# Network Applications: Overview, EMail

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http://zoo.cs.yale.edu/classes/cs433/

9/12/2017

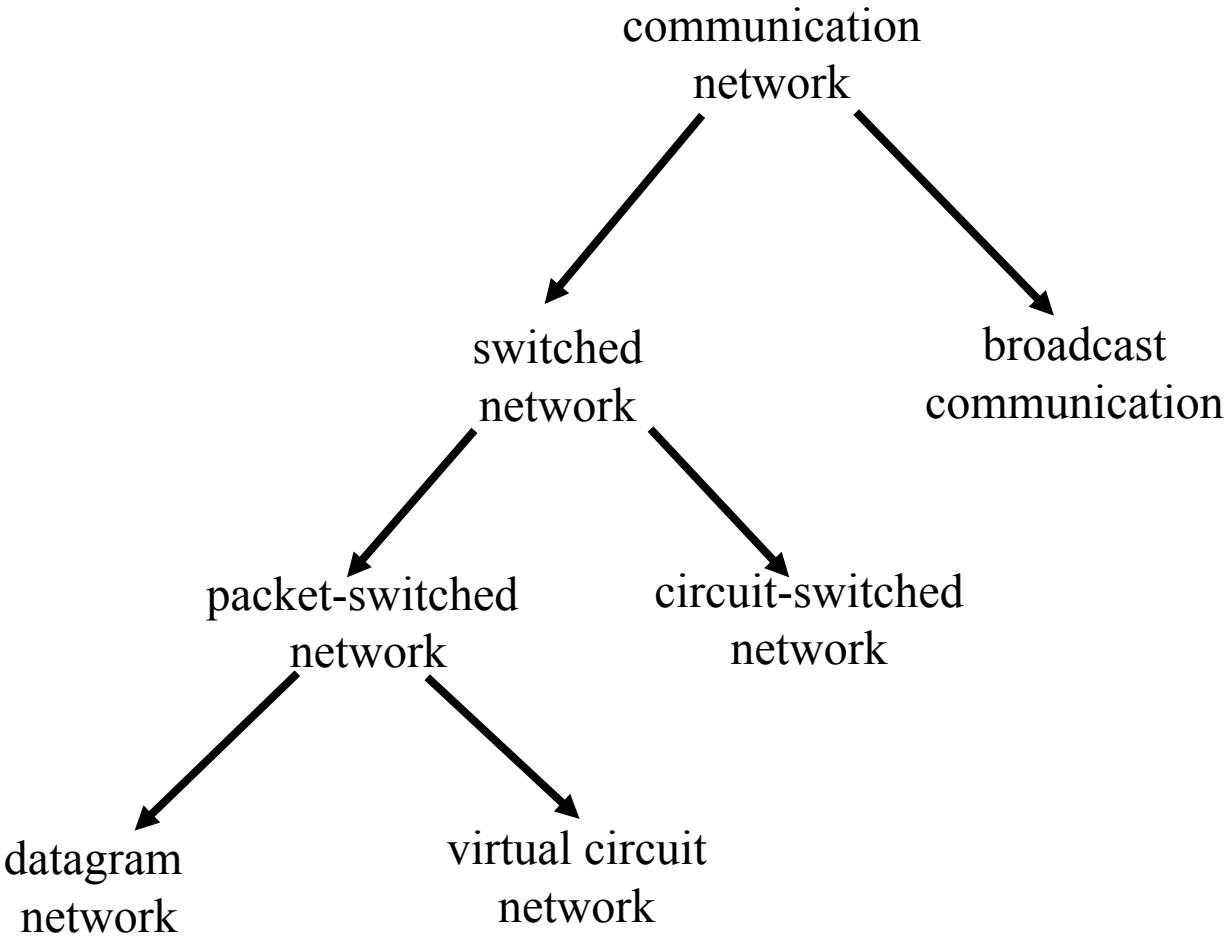
# Outline

- Admin and recap
- ISO/OSI Layering and Internet Layering
- Application layer overview
- Network applications
  - Email

# Admin

- Questions on Assignment One

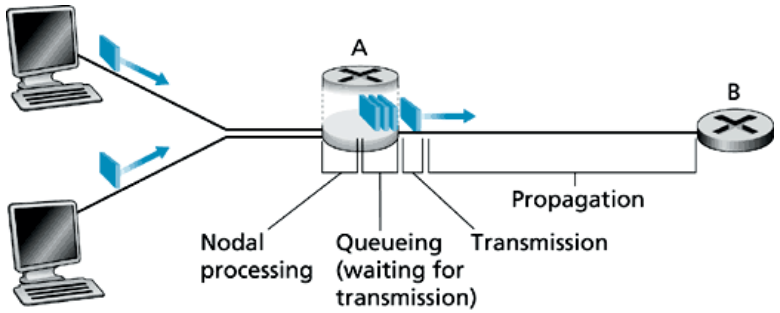
# Recap: Summary of the Taxonomy of Communication Networks



# Recap: Statistical Multiplexing

A simple model to compare bandwidth efficiency of
- reservation/dedication (aka circuit-switching) and
- no reservation (aka packet switching)

setup
- a single bottleneck link with rate R (L/R to trans. L bits)
- n flows; each flow has an arrival rate of a/n




- no reservation: all arrivals into the single link with rate R, the queueing delay + transmission delay:

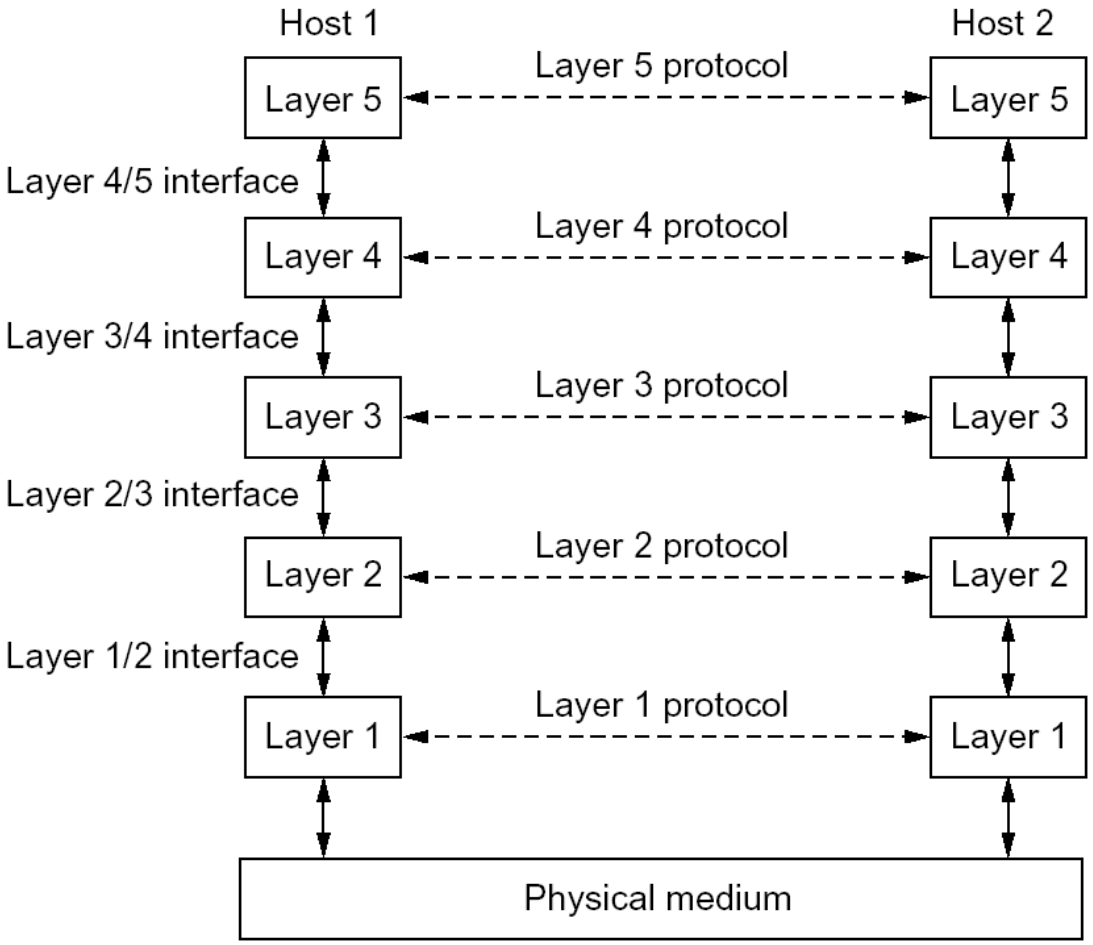
$$\frac{L}{R}\frac{1}{1-\rho}$$

- reservation: each flow uses its own reserved (sub)link with rate R/n, the queueing delay + transmission delay:

$$n\frac{L}{R}\frac{1}{1-\rho}$$

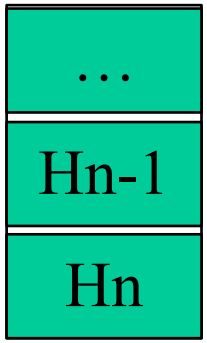
# Recap: Layering

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

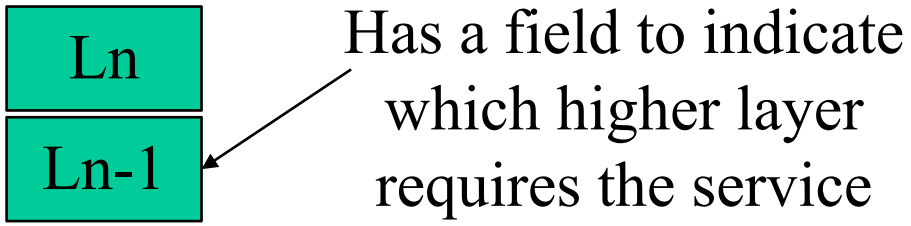


# Some Implications of Layered Architecture

- A packet as a stack container




- Each layer needs multiplexing and demultiplexing to serve layer above

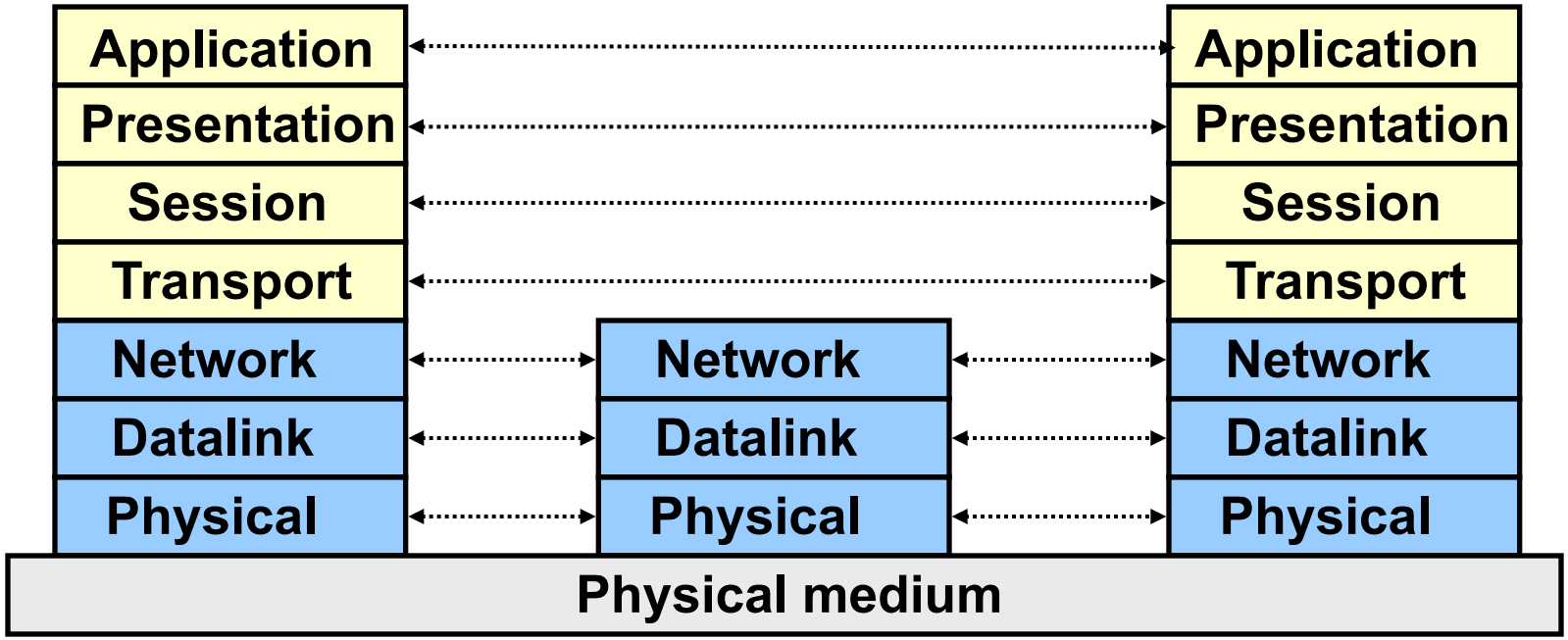


# Outline

- Recap
- *ISO/OSI Layering and Internet Layering*
- Application layer overview

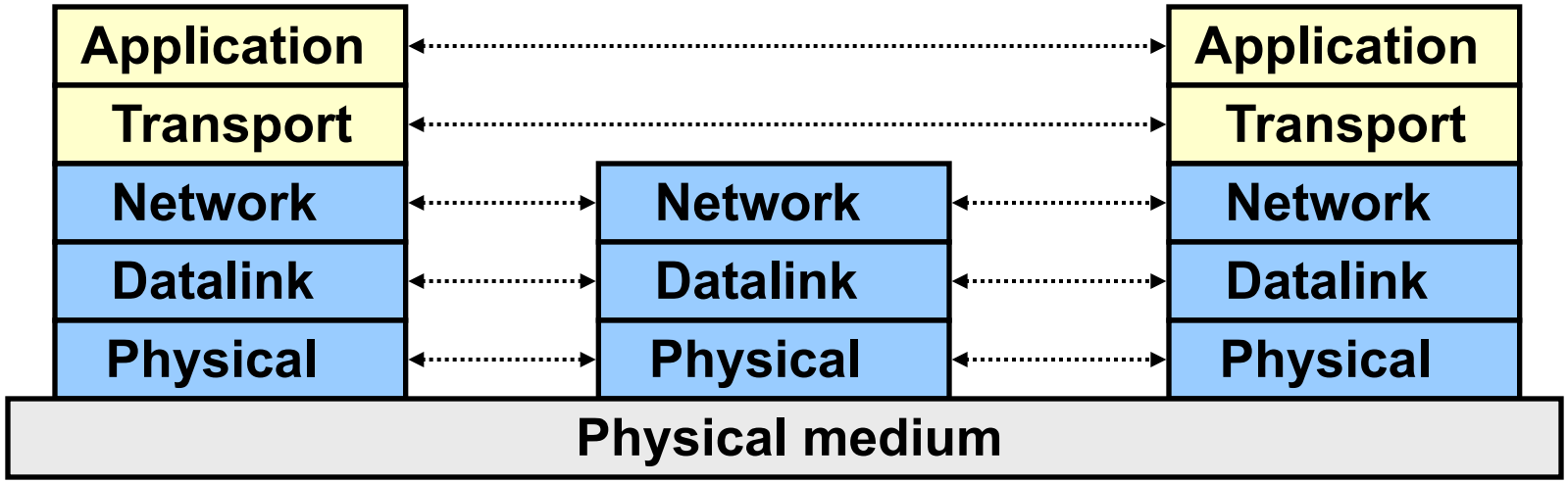
# ISO/OSI Reference Model

- Seven layers
  - highest four layers are implemented in host



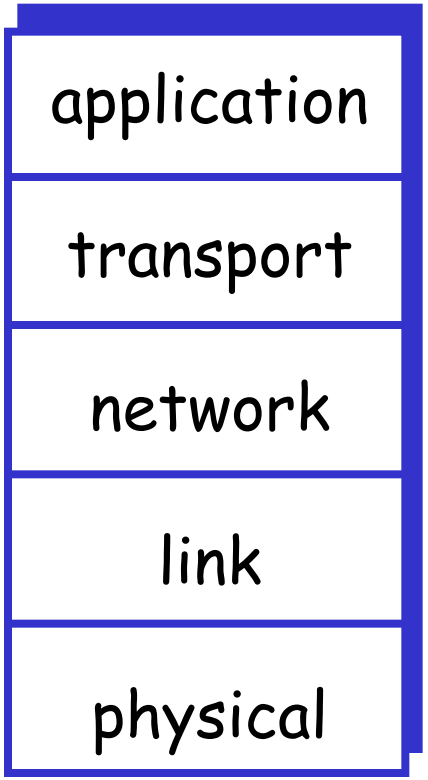
# Internet Layering

- Five layers
  - highest two layers are implemented in host

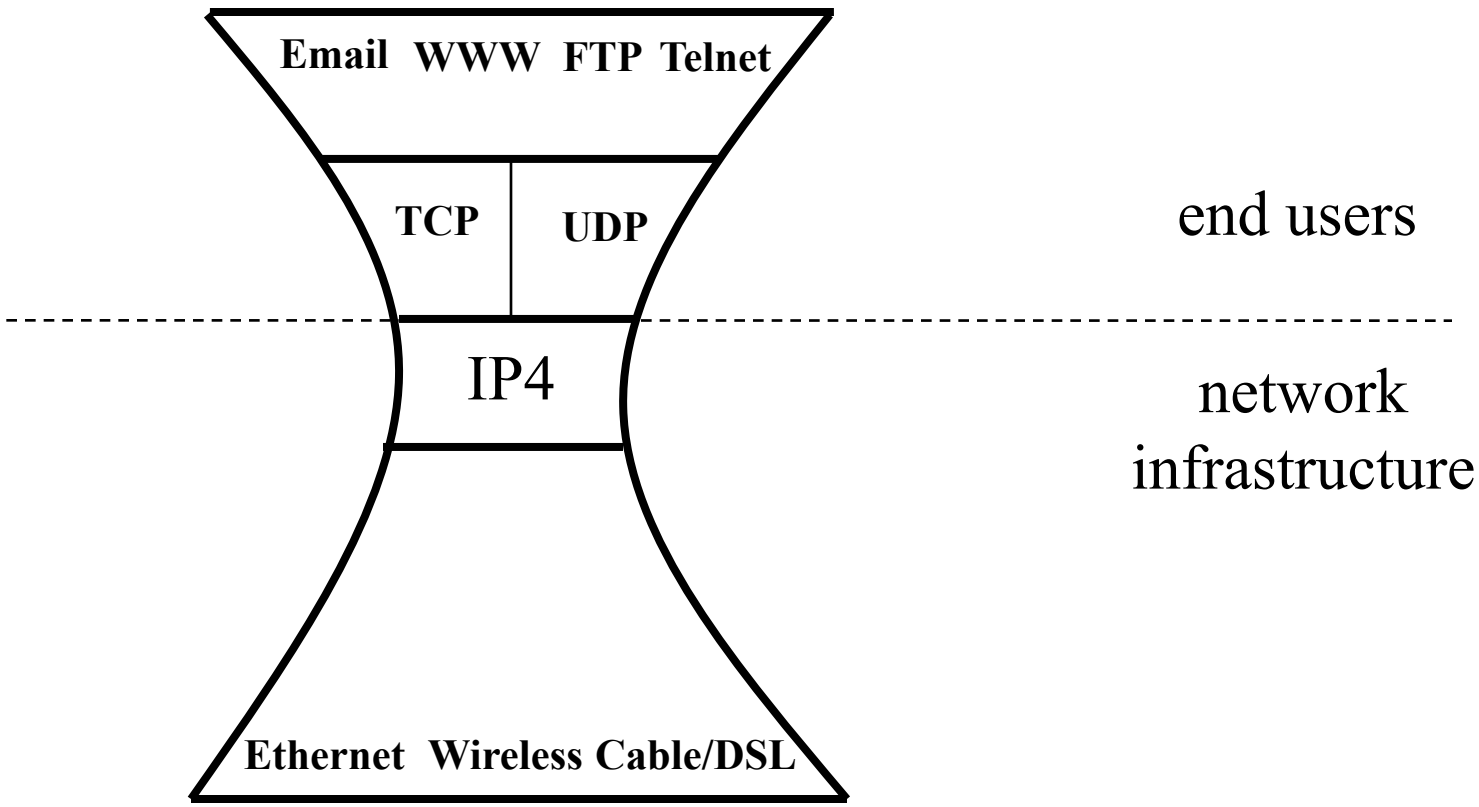


# Internet Protocol Layers

- Five layers
  - Application: applications
    - ftp, smtp, http, p2p, IP telephony, …
  - Transport: host-host data transfer
    - tcp (reliable), udp (not reliable)
  - Network: routing of datagram from source to destination
    - ipv4, ipv6
  - Link: data transfer between neighboring network elements
    - ethernet, 802.11, cable, DSL, …
  - Physical: bits "on the wire"
    - cable, wireless, optical fiber

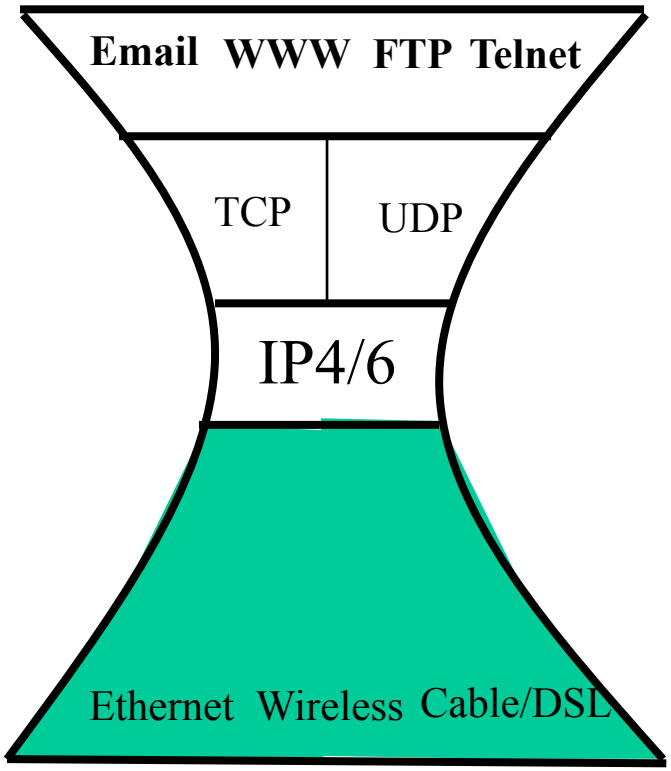


# The Hourglass Architecture of the Internet

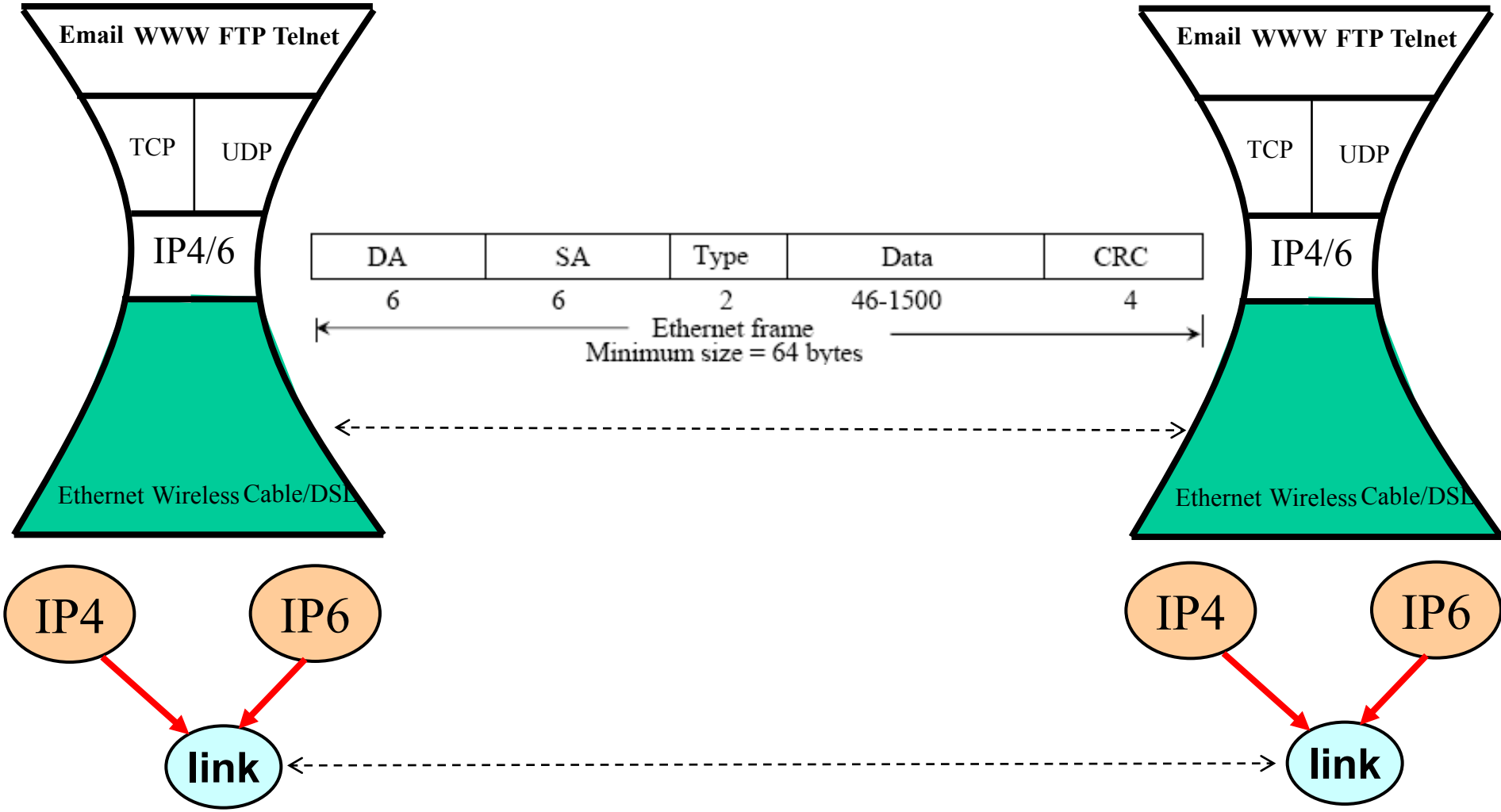


# Link Layer (Ethernet)

- 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

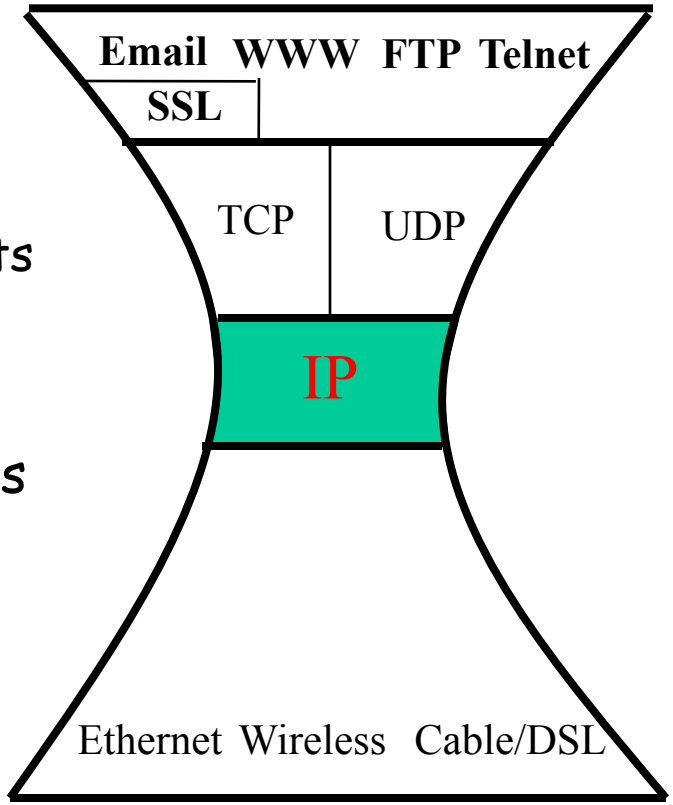


# Link Layer: Protocol Header (Ethernet)

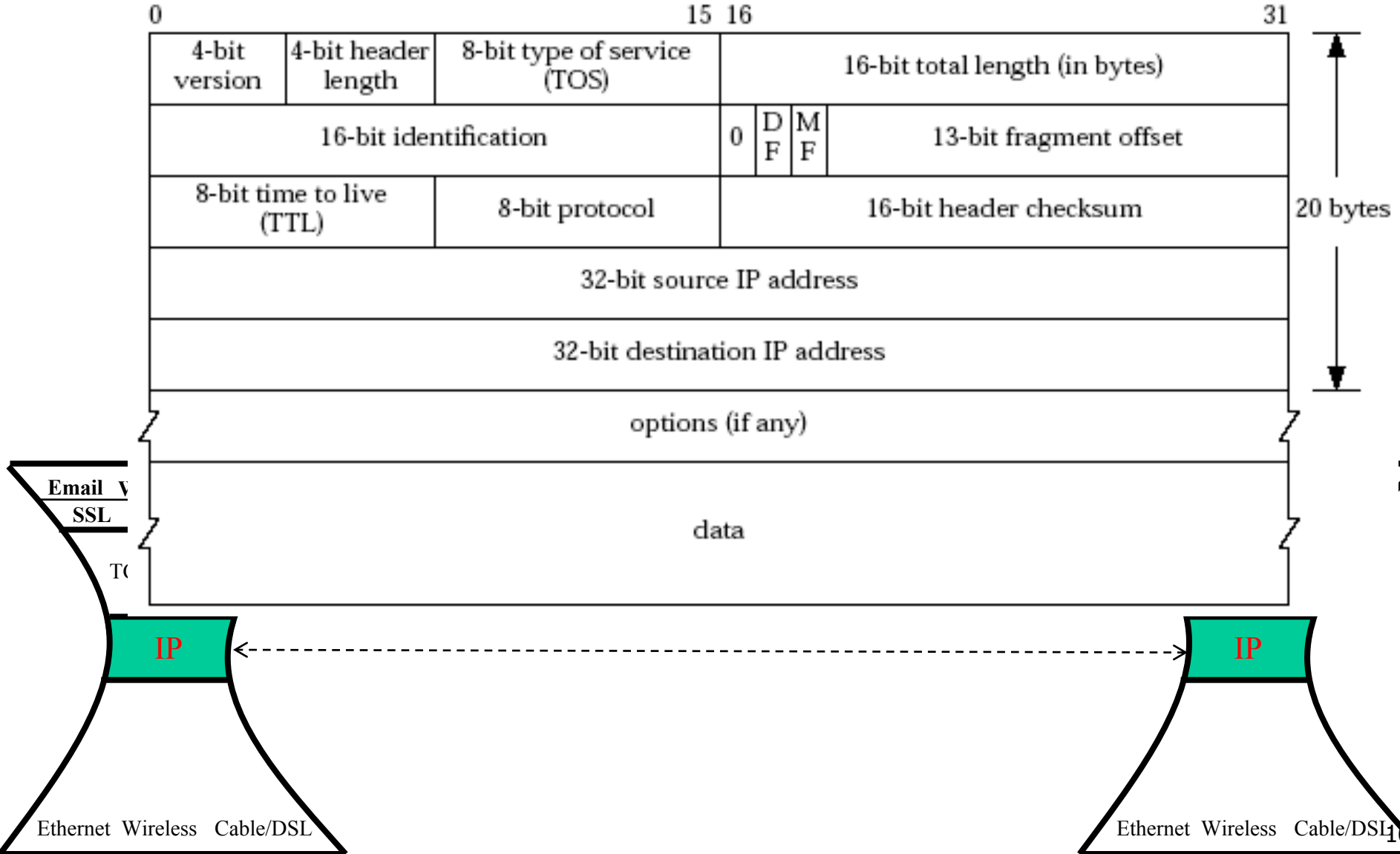


# Network Layer: IP

- 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

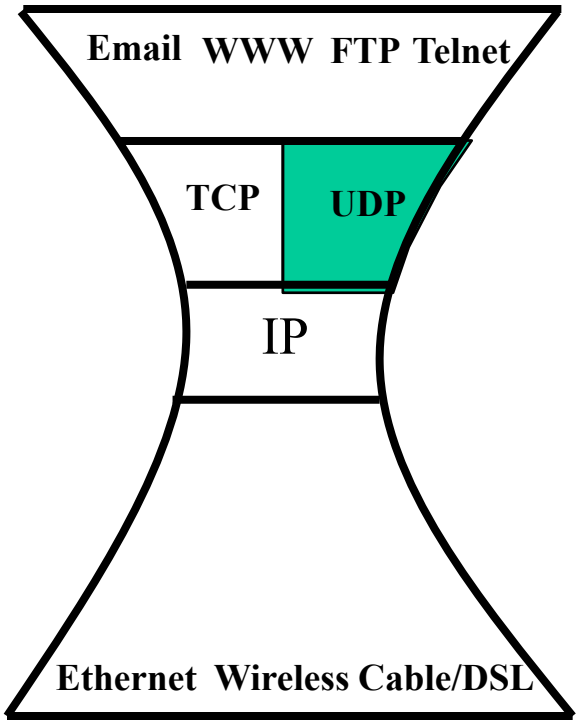


# Network Layer: IPv4 Header



# 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?

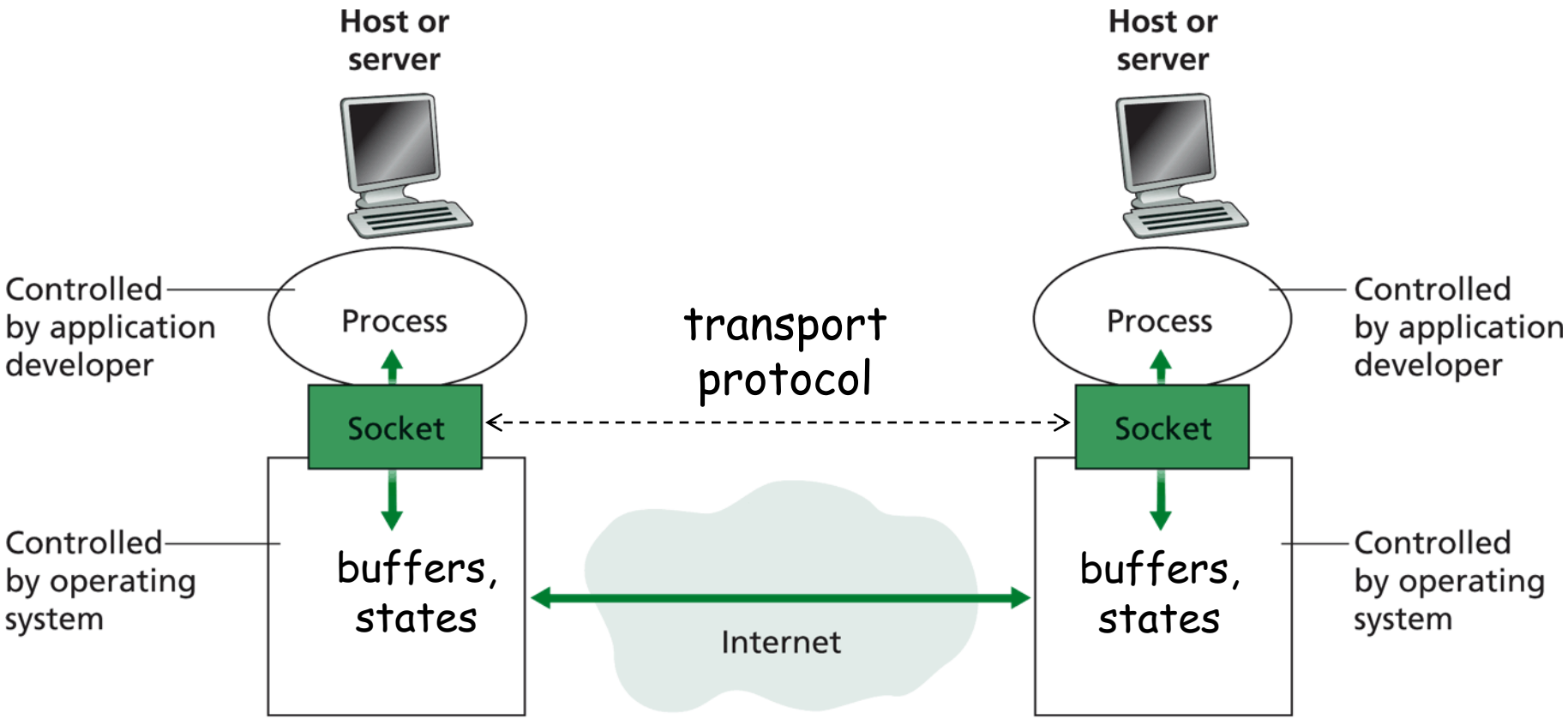


# Transport Services and APIs

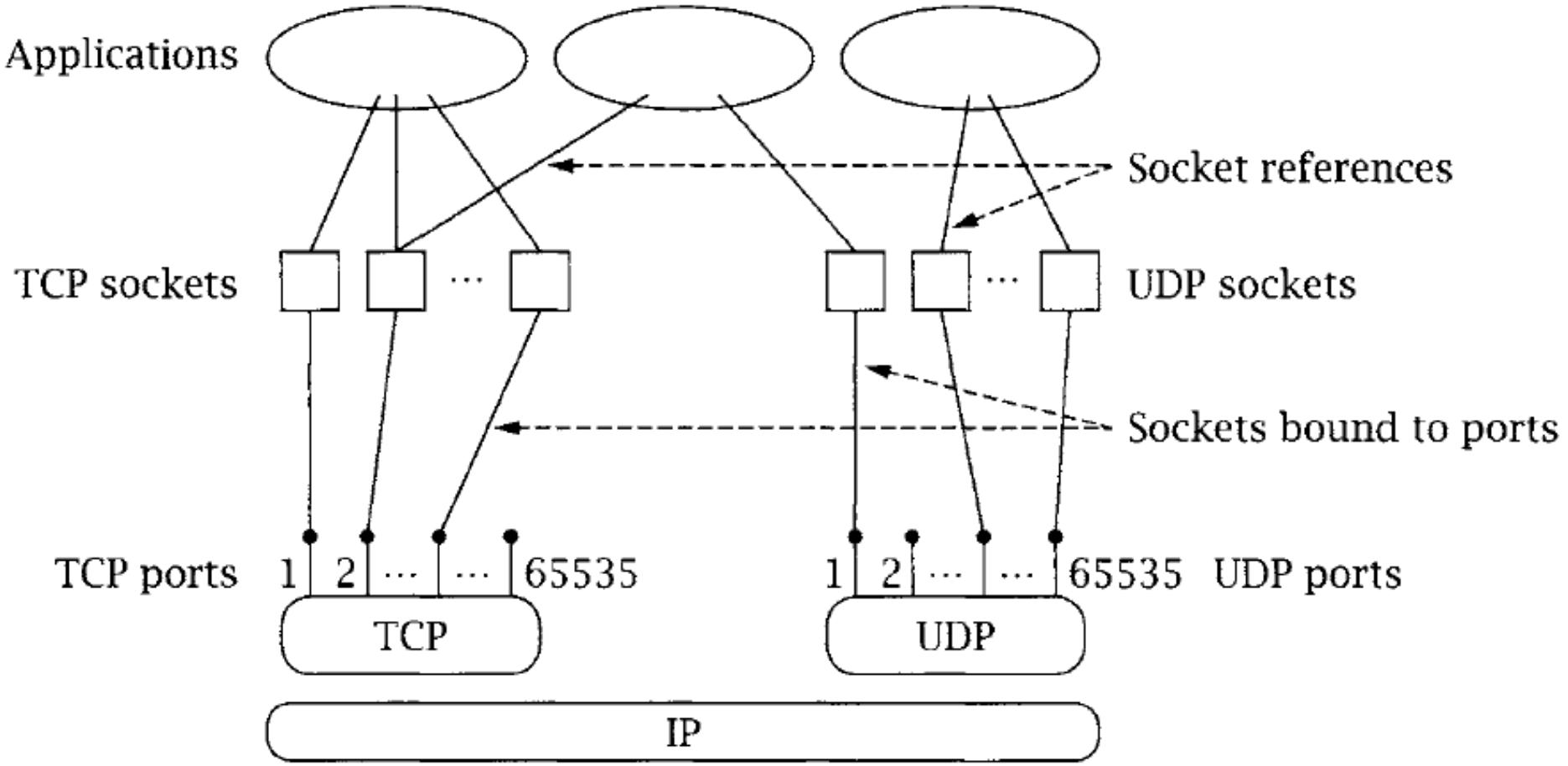
- Multiple services and APIs proposed in history
  - XTI (X/Open Transport Interface), a slight modification of the Transport Layer Interface (TLI) developed by AT&T.

- 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

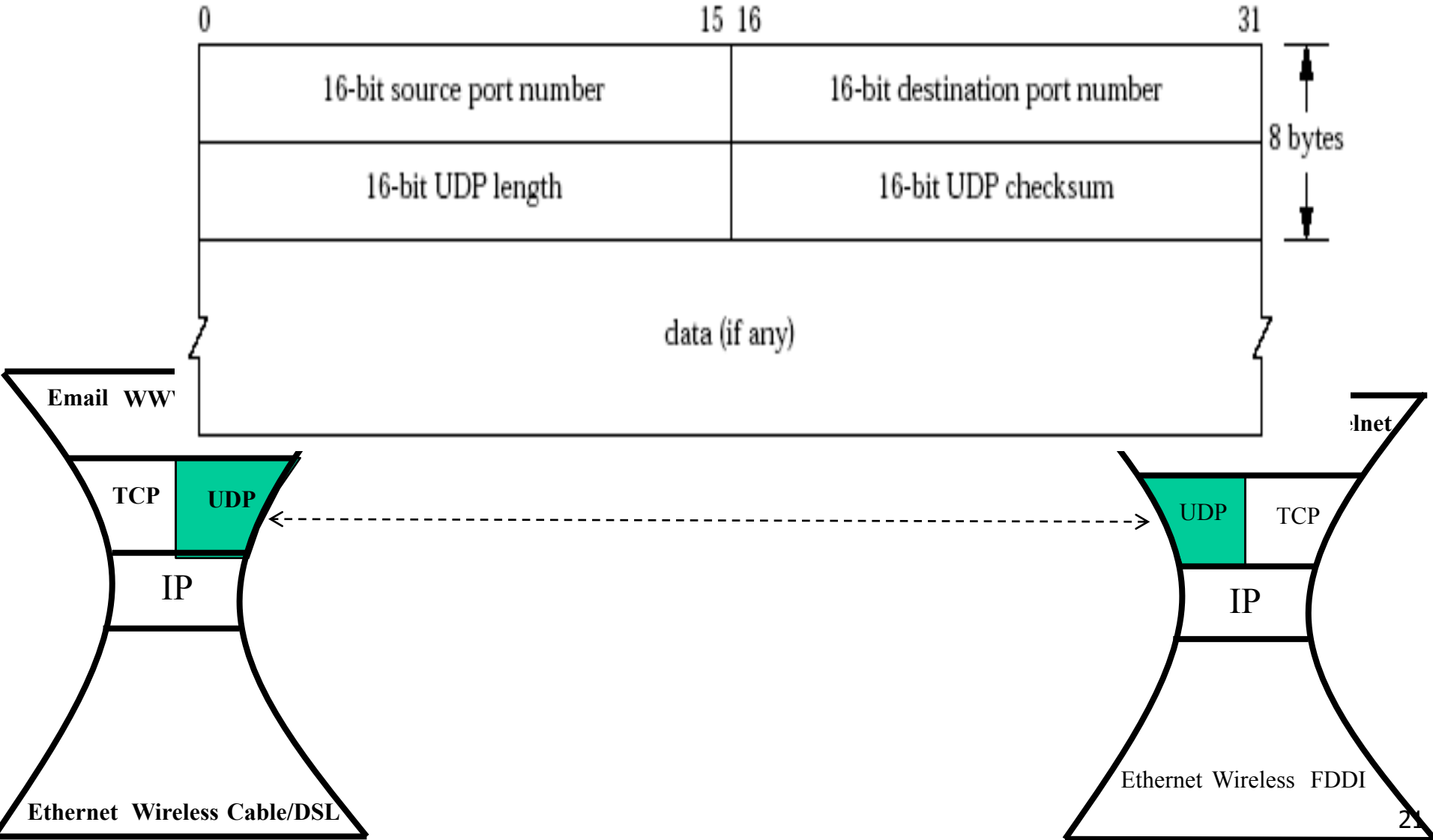
# Socket Service Model and API



# Multiplexing/Demultiplexing

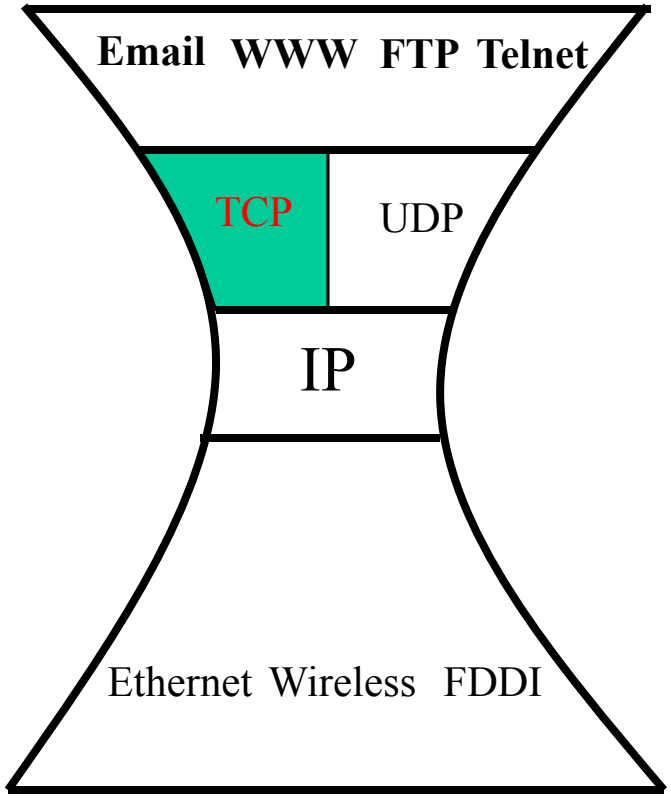


# Transport Layer: UDP Header

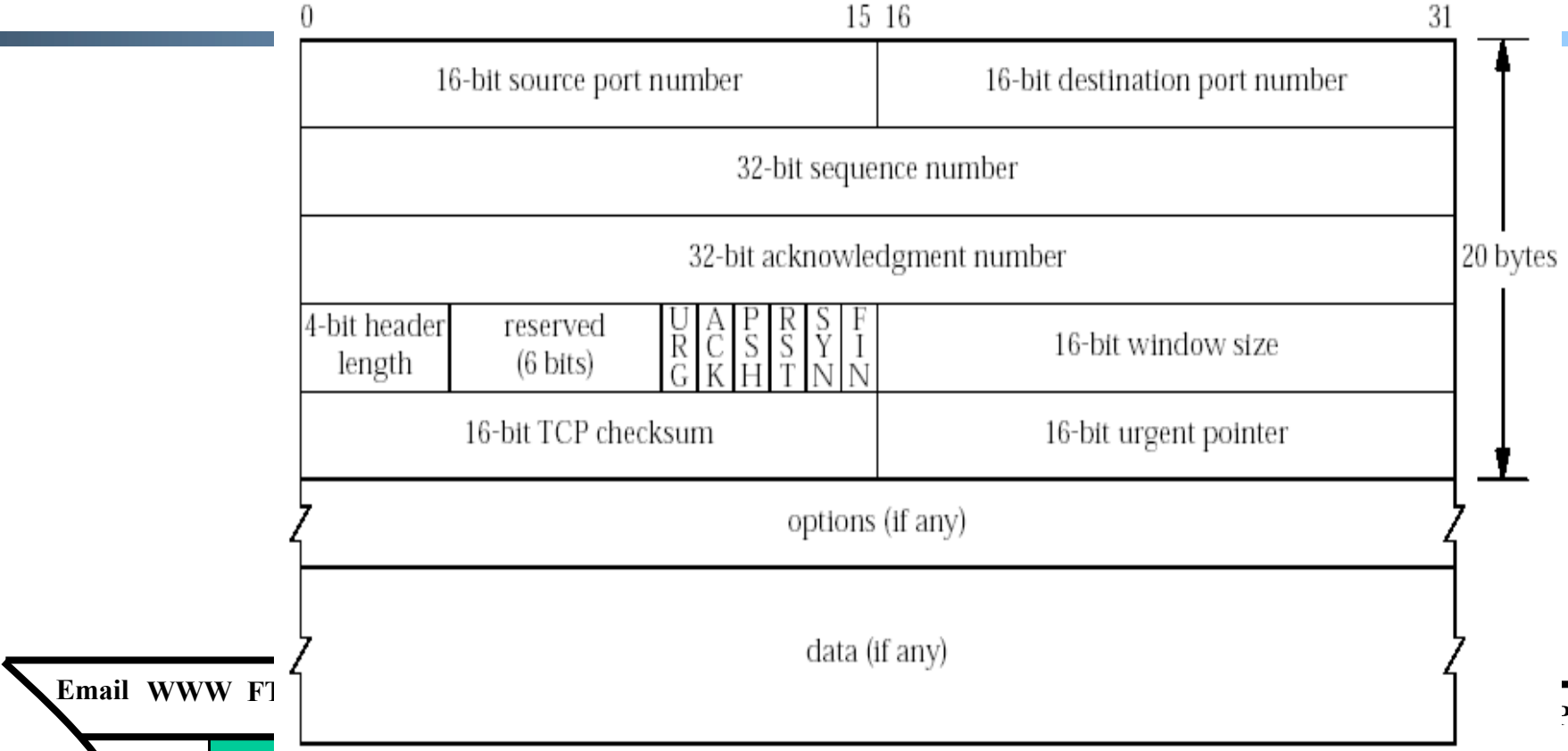


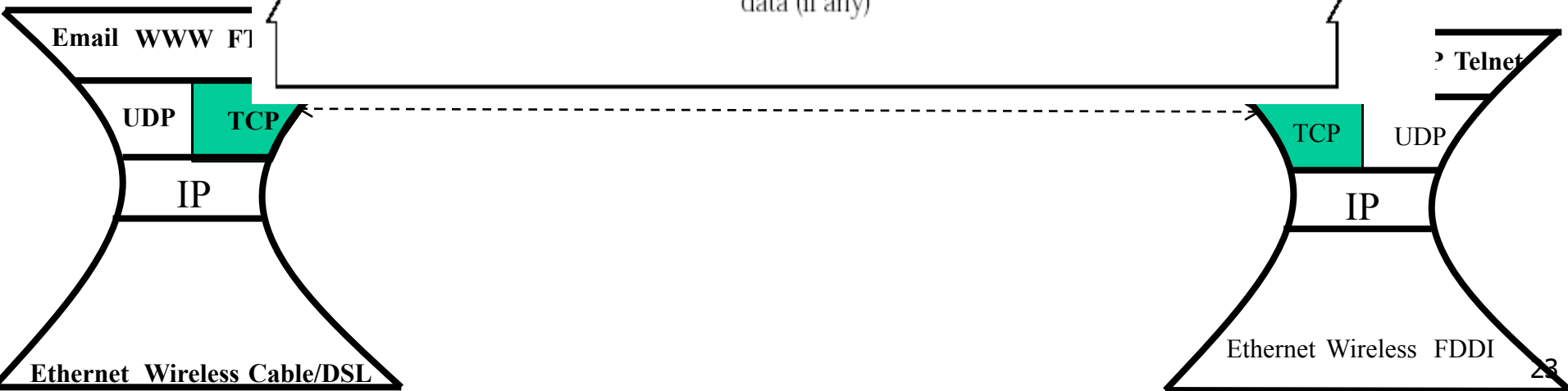
# Transport Layer: TCP

- 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

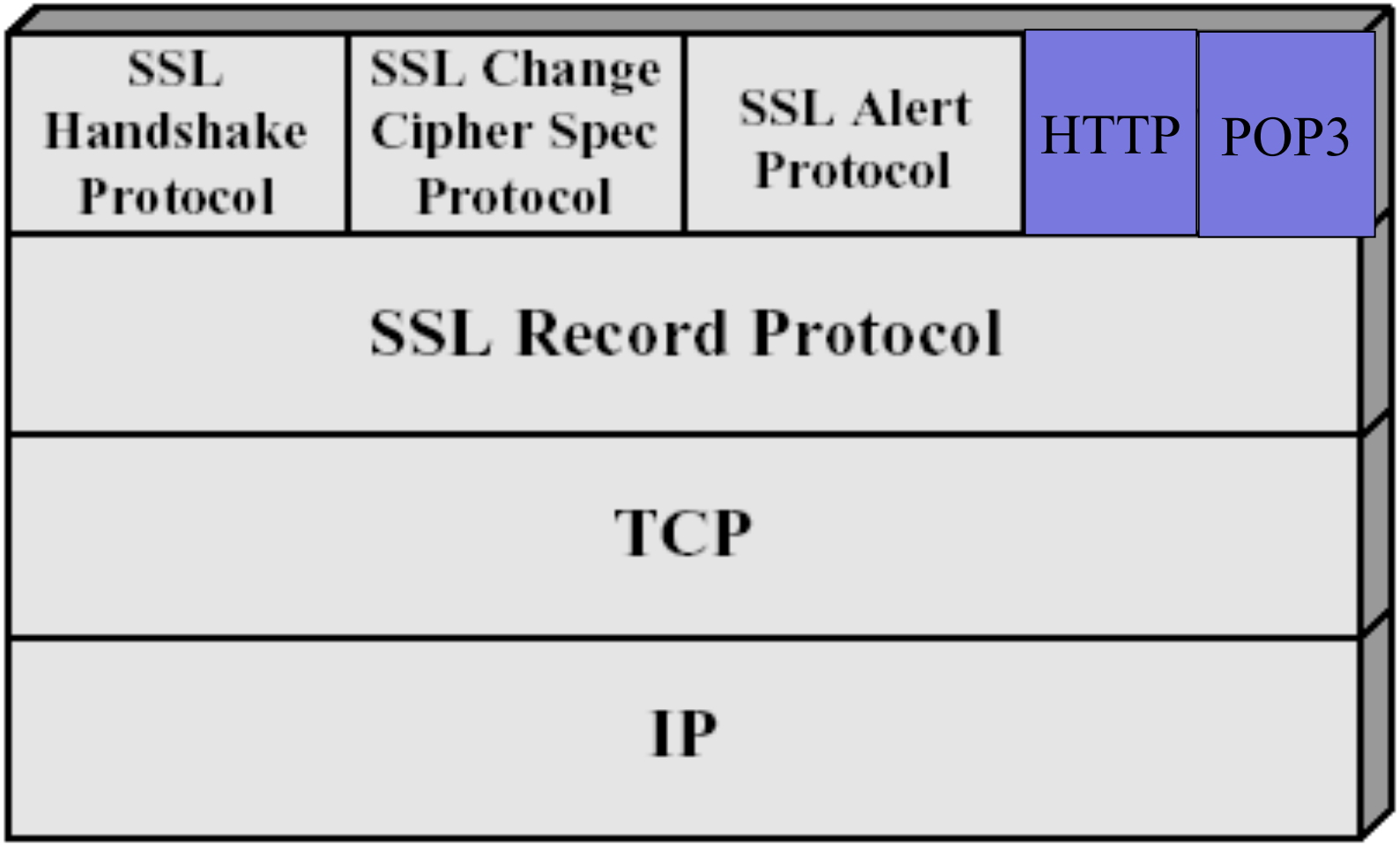


# Transport Layer: TCP Header

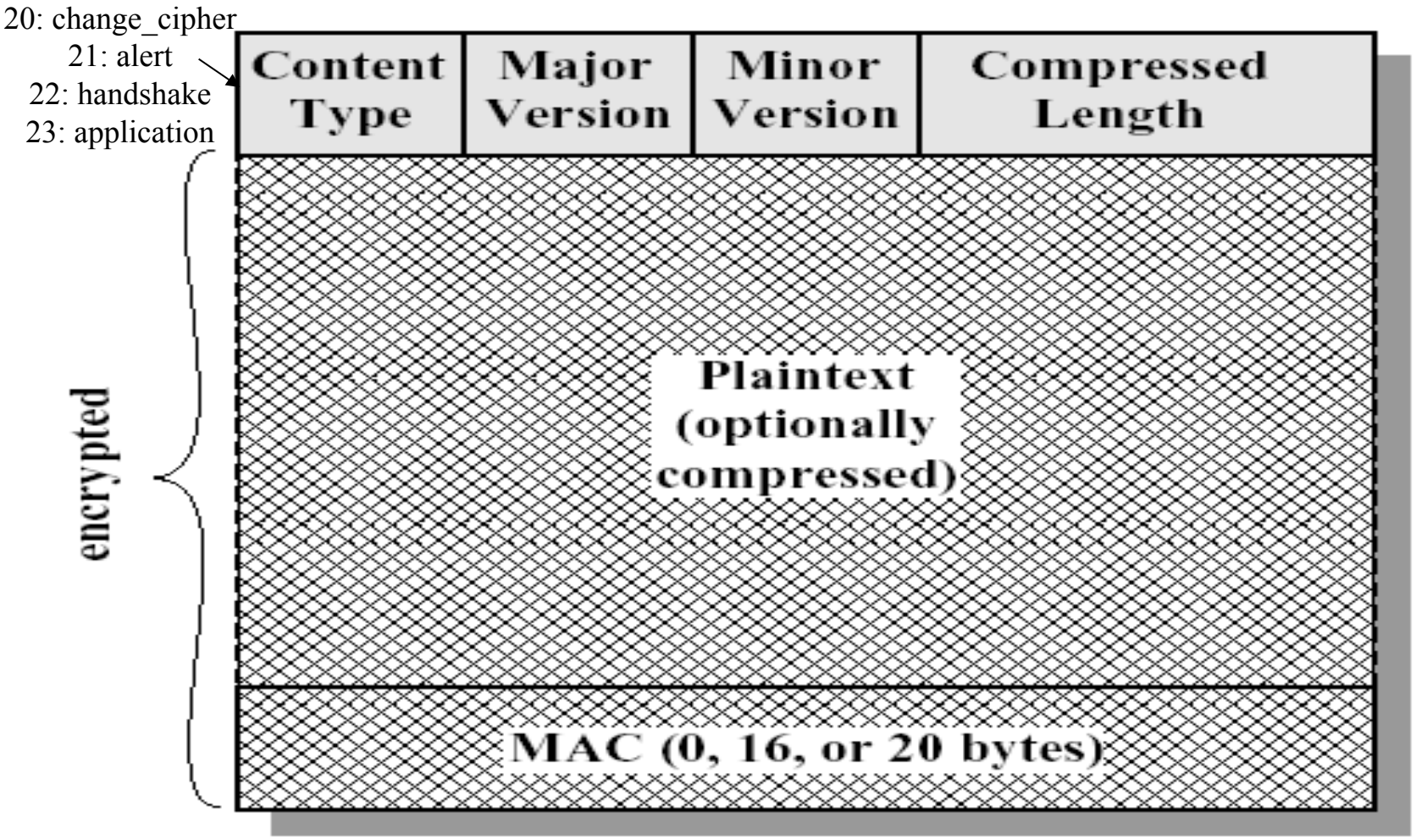


# Secure Socket Layer Architecture

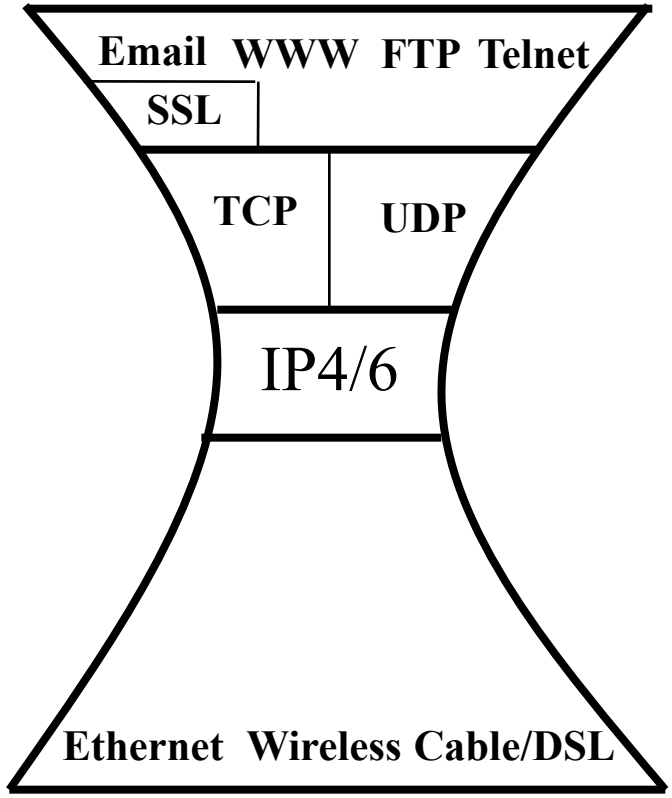


# SSL Record-Layer Packet Format

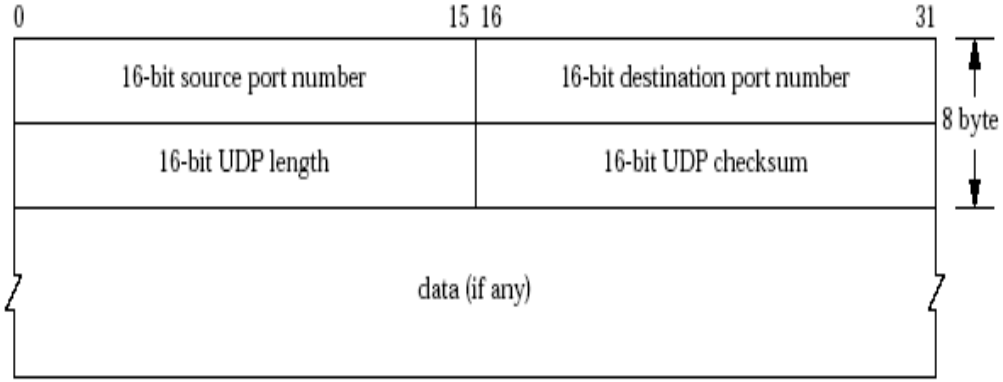


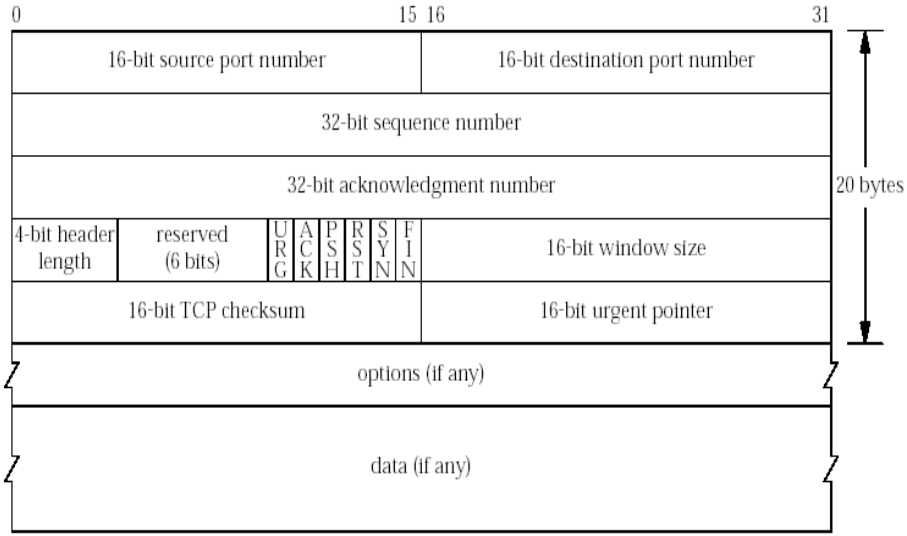
# Summary: The Big Picture of the Internet

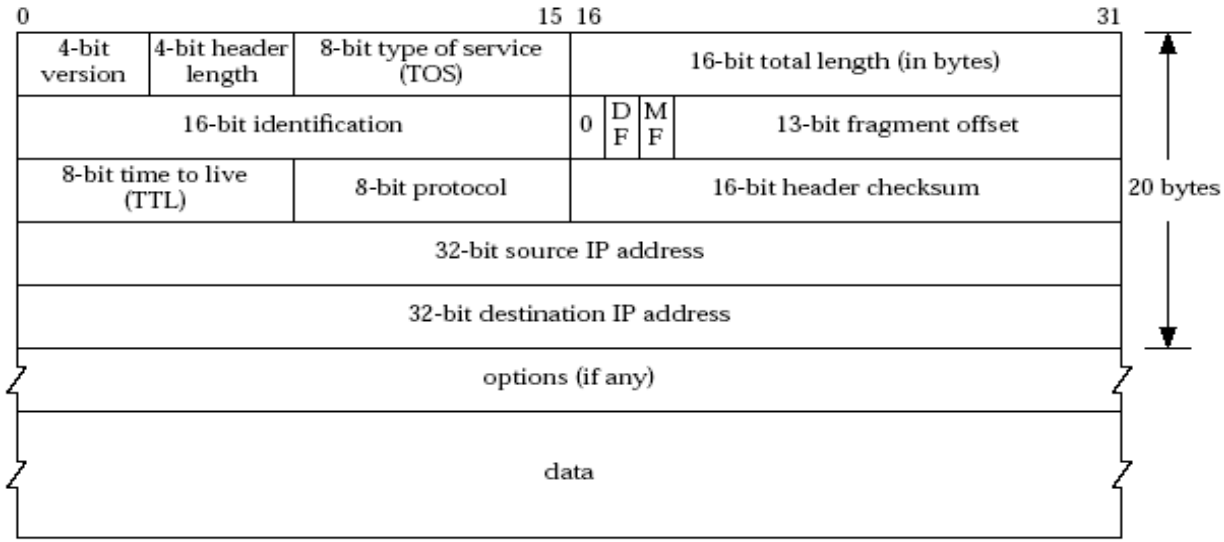
- Hosts and routers:
  - ~ 1 bil. hosts
  - autonomous systems organized roughly hierarchical
  - backbone links at 100 Gbps
- Software:
  - datagram switching with virtual circuit support at backbone
  - layered network architecture
    - use end-to-end arguments to determine the services provided by each layer
  - the hourglass architecture of the Internet

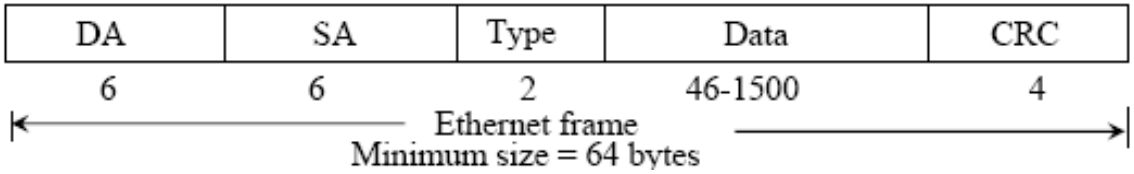


# Protocol Formats



# Outline

- Recap
- ISO/OSI Layering and Internet Layering
- *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

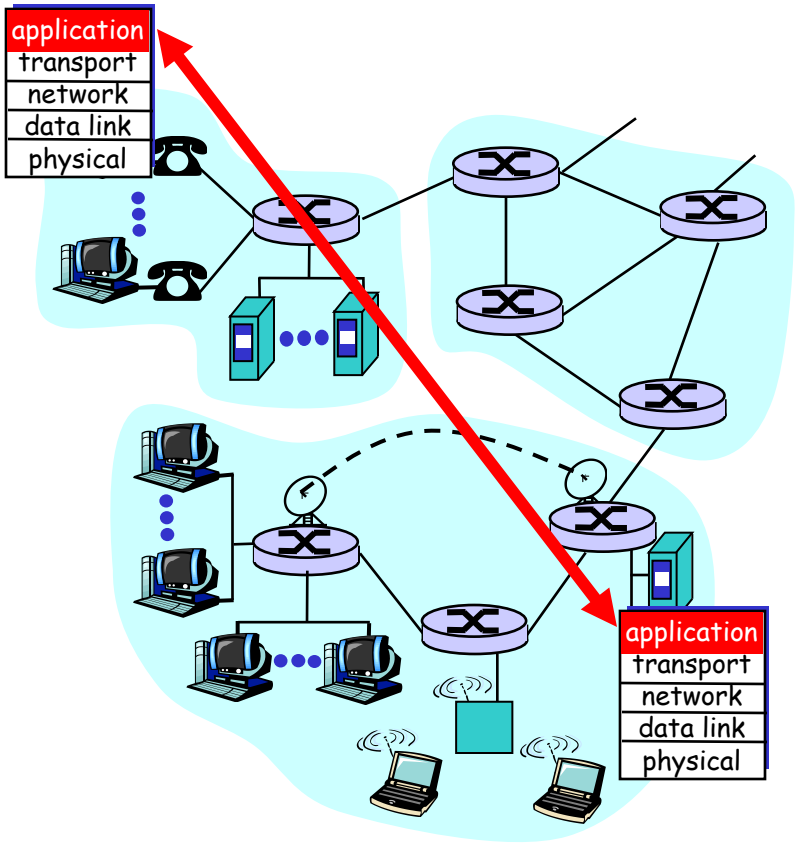
# Network Applications vs. Application-layer Protocols

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

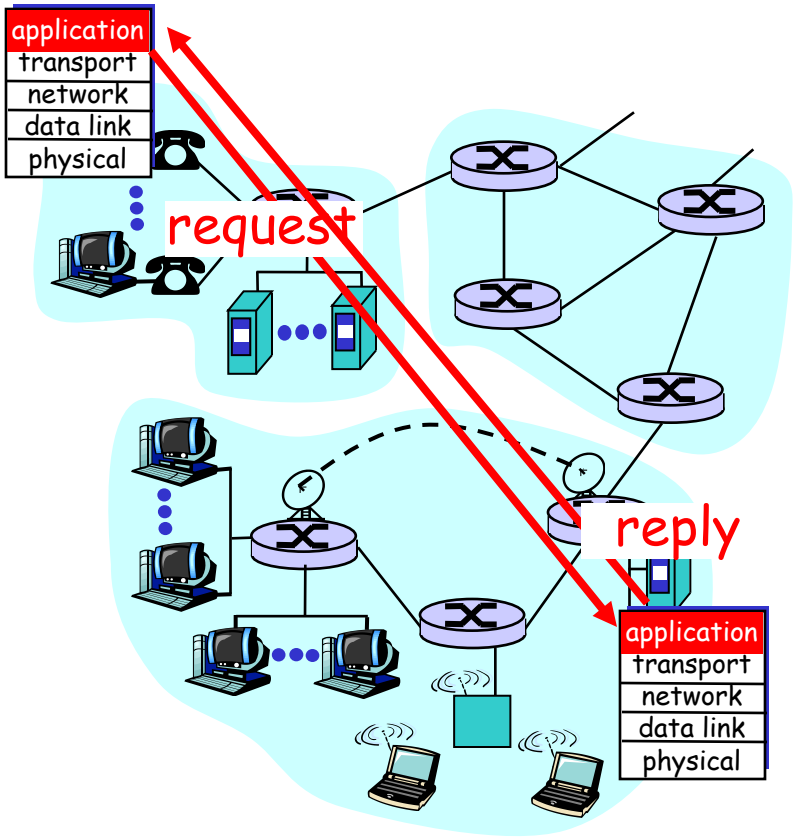
Typical network app has two pieces: *client* and *server*

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):

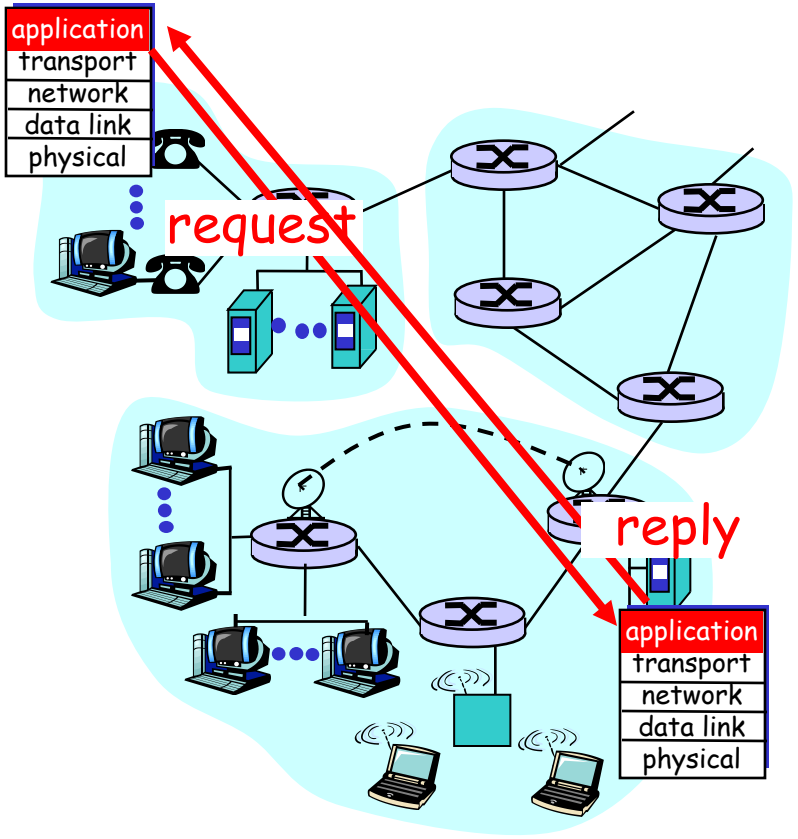
- provides requested service to client
- e.g., Web server sends requested Web page; mail server delivers e-mail



# 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
- ISO/OSI Layering and Internet Layering
- Application layer overview
- Network applications
  - Email

# Electronic Mail

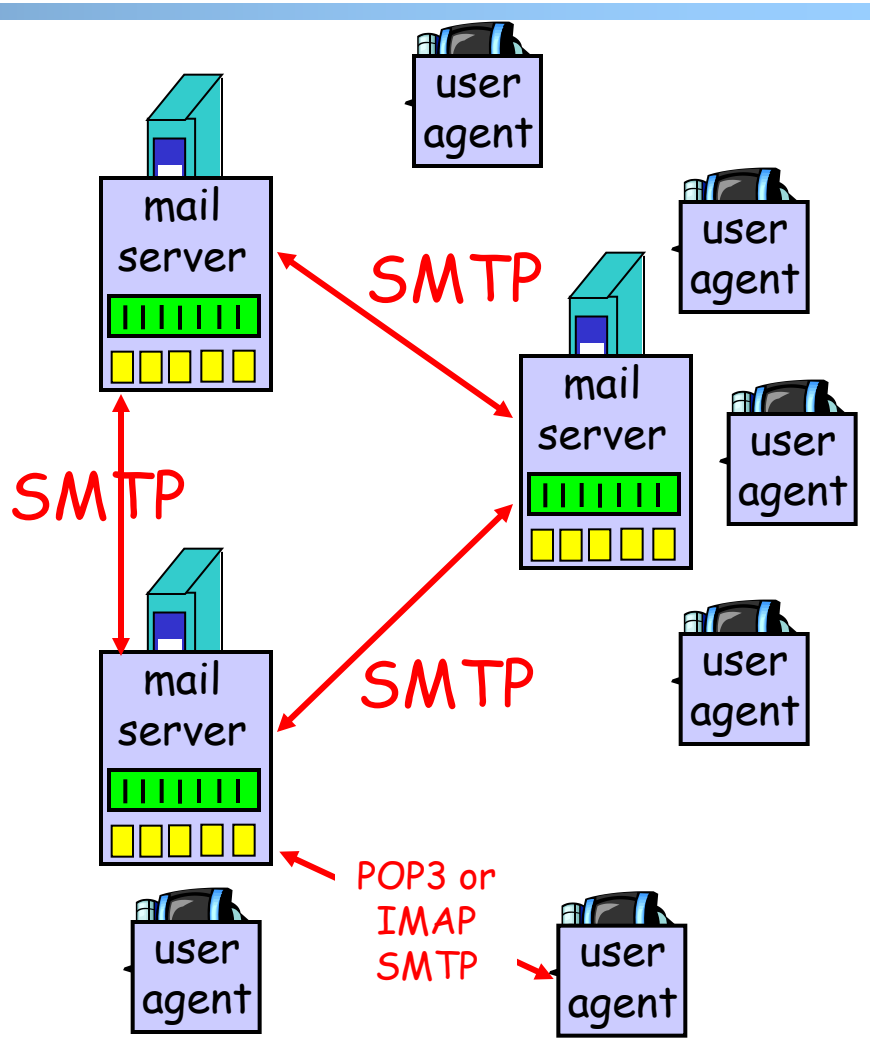
- Still active
  - 80B emails/day
  - 3.9B active email boxes

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

# Recall: SMTP

```
S: 220 mr1.its.yale.edu
C: HELO cyndra.yale.edu
S: 250  Hello cyndra.cs.yale.edu, pleased to meet you
C: MAIL FROM: <spoof@cs.yale.edu>
S: 250 spoof@cs.yale.edu... Sender ok
C: RCPT TO: <yry@yale.edu>
S: 250 yry@yale.edu ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: Date: Wed, 23 Jan 2008 11:20:27 -0500 (EST)
C: From: "Y. R. Yang" <yry@cs.yale.edu>
C: To: "Y. R. Yang" <yry@cs.yale.edu>
C: Subject: This is subject
C:
C: This is the message body!
C: Please don't spoof!
C:
C: .
S: 250 Message accepted for delivery
C: QUIT
S: 221 mr1.its.yale.edu closing connection
```

# 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

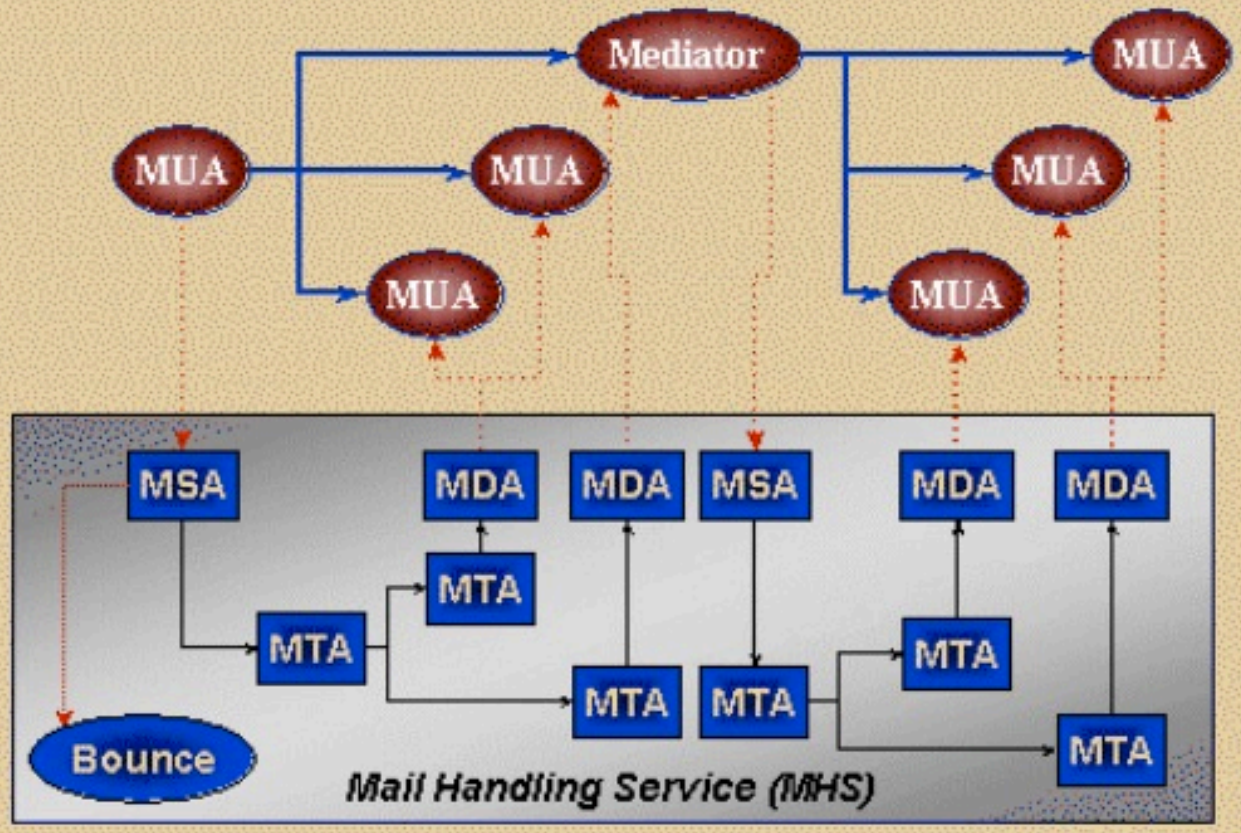
**MHS:** Mail Handling (transit) Service

**MSA:** Submission

**MTA**: Transfer

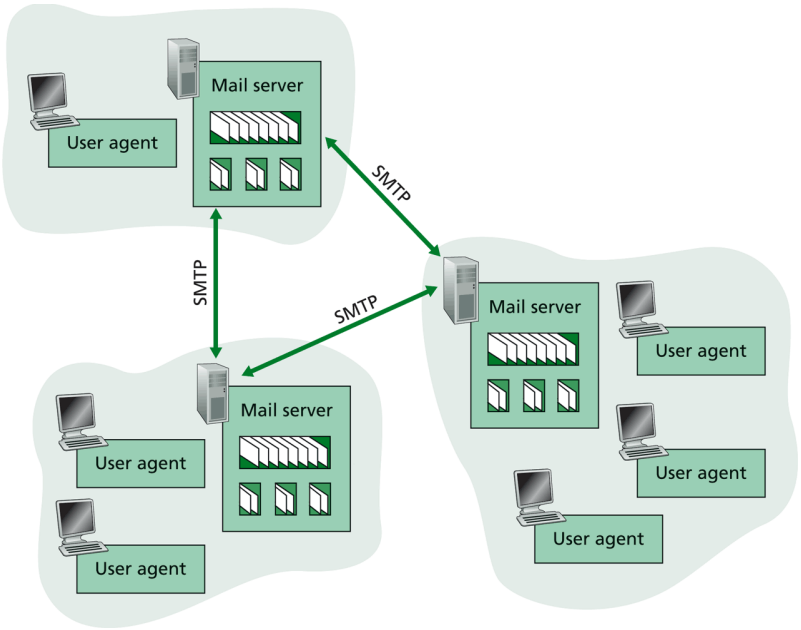
**MDA**: Delivery

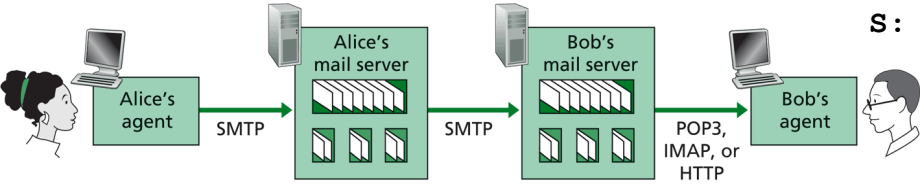
**Bounce**: Returns




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

# SMTP: Mail Transport Protocol Messages (Envelop Messages)




```
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C: HELO cyndra.yale.edu
S: 250  Hello cyndra.cs.yale.edu, pleased to meet you
C: MAIL FROM: <spoof@cs.yale.edu>
S: 250 spoof@cs.yale.edu... Sender ok
C: RCPT TO: <yry@yale.edu>
S: 250 yry@yale.edu ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: Date: Wed, 23 Jan 2008 11:20:27 -0500 (EST)
C: From: "Y. R. Yang" <yry@cs.yale.edu>
C: To: "Y. R. Yang" <yry@cs.yale.edu>
C: Subject: This is subject
C:
C: This is the message body!
C: Please don't spoof!
C:
C: .
S: 250 Message accepted for delivery
C: QUIT
S: 221 mr1.its.yale.edu closing connection
```

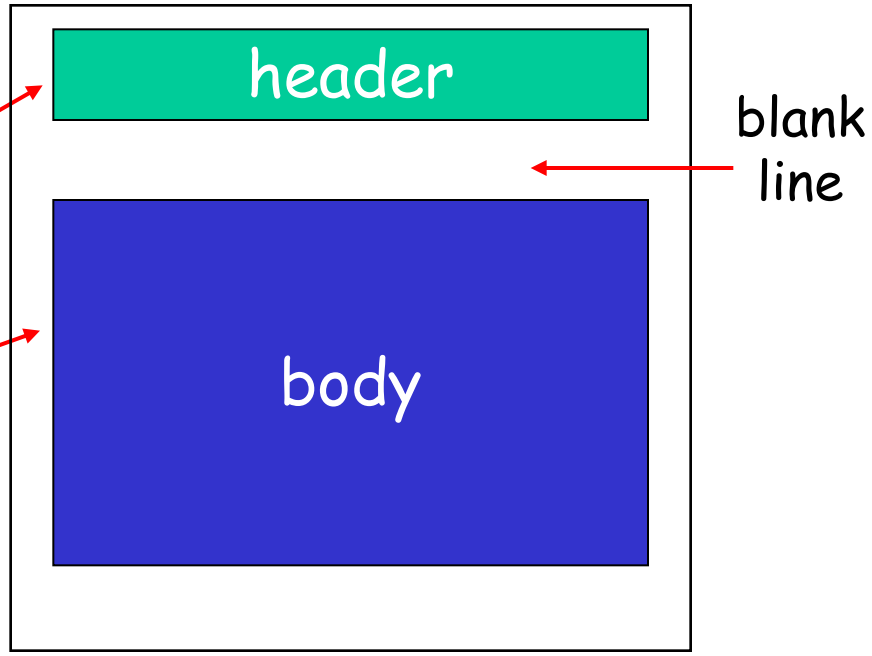
Email txt diff from SMTP protol msg

# Mail Message Data

SMTP: protocol for exchanging email msgs

RFC 822: standard for text message format:

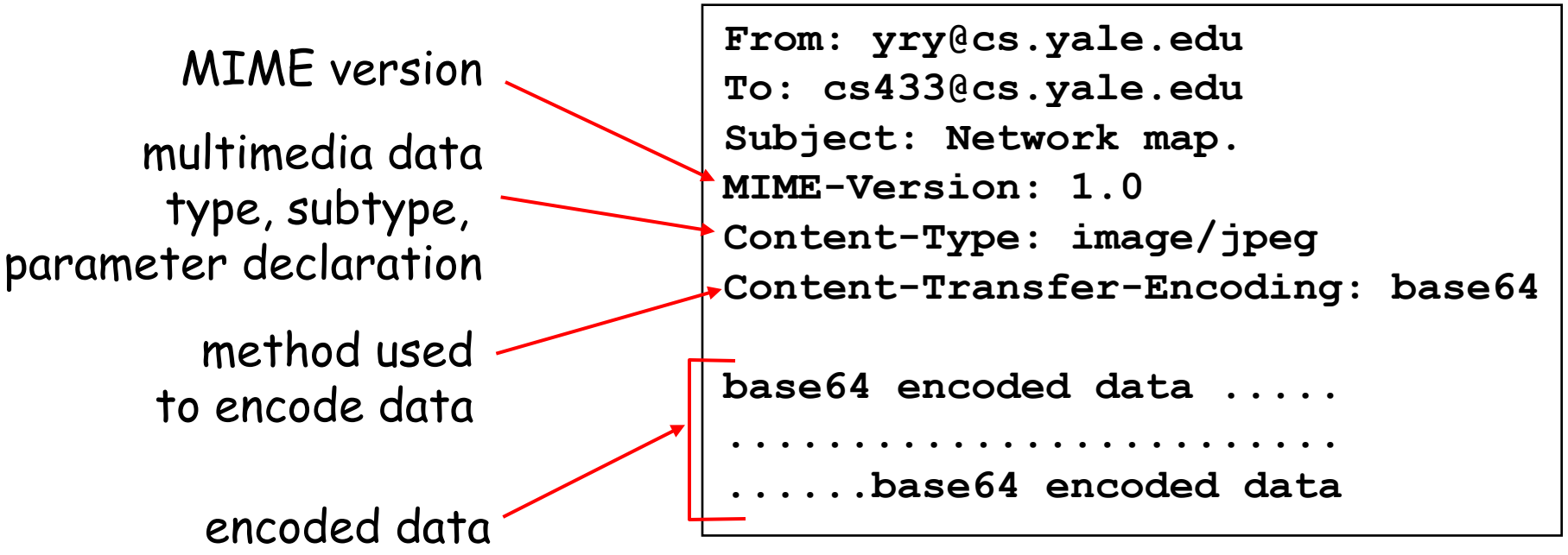
- Header lines, e.g.,
  - To:
  - From:
  - Subject:
- Body
  - the "message", ASCII characters only




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: yry@cs.yale.edu
To: cs433@cs.yale.edu
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`

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

## Transaction phase, client:

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

```
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
```

```
%openssl s_client -connect pop.gmail.com:995
```

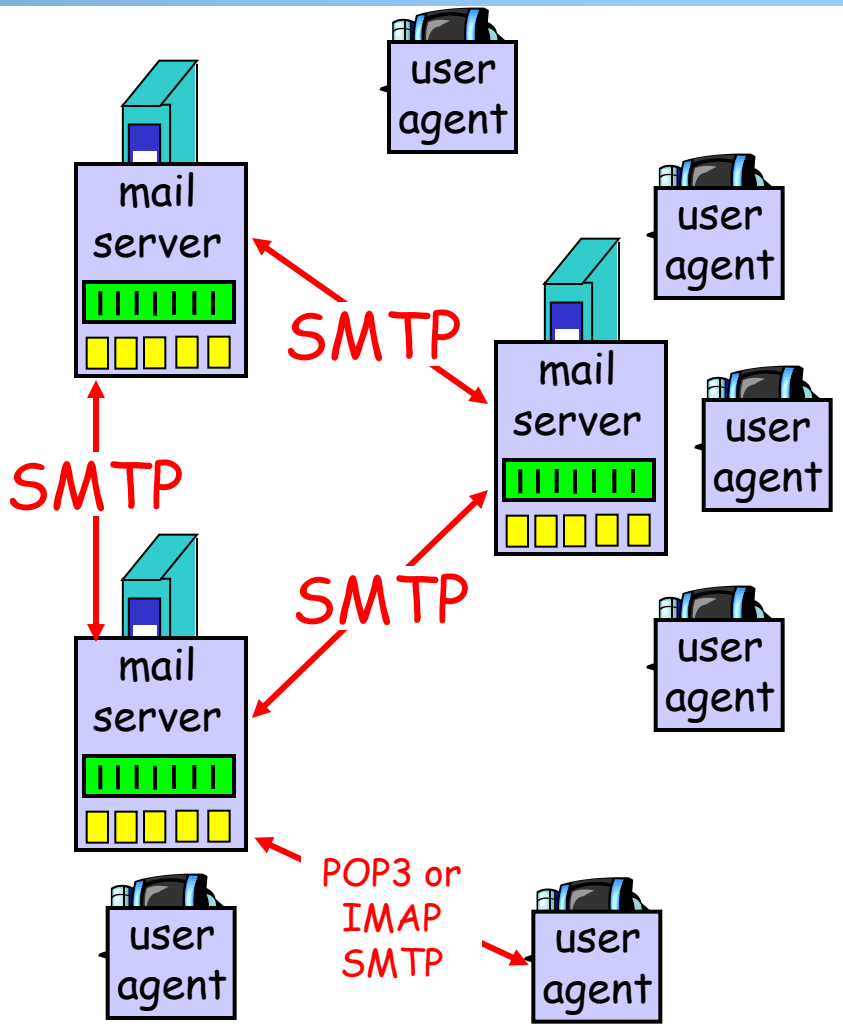
# Exercise

- Send email to yalecs433533 with attachment
- Retrieve using pop

# Evaluation of SMTP/POP/IMAP

**Key questions to ask about a C-S application**

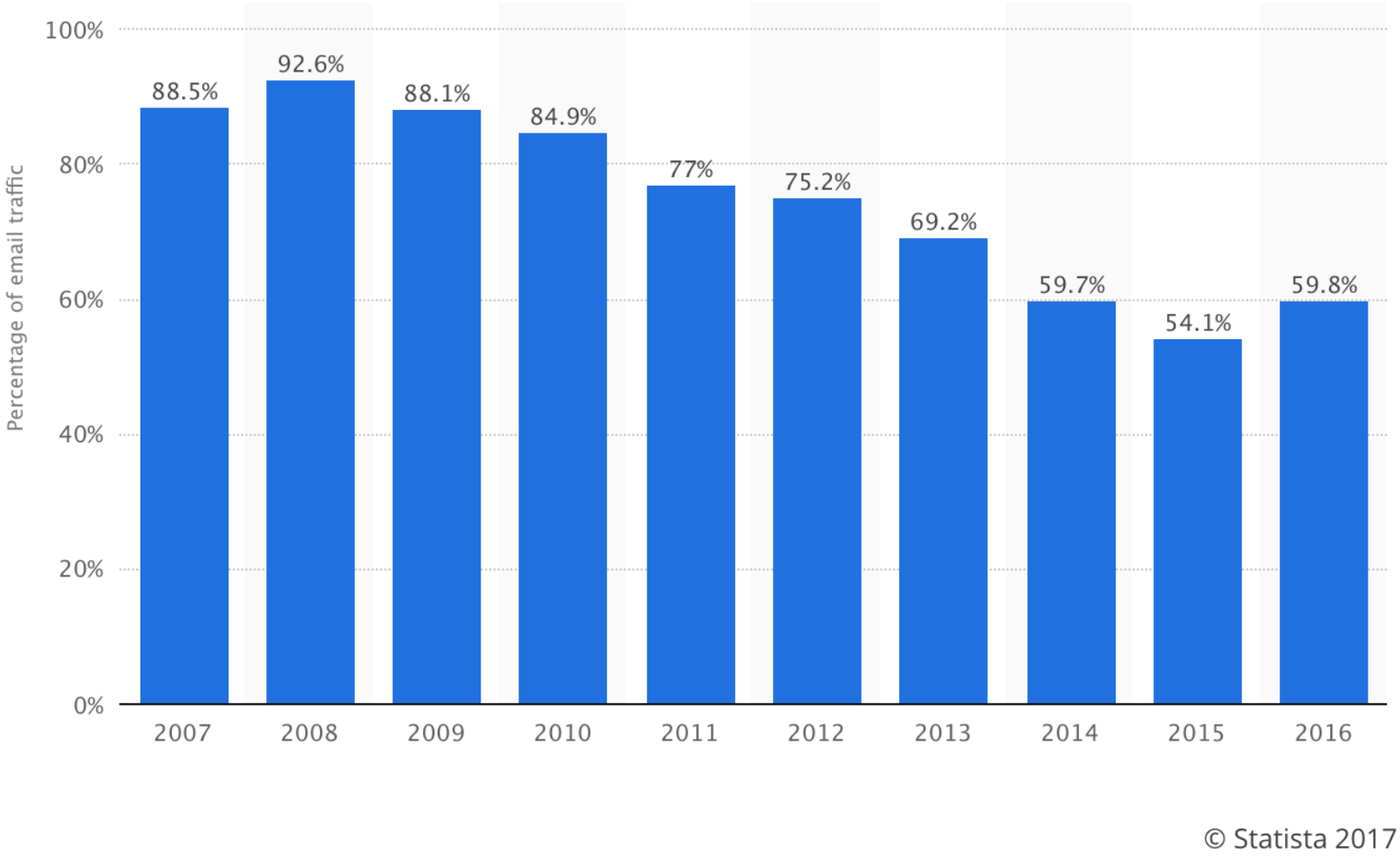
- **extensible**?
- **scalable**?
- **robust**?
- **security**?



# Email Security: Spam

- Spam (Google)

# Email Security Issue: Spam




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

# 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