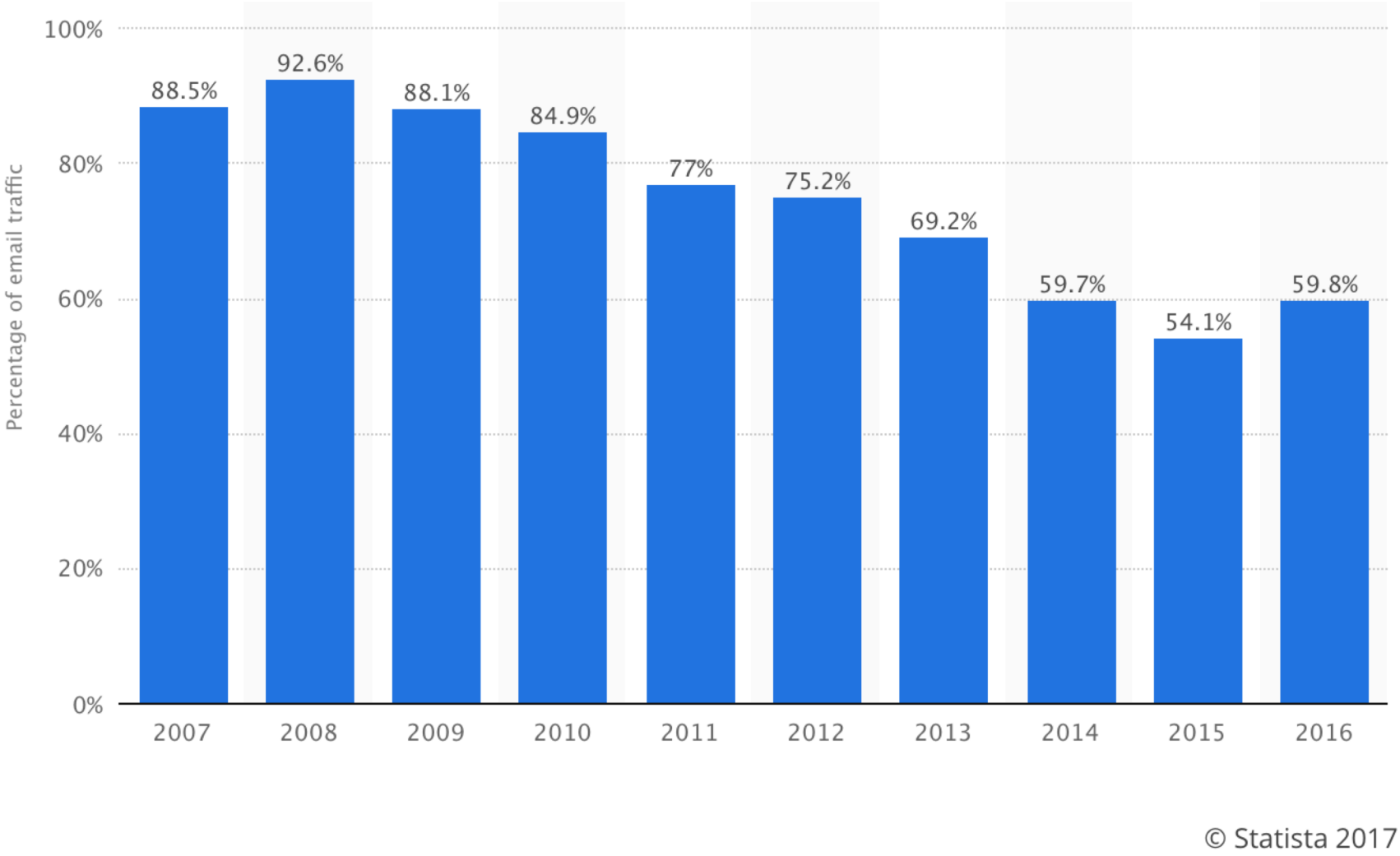
- extensible?
- scalable?
- robust?
- security?



Email Security: Spam

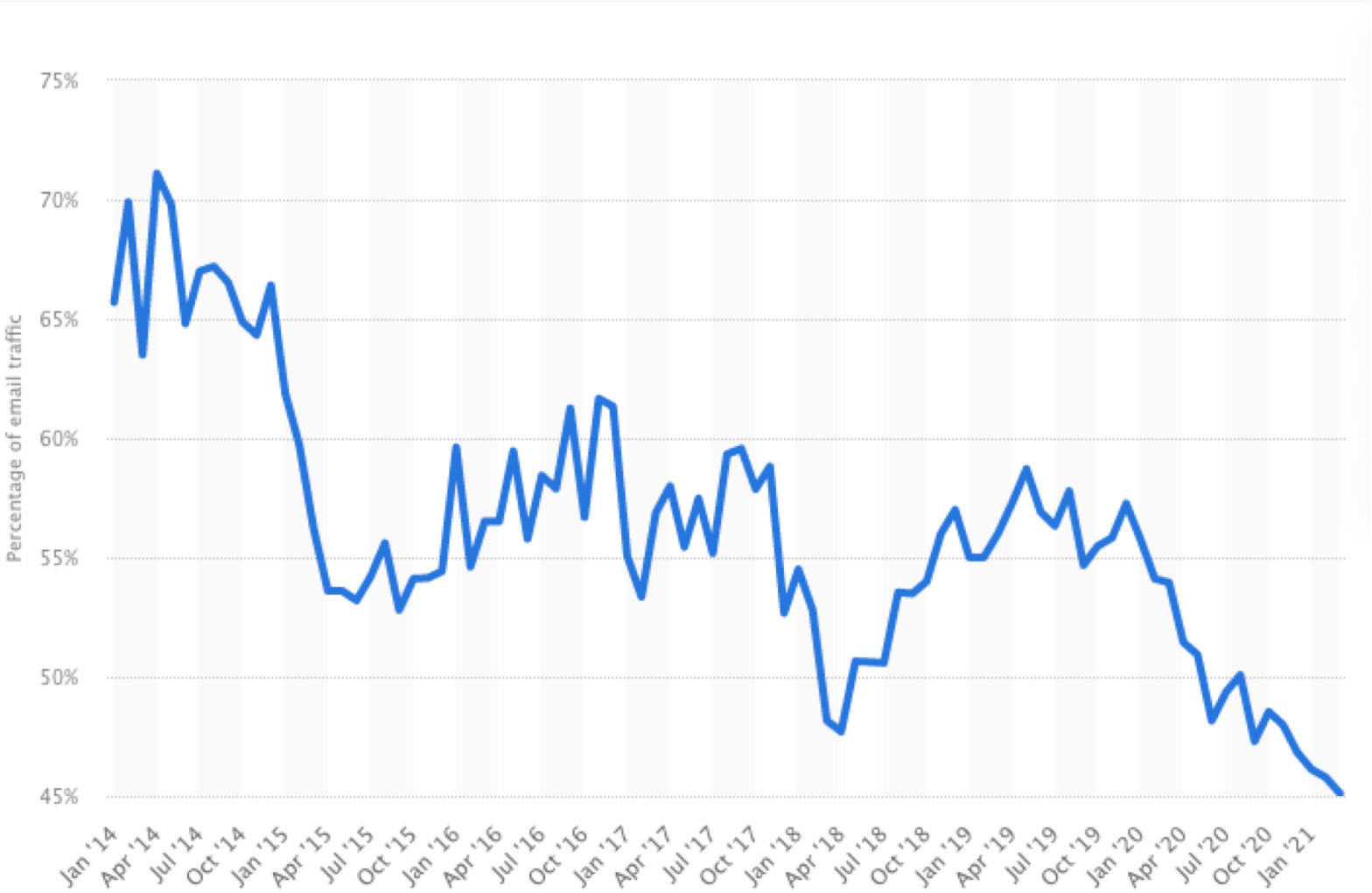
- Spam (Google)

Email Security Issue: Spam



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

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