

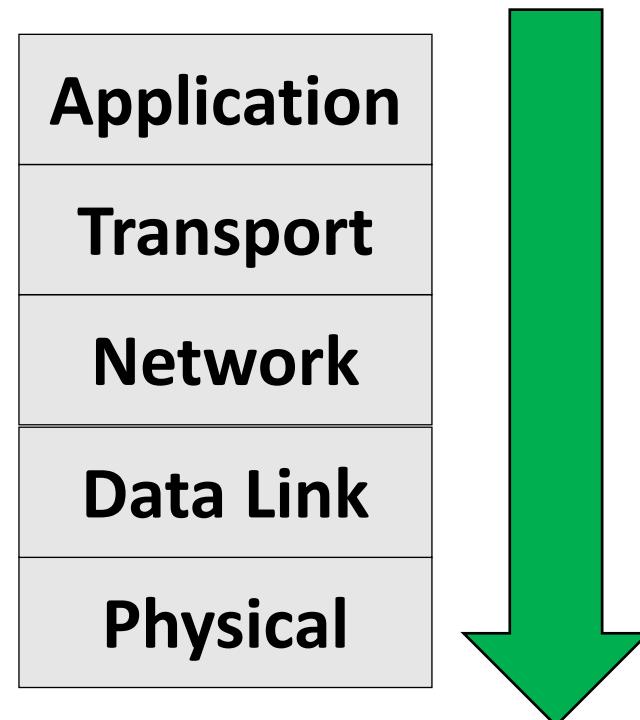


Application Layer

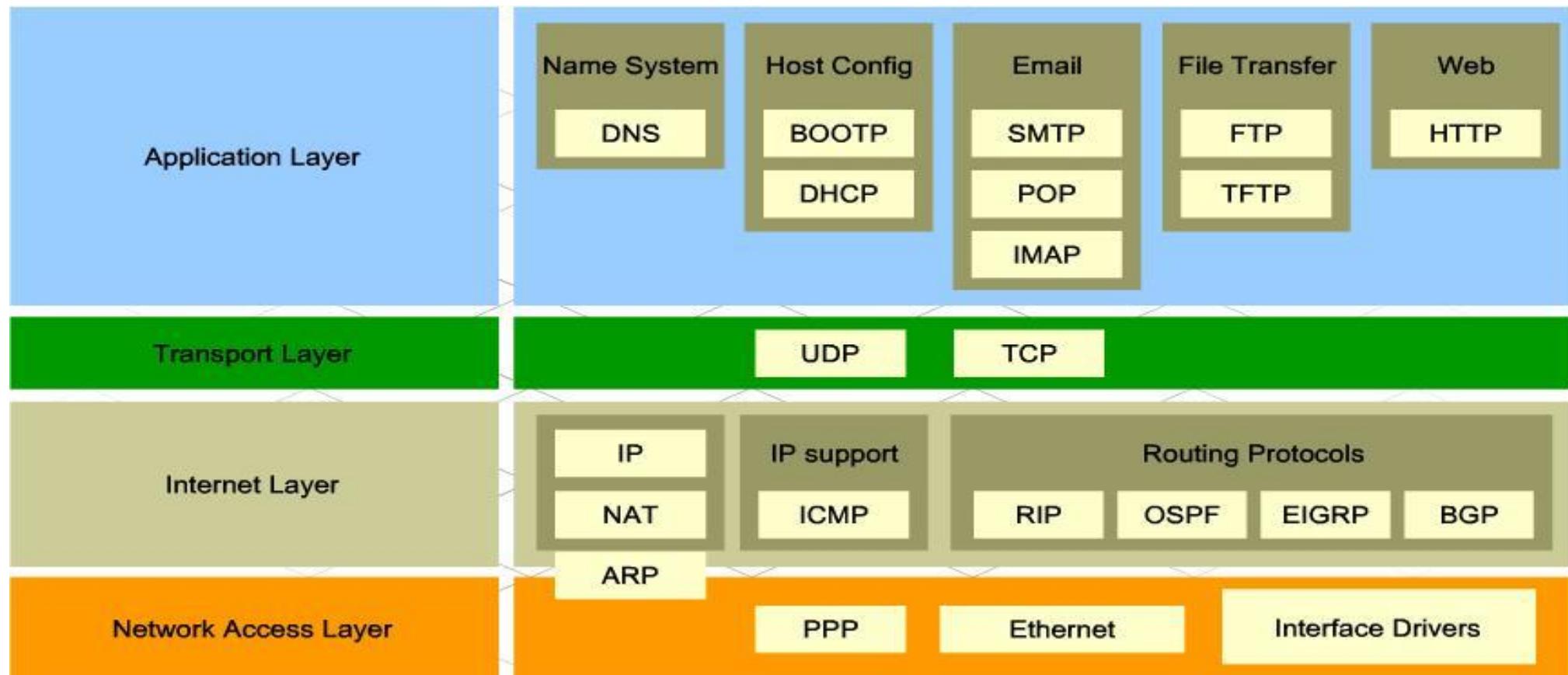
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Top Down Approach

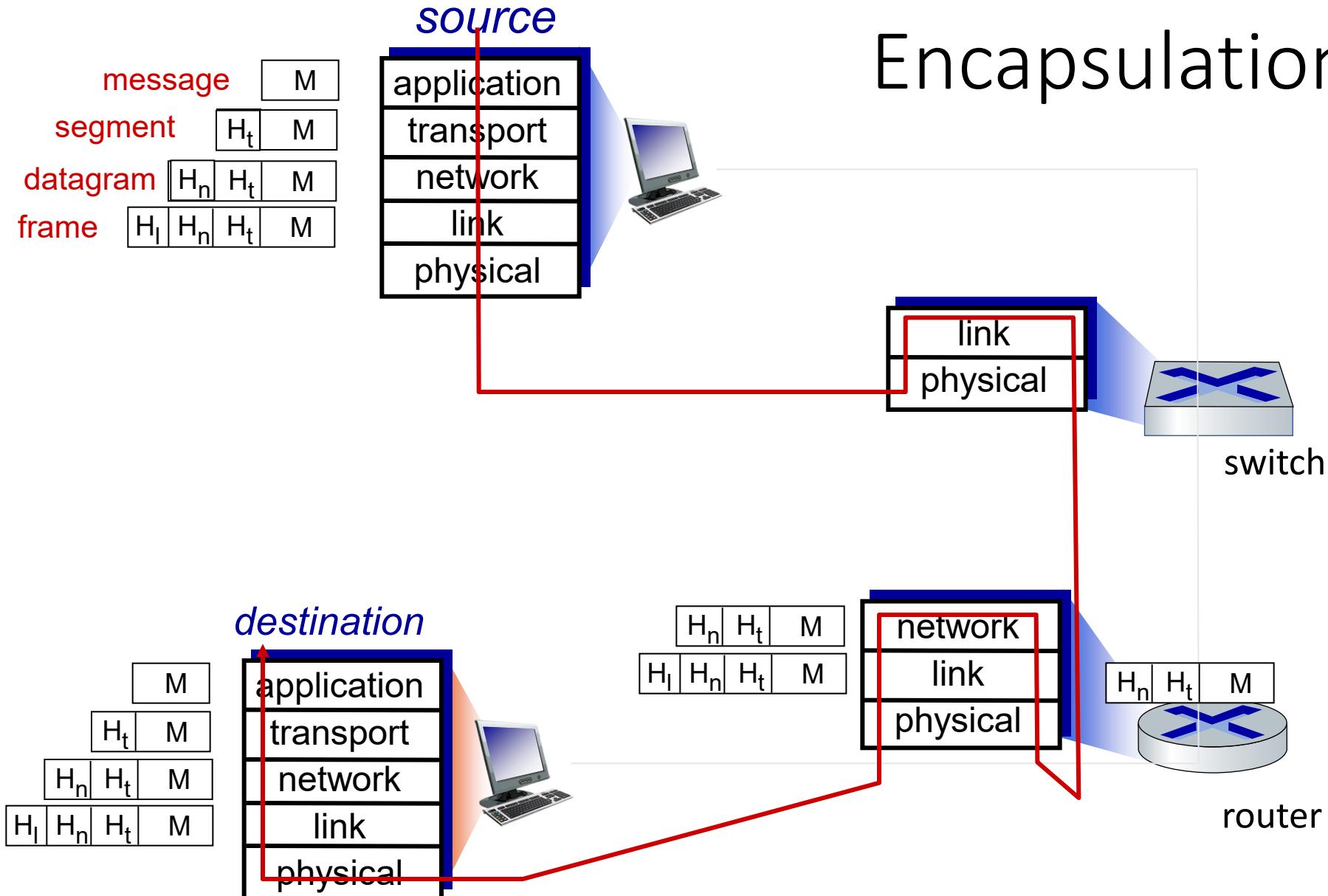


Protocols @ Different layers

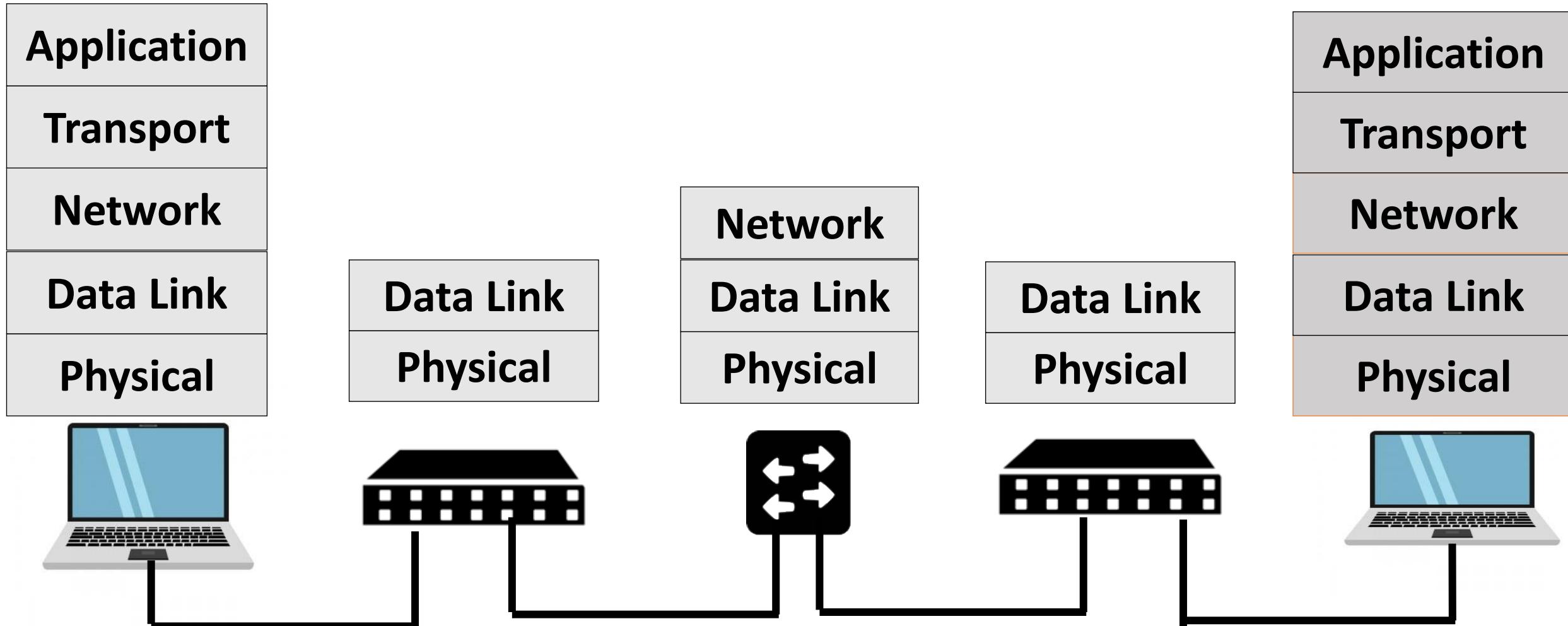


Source: <http://walkwidnetwork.blogspot.com/2013/04/application-layer-internet-protocol.html>

Encapsulation



Communication between two remote Machine



List of Application Layer protocols

Protocol Acronym	Protocol Name
BitTorrent	BitTorrent (peer-to-peer file sharing protocol)
FTP	File Transfer Protocol
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IMAP	Internet Message Access Protocol
NTP	Network Time Protocol
POP3	Post Office Protocol (version 3)
RDP	Remote Desktop Protocol
Skype	Skype (peer-to-peer VoIP protocol)
MSNP	Microsoft Notification Protocol
SIP	Session Initiation Protocol
SMB/CIFS	Server Message Block/Common Internet File System
SMTP	Simple Mail Transfer Protocol
SSH	Secure Shell
TELNET	Terminal Network
OpenVPN	OpenVPN (Virtual Private Network)
IPsec	IPsec (IP security)
PPTP	Point-to-Point Tunneling Protocol

RFCs for Application Layer Protocol-HTTP

[[Docs](#)] [[txt|pdf](#)] [[draft-ietf-http...](#)] [[Tracker](#)] [[Diff1](#)] [[Diff2](#)] [[Errata](#)]

PROPOSED STANDARD
[Errata Exist](#)

Internet Engineering Task Force (IETF)
Request for Comments: 7231
Obsoletes: [2616](#)
Updates: [2817](#)
Category: Standards Track
ISSN: 2070-1721

R. Fielding, Ed.
Adobe
J. Reschke, Ed.
greenbytes
June 2014

<https://tools.ietf.org/html/>

Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content

Abstract

The Hypertext Transfer Protocol (HTTP) is a stateless application-level protocol for distributed, collaborative, hypertext information systems. This document defines the semantics of HTTP/1.1 messages, as expressed by request methods, request header fields, response status codes, and response header fields, along with the payload of messages (metadata and body content) and mechanisms for content negotiation.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in [Section 2 of RFC 5741](#).

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at
<http://www.rfc-editor.org/info/rfc7231>.

RFC: 7231

<https://tools.ietf.org/html/rfc7231>

RFCs for Application Layer Protocol-DNS

Network Working Group
Request for Comments: 1035
Obsoletes: RFCs 882, 883, 973

P. Mockapetris
ISI
November 1987

DOMAIN NAMES - IMPLEMENTATION AND SPECIFICATION

1. STATUS OF THIS MEMO

This RFC describes the details of the domain system and protocol, and assumes that the reader is familiar with the concepts discussed in a companion RFC, "Domain Names - Concepts and Facilities" [RFC-1034].

The domain system is a mixture of functions and data types which are an official protocol and functions and data types which are still experimental. Since the domain system is intentionally extensible, new data types and experimental behavior should always be expected in parts of the system beyond the official protocol. The official protocol parts include standard queries, responses and the Internet class RR data formats (e.g., host addresses). Since the previous RFC set, several definitions have changed, so some previous definitions are obsolete.

Experimental or obsolete features are clearly marked in these RFCs, and such information should be used with caution.

The reader is especially cautioned not to depend on the values which appear in examples to be current or complete, since their purpose is primarily pedagogical. Distribution of this memo is unlimited.

RFC: 1035

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

RFCs for Application Layer Protocol-SMTP

[[Docs](#)] [[txt|pdf](#)] [[draft-klensin-r...](#)] [[Tracker](#)] [[Diff1](#)] [[Diff2](#)] [[Errata](#)]
Updated by: [7504](#) DRAFT STANDARD
Network Working Group Errata Exist
Request for Comments: 5321 J. Klensin
Obsoletes: [2821](#) October 2008
Updates: [1123](#)
Category: Standards Track

Simple Mail Transfer Protocol

Status of This Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Abstract

This document is a specification of the basic protocol for Internet electronic mail transport. It consolidates, updates, and clarifies several previous documents, making all or parts of most of them obsolete. It covers the SMTP extension mechanisms and best practices for the contemporary Internet, but does not provide details about particular extensions. Although SMTP was designed as a mail transport and delivery protocol, this specification also contains information that is important to its use as a "mail submission" protocol for "split-UA" (User Agent) mail reading systems and mobile environments.

RFC: 5321

<https://tools.ietf.org/html/rfc5321>

Chapter 2

Application Layer

A note on the use of these PowerPoint slides:

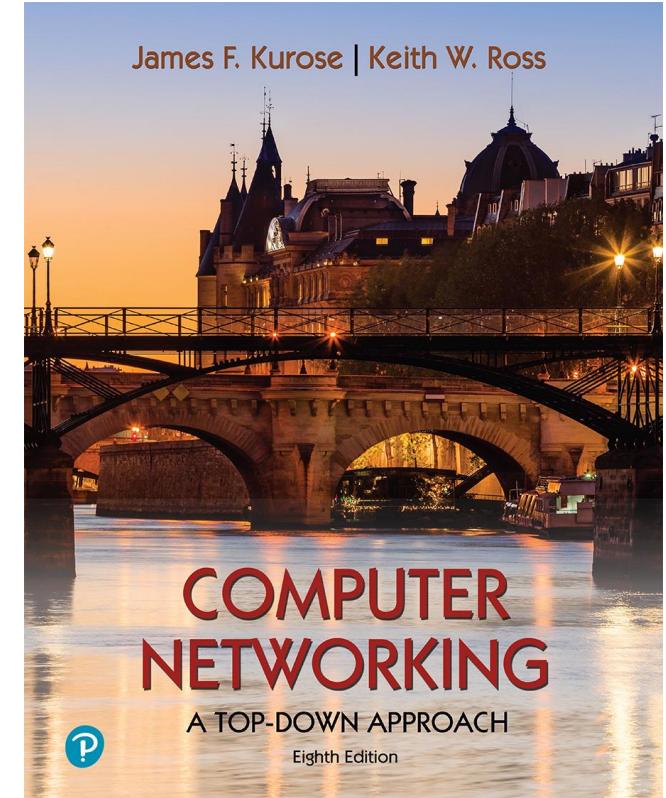
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- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
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*Computer Networking: A
Top-Down Approach*
8th edition n
Jim Kurose, Keith Ross
Pearson, 2020

Application layer: overview

- Principles of network applications
- Web and HTTP
- E-mail, SMTP, IMAP
- The Domain Name System DNS
- P2P applications
- video streaming and content distribution networks
- socket programming with UDP and TCP



Some network apps

- social networking
- Web
- text messaging
- e-mail
- multi-user network games
- streaming stored video
(YouTube, Hulu, Netflix)
- P2P file sharing
- voice over IP (e.g., Skype)
- real-time video conferencing
- Internet search
- remote login
- ...

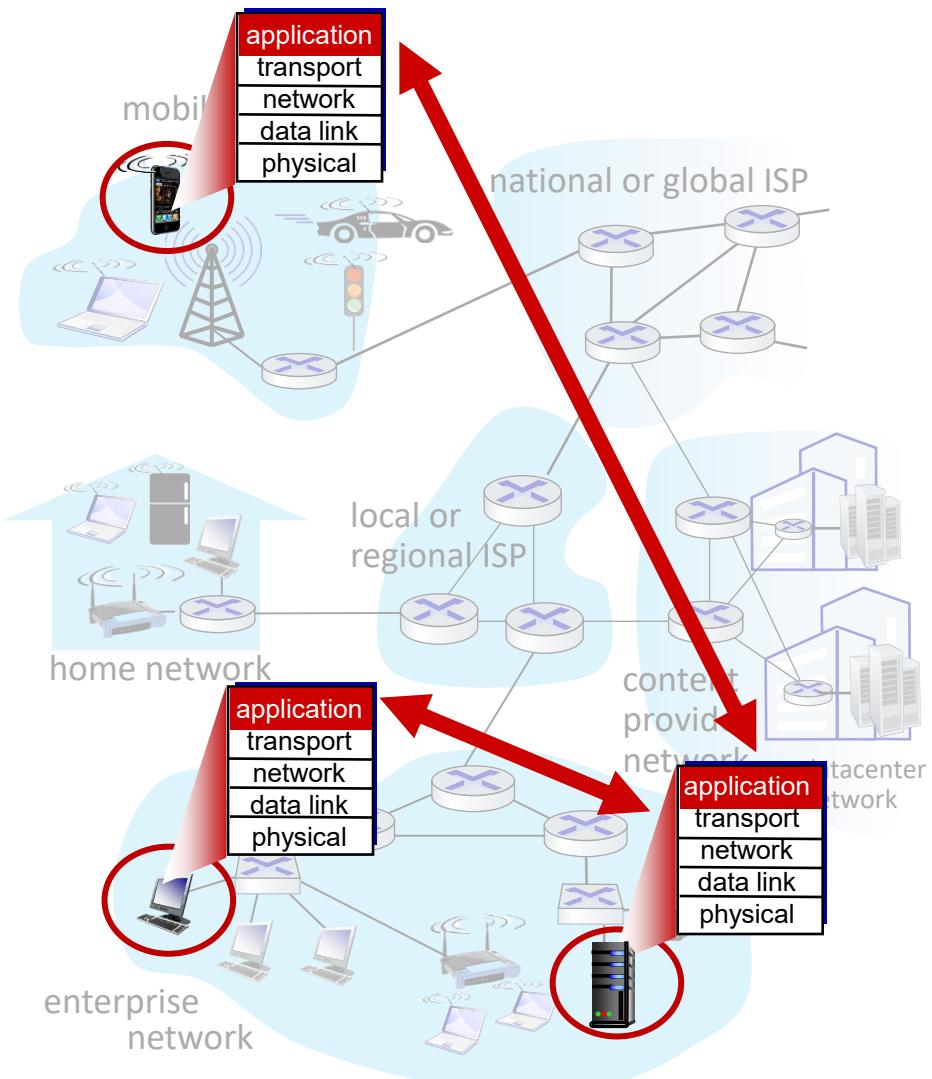
Creating a network app

write programs that:

- run on (different) end systems
- communicate over network
- e.g., web server software
communicates with browser software

**no need to write software for
network-core devices**

- network-core devices do not run user applications
- applications on end systems allows for rapid app development



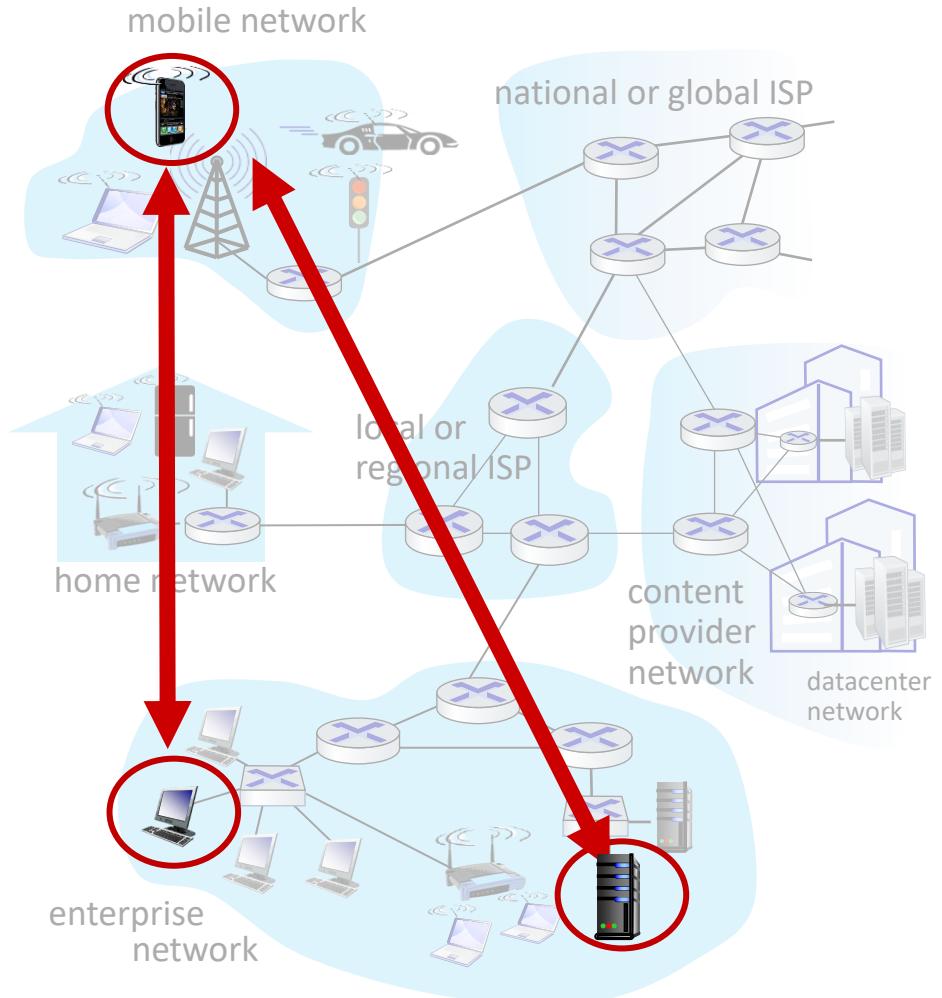
Client-server paradigm

server:

- always-on host
- permanent IP address
- often in data centers, for scaling

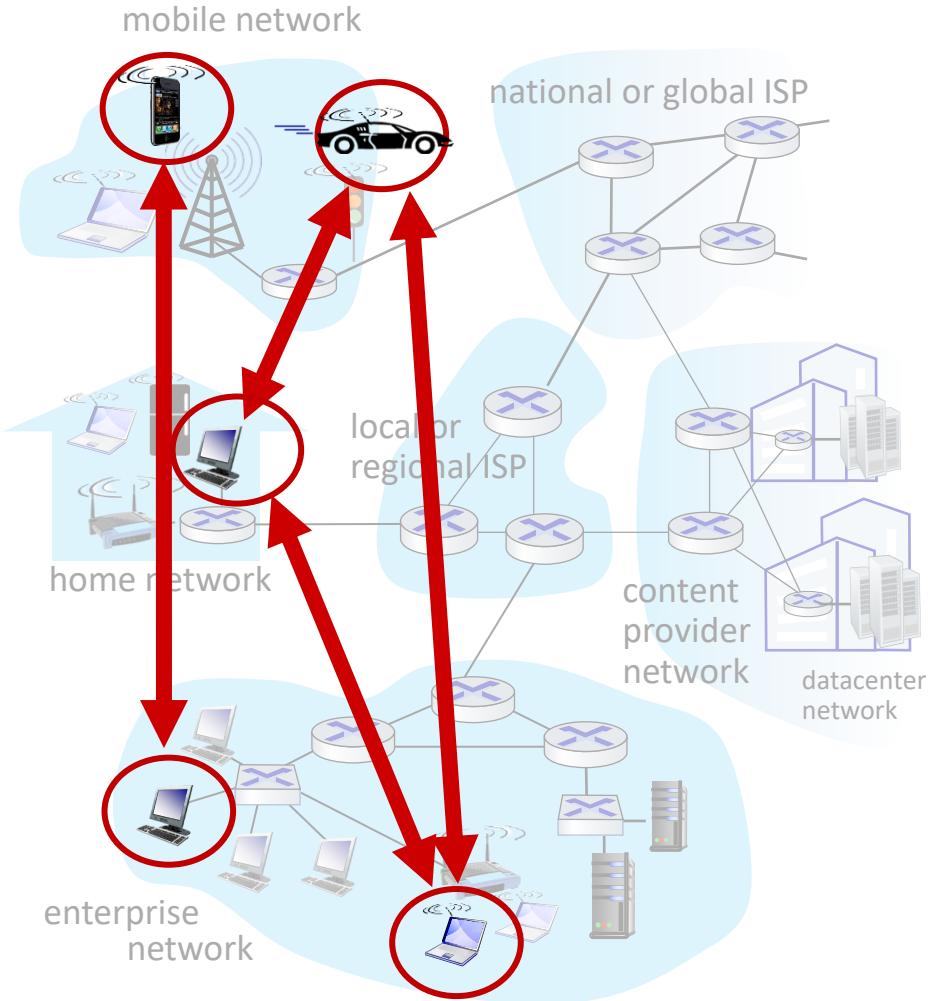
clients:

- contact, communicate with server
- may have dynamic IP addresses
- do *not* communicate directly with each other
- examples: HTTP, IMAP, FTP



Peer-peer architecture

- no always-on server
- arbitrary end systems directly communicate
- peers request service from other peers, provide service in return to other peers
 - *self scalability* – new peers bring new service capacity, as well as new service demands
- peers are intermittently connected and change IP addresses
 - complex management
- example: P2P file sharing



Processes communicating

- process*: program running within a host
- within same host, two processes communicate using **inter-process communication** (defined by OS)
 - processes in different hosts communicate by exchanging **messages**

clients, servers

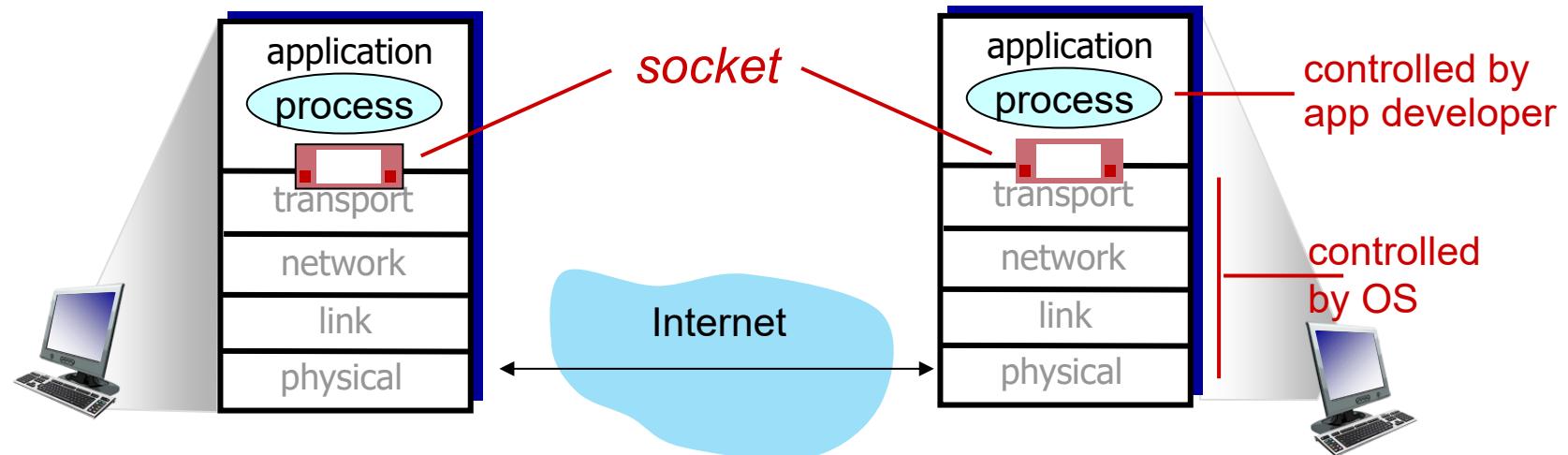
client process: process that initiates communication

server process: process that waits to be contacted

- note: applications with P2P architectures have client processes & server processes

Sockets

- process sends/receives messages to/from its **socket**
- socket analogous to a door
 - sending process pushes the message outdoor
 - sending process relies on transport infrastructure on other side of door to deliver message to socket at receiving process
 - two sockets involved: one on each side



Addressing processes

- to receive messages, process must have *identifier*
- host device has unique 32-bit IP address
- Q: does IP address of host on which process runs suffice for identifying the process?
 - A: no, *many* processes can be running on same host
- *identifier* includes both **IP address** and **port numbers** associated with process on host.
- example port numbers:
 - HTTP server: 80
 - mail server: 25
- to send HTTP message to gaia.cs.umass.edu web server:
 - **IP address:** 128.119.245.12
 - **port number:** 80
- more shortly...

An application-layer protocol defines:

- types of messages exchanged,
 - e.g., request, response
- message syntax:
 - what fields in messages & how fields are delineated
- message semantics
 - meaning of information in fields
- rules for when and how processes send & respond to messages

open protocols:

- defined in RFCs, everyone has access to protocol definition
- allows for interoperability
- e.g., HTTP, SMTP

proprietary protocols:

- e.g., Skype

What transport service does an app need?

data integrity

- some apps (e.g., file transfer, web transactions) require 100% reliable data transfer
- other apps (e.g., audio) can tolerate some loss

throughput

- some apps (e.g., multimedia) require minimum amount of throughput to be “effective”
- other apps (“elastic apps”) make use of whatever throughput they get

timing

- some apps (e.g., Internet telephony, interactive games) require low delay to be “effective”

security

- encryption, data integrity, ...

Transport service requirements: common apps

application	data loss	throughput	time sensitive?
file transfer/download	no loss	elastic	no
e-mail	no loss	elastic	no
Web documents	no loss	elastic	no
real-time audio/video	loss-tolerant	audio: 5Kbps-1Mbps video:10Kbps-5Mbps	yes, 10's msec
streaming audio/video	loss-tolerant	same as above	yes, few secs
interactive games	loss-tolerant	Kbps+	yes, 10's msec
text messaging	no loss	elastic	yes and no

Internet transport protocols services

TCP service:

- ***reliable transport*** between sending and receiving process
- ***flow control***: sender won't overwhelm receiver
- ***congestion control***: throttle sender when network overloaded
- ***does not provide***: timing, minimum throughput guarantee, security
- ***connection-oriented***: setup required between client and server processes

UDP service:

- ***unreliable data transfer*** between sending and receiving process
- ***does not provide***: reliability, flow control, congestion control, timing, throughput guarantee, security, or connection setup.

Q: why bother? *Why* is there a UDP?

Internet transport protocols services

application	application layer protocol	transport protocol
file transfer/download	FTP [RFC 959]	TCP
e-mail	SMTP [RFC 5321]	TCP
Web documents	HTTP 1.1 [RFC 7320]	TCP
Internet telephony	SIP [RFC 3261], RTP [RFC 3550], or proprietary	TCP or UDP
streaming audio/video	HTTP [RFC 7320], DASH	TCP
interactive games	WOW, FPS (proprietary)	UDP or TCP

Application layer: overview

- Principles of network applications
- **Web and HTTP**
- E-mail, SMTP, IMAP
- The Domain Name System
DNS
- P2P applications
- video streaming and content distribution networks
- socket programming with UDP and TCP



Web and HTTP

First, a quick review...

- web page consists of *objects*, each of which can be stored on different Web servers
- object can be HTML file, JPEG image, Java applet, audio file,...
- web page consists of *base HTML-file* which includes *several referenced objects, each* addressable by a *URL*, e.g.,

www.someschool.edu/someDept/pic.gif

The URL 'www.someschool.edu/someDept/pic.gif' is shown. A horizontal brace is positioned below the first part of the URL, 'www.someschool.edu', with the label 'host name' centered below it. Another horizontal brace is positioned below the remaining part of the URL, '/someDept/pic.gif', with the label 'path name' centered below it.

HTTP overview

HTTP: hypertext transfer protocol

- Web's application layer protocol
- client/server model:
 - *client*: browser that requests, receives, (using HTTP protocol) and “displays” Web objects
 - *server*: Web server sends (using HTTP protocol) objects in response to requests



HTTP overview (continued)

HTTP uses TCP:

- client initiates TCP connection (creates socket) to server, port 80
- server accepts TCP connection from client
- HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)
- TCP connection closed

HTTP is “stateless”

- server maintains *no* information about past client requests

HTTP connections: two types

Non-persistent HTTP

1. TCP connection opened
2. at most one object sent over TCP connection
3. TCP connection closed

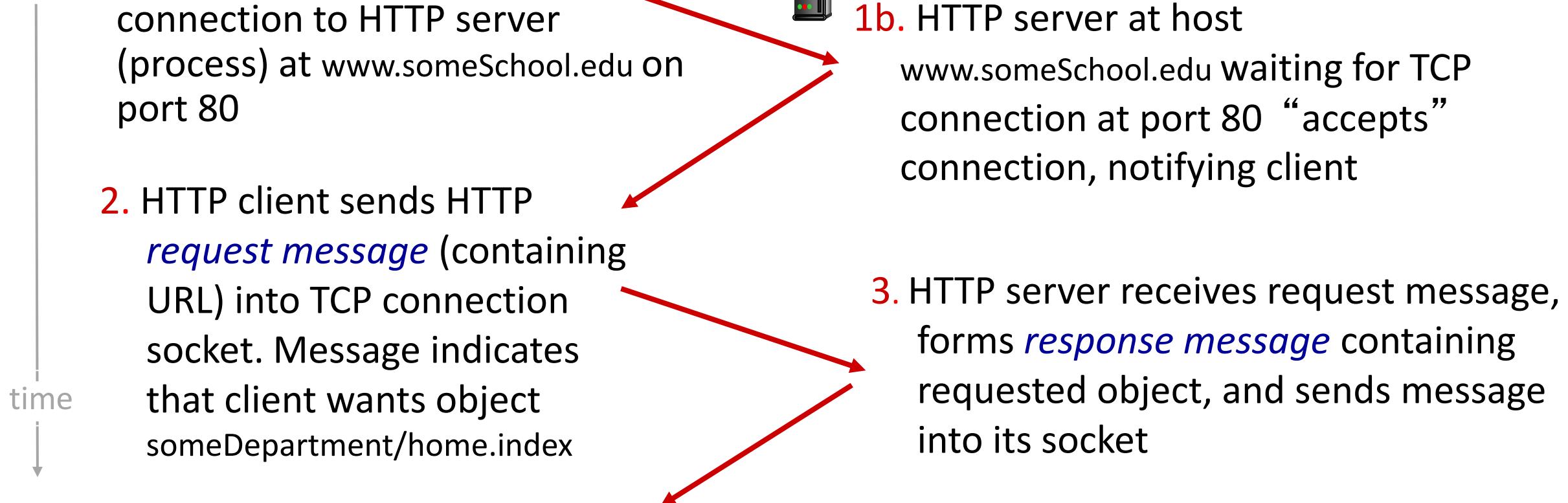
downloading multiple objects required multiple connections

Persistent HTTP

- TCP connection opened to a server
- multiple objects can be sent over *single* TCP connection between client, and that server
- TCP connection closed

Non-persistent HTTP: example

User enters URL: `www.someSchool.edu/someDepartment/home.index`
(containing text, references to 10 jpeg images)



Non-persistent HTTP: example (cont.)

User enters URL: `www.someSchool.edu/someDepartment/home.index`
(containing text, references to 10 jpeg images)



5. HTTP client receives response message containing html file, displays html. Parsing html file, finds 10 referenced jpeg objects

6. Steps 1-5 repeated for each of 10 jpeg objects



4. HTTP server closes TCP connection.

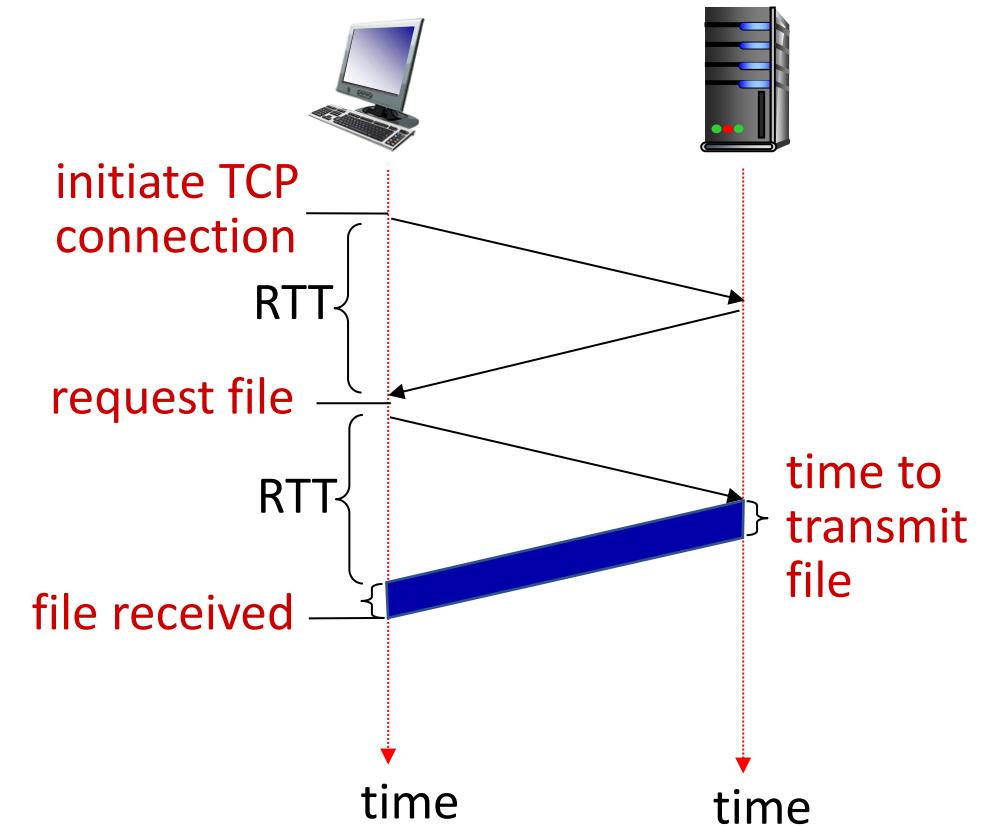
time

Non-persistent HTTP: response time

RTT (definition): time for a small packet to travel from client to server and back

HTTP response time (per object):

- one RTT to initiate TCP connection
- one RTT for HTTP request and first few bytes of HTTP response to return
- object/file transmission time



$$\text{Non-persistent HTTP response time} = 2\text{RTT} + \text{file transmission time}$$

Persistent HTTP (HTTP 1.1)

Non-persistent HTTP issues:

- requires 2 RTTs per object
- OS overhead for *each* TCP connection
- browsers often open multiple parallel TCP connections to fetch referenced objects in parallel

Persistent HTTP (HTTP1.1):

- server leaves connection open after sending response
- subsequent HTTP messages between same client/server sent over open connection
- client sends requests as soon as it encounters a referenced object
- as little as one RTT for all the referenced objects (cutting response time in half)

HTTP request message

- two types of HTTP messages: *request, response*
- **HTTP request message:**

- ASCII (human-readable format)

request line (GET, POST,
HEAD commands)

header
lines

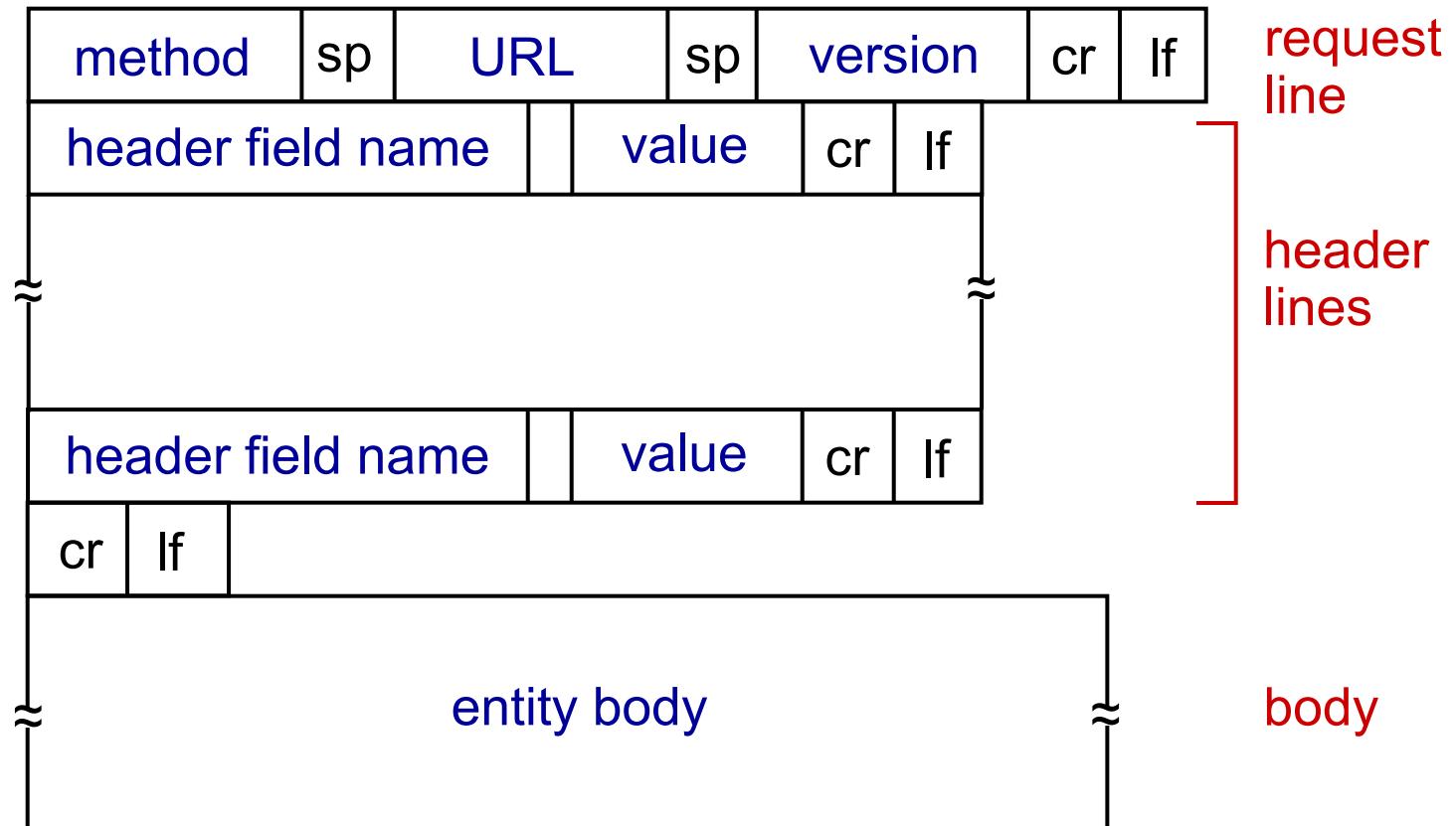
carriage return, line feed
at start of line indicates
end of header lines

```
GET /index.html HTTP/1.1\r\n
Host: www-net.cs.umass.edu\r\n
User-Agent: Firefox/3.6.10\r\n
Accept: text/html,application/xhtml+xml\r\n
Accept-Language: en-us,en;q=0.5\r\n
Accept-Encoding: gzip,deflate\r\n
Accept-Charset: ISO-8859-1,utf-8;q=0.7\r\n
Keep-Alive: 115\r\n
Connection: keep-alive\r\n
\r\n
```

carriage return character
line-feed character

* Check out the online interactive exercises for more
examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

HTTP request message: general format



Other HTTP request messages

GET method: (Read)

- include user data in URL field of HTTP GET request message

POST method: (Create)

- user input sent from client to server in entity body of HTTP POST request message

`www.somesite.com/animalsearch?monkeys&banana`

HEAD method: (only header)

- requests headers (only) that would be returned *if* specified URL were requested with an HTTP GET method.

PUT method: (update)

- uploads new file (object) to server
- completely replaces file that exists at specified URL with content in entity body of POST HTTP request message

HTTP response message

status line (protocol
status code status phrase)

HTTP/1.1 200 OK\r\nDate: Sun, 26 Sep 2010 20:09:20 GMT\r\nServer: Apache/2.0.52 (CentOS) \r\nLast-Modified: Tue, 30 Oct 2007 17:00:02
GMT\r\n

header
lines

data, e.g., requested
HTML file

ETag: "17dc6-a5c-bf716880"\r\nAccept-Ranges: bytes\r\nContent-Length: 2652\r\nKeep-Alive: timeout=10, max=100\r\nConnection: Keep-Alive\r\nContent-Type: text/html; charset=ISO-8859-
1\r\n\r\ndata data data data data ...

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

HTTP response status codes

- status code appears in 1st line in server-to-client response message.
- some sample codes:

200 OK

- request succeeded, requested object later in this message

301 Moved Permanently

- requested object moved, new location specified later in this message (in Location: field)

400 Bad Request

- request msg not understood by server

404 Not Found

- requested document not found on this server

505 HTTP Version Not Supported