Application Layers 1 应用层

Principle of network application 网络应用原理

Application	App layer protocol	Underlying Transport Protocol
E-mail	SMTP[RFC 2281], POP3, IMAP	TCP
Remote terminal Access	Telnet [RFC 854], SSH	TCP
Web	HTTP [RFC 2616], HTTPS	TCP
File Transfer	FTP [959], SFTP	TCP
Multimedia	HTTP / RTP [RFC 1889]	TCP or UDP
VoIP	SIP, RTP or proprietary	TCP or UDP

Client-server architecture 主从式架构

- **Server** 服务端
  - Always-on host 始终在线的主机
  - Permanent IP address 永久 IP 地址
  - High performance / Distributed computing 高性能/分布式计算
  - Server process: waits to be contacted (Listen) 服务器进程：等待被联系 （Listen）
- **Clients** 客户端
  - Link to the server for service 链接到服务器以进行服务
  - May be intermittently connect to the internet 可能会间歇性地连接到 Internet
  - Dynamic IP address 动态 IP 地址
  - Do not communicate directly with each other 不要直接相互通信
  - Client process: initiates communication 客户端进程：启动通信

P2P Architecture P2P 架构

- No always-on server is needed 不需要始终在线服务器
- End systems directly exchange data 终端系统直接交换数据
- Client process / server process on the same host 客户端进程/服务器进程在同一主机上
- Peers request service from other peers, provide service in return to other peers
  对等体向其他对等体请求服务，并向其他对等体提供服务
  - *Self scalability* – new peers bring new service capacity, as well as new service demands
    自我扩展性 - 新的对等体带来新的服务能力,以及新的服务需求
- Peers are intermittently connected 对等体连接间歇

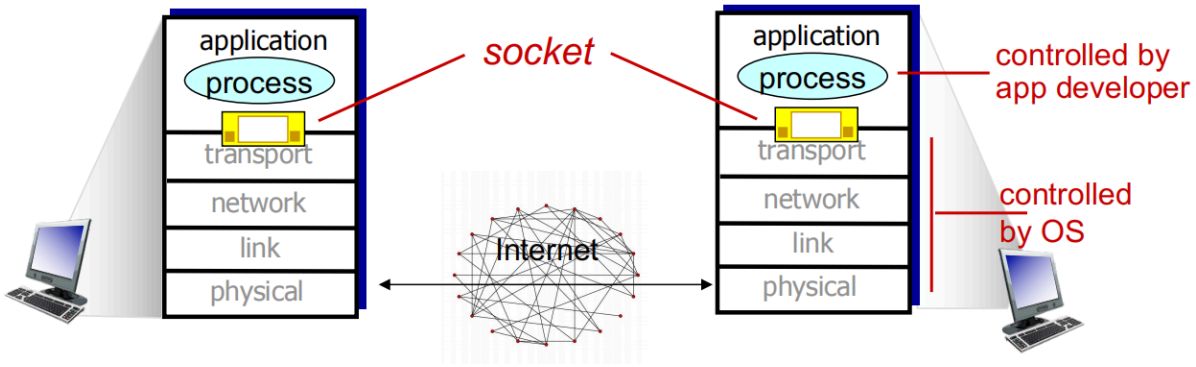
- Dynamic IP addresses 动态IP地址
- Q: Did you use Thunder Downloader(迅雷)? Why does it download so fast?

Socket 套接字

- Process sends/receives messages to/from its socket

  进程向/从其套接字发送/接收消息
- Socket analogous to door 套接字类似于门
- Sending process shoves message out door 发送过程将消息推到门外
- Sending process relies on transport infrastructure on other side of door to deliver message to socket at receiving process

  发送过程依赖于门另一侧的传输基础设施,以便在接收过程中将消息传送到插座



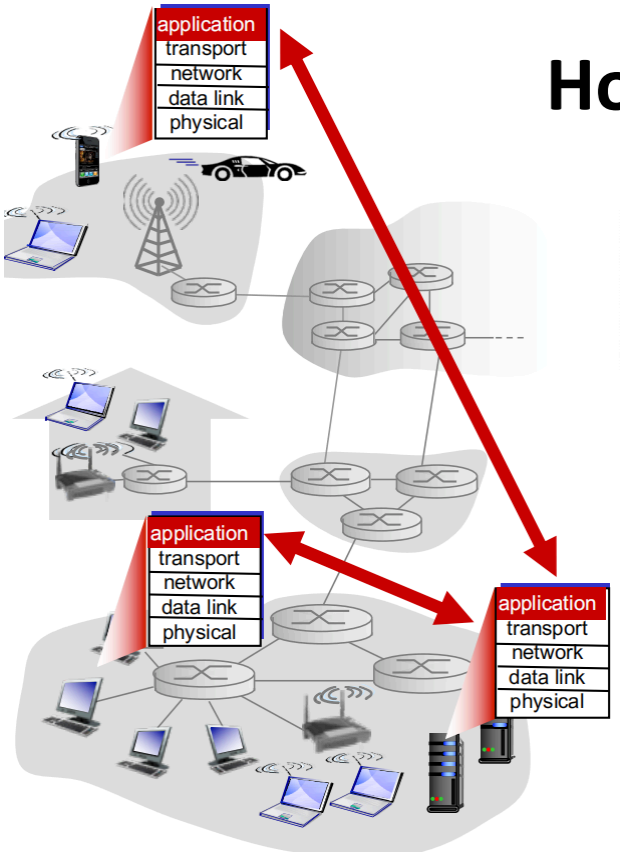
Addressing processes 寻址过程

- To receive messages, process must have identifier

  要接收消息,进程必须具有标识符
- Host device has unique 32-bit IPv4 and/or 128-bit IPv6

  主机设备具有唯一的 32 位 IPv4 和/或 128 位 IPv6
- Process network identifier： 进程网络标识符:
  - **IPv4**:port 192.168.1.100:80
  - **IPv6**:port [240e:3a1:4cb1:69d0:f40c:4269:74a2:7ea3]:80

Application-layer protocol defines 应用层协议定义



- **Types of messages exchanged** 交换的消息类型
  - e.g., request, response
- **Message syntax:** 消息语法
  - what fields in messages & how fields are delineated 消息中的字段和字段是如何划分的
- **Message semantics:** 消息语义
  - meaning of information in fields 字段中信息的含义
- **Message timing:** 消息计时：
  - when and how 何时以及如何

区分接口类型：

- **Open protocols:** 公用端口
  - Defined in RFCs
  - Allows for interoperability
  - e.g., HTTP, SMTP, FTP
- **Proprietary protocols:** 专有端口
- e.g., Skype, Games, you own protocols...

Data Integrity

- 100% reliable data transfer

or

- Tolerate some loss

Throughput

- Some apps require minimum amount of throughput to be “effective”
- Others do not require

- Some apps require low delay

Timing

- Some apps require encryption
- Data integrity check

Security

Transport service requirements: common apps

Applications	Data loss	Throughput	Time sensitive
File transfer	No loss	Elastic	No
E-mail	No loss	Elastic	No
Web documents	No loss	Elastic	No
Real-time video/audio	Loss-tolerant	Based on quality*	Yes 100 ms
Stored video/audio	Loss-tolerant	Based on quality*	Yes few second
Interactive games	Loss-tolerant	Few kpbs	Yes 100 ms
Text messaging	No loss	Elastic	Yes or No

* Audio: 5k to 1Mpbs, Video: 10kpbs - 10 Mbps or more

Internet transport protocols services 网络传输协议服务

TCP service:

- **Reliable transport** between sending and receiving process

  发送和接收过程之间的**可靠传输**
- **Flow control**: sender won’t overwhelm receiver

  流量控制：发送方不会压倒接收方
- **Congestion control**: throttle sender when network overloaded

  拥塞控制：网络过载时限制发送方
- **Does not offer**: timing, minimum throughput guarantee, security

  不提供：计时、最小吞吐量保证、安全性
- **Connection-oriented**: setup required between client and server processes

  面向连接：客户端和服务器进程之间需要设置

UDP service:

- **Unreliable data transfer** between sending and receiving process

  发送和接收过程之间的 **不可靠的数据传输**

- **Does not offer**: reliability, flow control, congestion control, timing, throughput guarantee, security, or connection setup,

  不提供：可靠性、流量控制、拥塞控制、计时、吞吐量保证、安全性或连接设置，
- Online games, live streaming

Securing TCP - Secure Sockets Layer (SSL)

TCP & UDP

- No encryption 无加密
- Cleartext psws -> Internet 明文密码-> Internet

SSL is at app layer

- Apps use SSL libraries, that "talk" to TCP

SSL

- Provides encrypted TCP connection 提供加密的 TCP 连接 -
- Data integrity 数据完整性
- End-point authentication 端点认证

SSL socket API

- Cleartext psw -> encrypted psw -> Internet
- Lecture 11/12 will talk more

Web Application 网站应用

WWW: World Wide Web

HTTP: Hypertext Transfer Protocol

Web page consists of *base HTML-file* which includes *several referenced objects, addressable by a URL (uniform resource locator)*

网页由 *基本 HTML 文档* 组成，其中包括 *几个引用的 对象，可通过 URL（统一资源定位器）寻址*

HTTP

*HTTP is "**stateless**"* 无状态的

- server maintains no information about past client requests

  服务器不保留有关过去客户端请求的信息
- **Application layer protocol** 是应用层的协议
- **Client/server model** cs模型
  - *Client:* browser that requests, receives, (using HTTP protocol) and show Web objects (Render)

    客户端:请求、接收(使用HTTP协议)和显示Web对象(渲染)的浏览器
  - *Server:* Web server sends (using HTTP protocol) objects in response to requests

    服务器:Web服务器发送(使用HTTP协议)对象以响应请求

Uses TCP:

1. Client initiates TCP connection (creates socket) to server, port 80(443 for https)

   客户端启动与服务器的 TCP 连接（创建套接字），端口 80（https 为 443）

2. Server accepts TCP connection from client

   服务器接受来自客户端的 TCP 连接

3. HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)

   在浏览器（HTTP 客户端）和 Web 服务器（HTTP 服务器）之间交换的 HTTP 消息（应用进程层协议消息）

4. TCP connection closed

   TCP 连接关闭

HTTP connections

- **Non-persistent HTTP** 非持久性
  - At most one object sent over TCP connection

    最多 1 个通过 TCP 连接发送的对象
  - connection then closed

    连接然后关闭
  - Downloading multiple objects required multiple connections

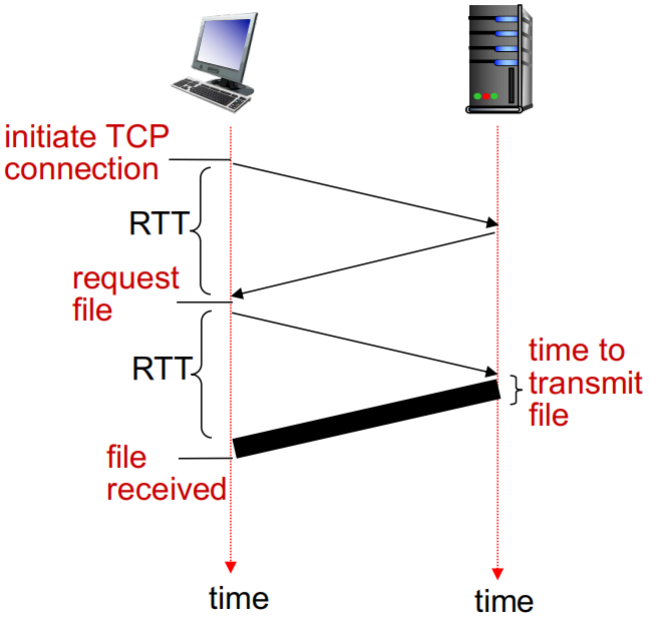
    下载多个对象需要多个连接
- **Persistent HTTP** 持久性HTTP
  - Multiple objects can be sent over single TCP connection between client, server

    可以通过客户端、服务器之间的单个 TCP 连接发送多个对象

None-persistent HTTP: response time 非持久HTTP:响应时间

- **RTT** (Round Trip Time): 往返时间
  - time for a small packet to travel from client to server and back round trip time

    小数据包在客户端之间传输和返回往返的时间
- HTTP response time: 响应时间
  - One RTT to initiate TCP connection
  - One RTT for HTTP request and first few bytes of HTTP response to return
  - File transmission time
  - Non-persistent HTTP response time = 2RTT+ file transmission time



Issues

- Non-persistent HTTP issues:
  - Requires 2 RTTs per object

    每个链接需要两次往返时间
  - OS overhead for each TCP connection

    每个 TCP 连接的 OS 开销
  - Browsers often open parallel TCP connections to fetch referenced objects

    浏览器通常会打开并行 TCP 连接来获取引用的对象
- Persistent HTTP issues:
  - Server leaves connection open after sending response

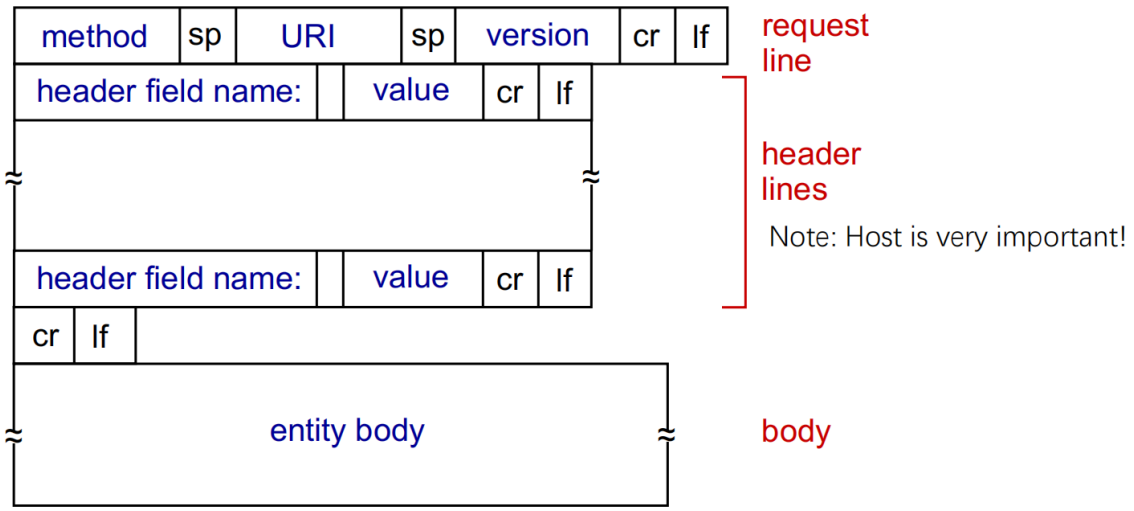
    服务器在发送响应后保持连接打开
  - Subsequent HTTP messages between same client/server sent over open connection

    同一客户端/服务器之间通过开放连接发送的后续 HTTP 消息
  - Client sends requests as soon as it encounters a referenced object

    客户端在遇到引用对象后立即发送请求
  - As little as one RTT for all the

    只需一个 RTT 即可获得所有

HTTP Request Message Format



例如：

GET /domain/index.html HTTP/1.1

Host: www.example.com

Connection: close

User-agent: Mozilla/5.0

Accept-language: en

General HTTP methods

GET, POST, PUT, DELETE, PATCH, HEAD, TRACE, OPTIONS, CONNECT

HTTP response status codes 请求状态码

• **Some sample codes**:

• 200 OK

• 301 Move Permanently

• 400 Bad Request

• 404 Not Found

• 505 HTTP Version Not Supported

- 1xx: Informational - Request received, continuing process
- 2xx: Success - The action was successfully received, understood, and accepted
- 3xx: Redirection - Further action must be taken in order to complete the request
- 4xx: Client Error - The request contains bad syntax or cannot be fulfilled
- 5xx: Server Error - The server failed to fulfill an apparently valid request

响应报文例如：

HTTP1.1 200 ok

Connection: close

Date: Tue, 18 Aug 2015 15:10:03 GMT

Server: Aphache/2.2.3 (CentOS)

Last-Modified: Tue, 18 Aug 2015 15:11:03 GMT

Content-Length: 6821

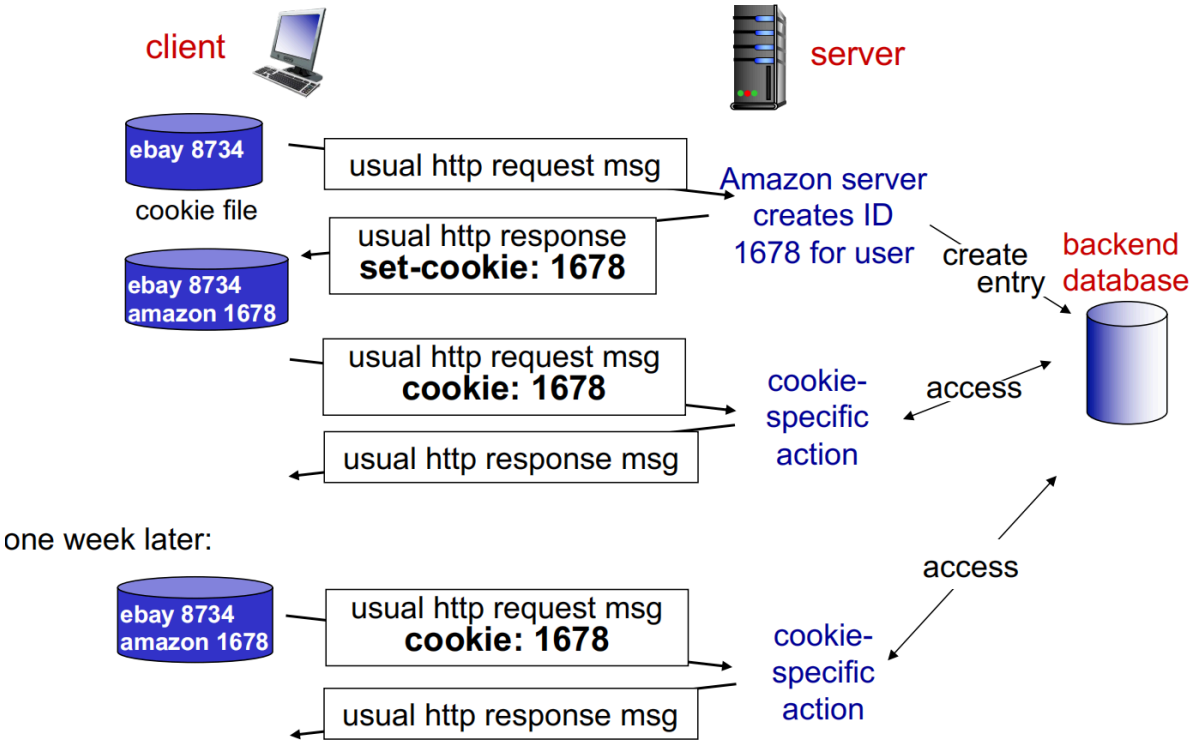
Content-Type: text/html

(Data)

User-server State: Cookies

Four components:

1. cookie header line of HTTP response message
2. cookie header line in next HTTP request message
3. cookie file kept on user’s host, managed by user’s browser
4. back-end database at Web site



- **What cookies can be used for:**
  - Authorization 认证
  - Recommendations 建议
  - User session state 用户的session状态

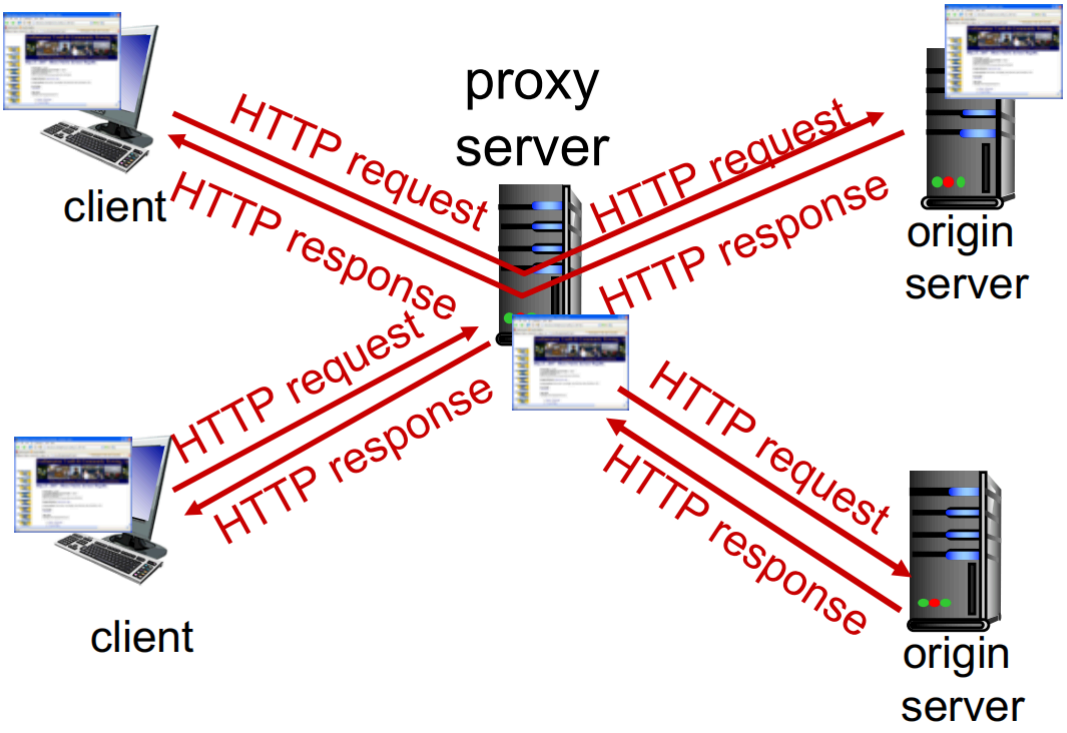
Web Caches (Proxy server) Web 缓存（代理服务器）

Goal: satisfy client request without involving origin server

目标：在不涉及源站的情况下满足客户端请求

- **User sets browser: Web accesses via cache** 用户设置浏览器：通过缓存进行 Web 访问
- **Browser sends all HTTP requests to cache** 浏览器将所有 HTTP 请求发送到缓存
  - object in cache: cache returns object
  - else cache requests object from origin server, then returns object to client

    缓存中的对象：缓存返回对象，否则缓存从源服务器请求对象，然后将对象返回给客户端



- **Cache acts as both client and server** 缓存同时充当客户端和服务器
  - server for original requesting client 原始请求客户端的服务器
  - client to origin server 客户端到源服务器
- Typically cache is installed by ISP (university, company, residential ISP（Internet Service Provider服务供应商）)

  通常缓存由 ISP（大学、公司、住宅 ISP）安装
- Why Web Caching 为什么选择 Web 缓存
  - reduce response time for client request 缩短客户请求的响应时间
  - reduce traffic on an institution's access link 减少机构访问链接上的流量
  - Internet dense with caches: enables " poor " content providers to effectively deliver content (so too does P2P file sharing)

    互联网缓存密集：使"穷"内容提供商能够有效地交付内容（P2P 文档共享也是如此）

Cache Examples

- Assumptions:
  - avg object size: 100K bits
  - avg request rate from browsers to origin servers:15/sec
  - avg data rate to browsers: 1.50 Mbps
  - RTT from institutional router to any origin server: 2 sec
  - access link rate: 1.54 Mbps
- Consequences:
  - LAN utilization: 1.50 / 1000 = 0.15%
  - access link utilization = 1.50/1.54 = 97.4%
  - total delay = Internet delay + access delay + LAN delay = 2 sec + minutes + usecs

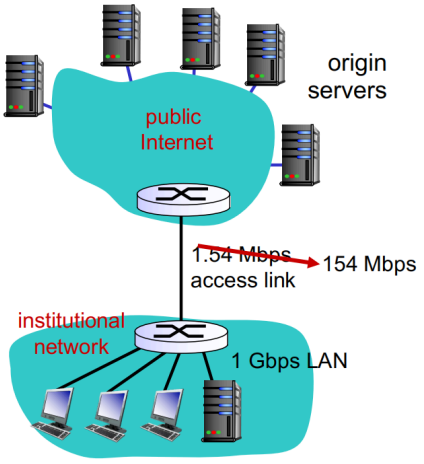
Caching example: fatter access link

Assumptions:

- avg object size: 100K bits
- avg request rate from browsers to origin servers:15/sec
- avg data rate to browsers: 1.50 Mbps
- RTT from institutional router to any origin server: 2 sec
- access link rate: 1.54 Mbps → 15.4 Mbps

Consequences:

- LAN utilization: 0.15%
- access link utilization = 97.4 % → 9.74%
- total delay = Internet delay + access delay + LAN delay
  = 2 sec + minutes + usecs → msecs



Cost: increased access link speed (not cheap!)

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Caching example: install local cache

Assumptions:

- avg object size: 100K bits
- avg request rate from browsers to origin servers:15/sec
- avg data rate to browsers: 1.50 Mbps
- RTT from institutional router to any origin server: 2 sec
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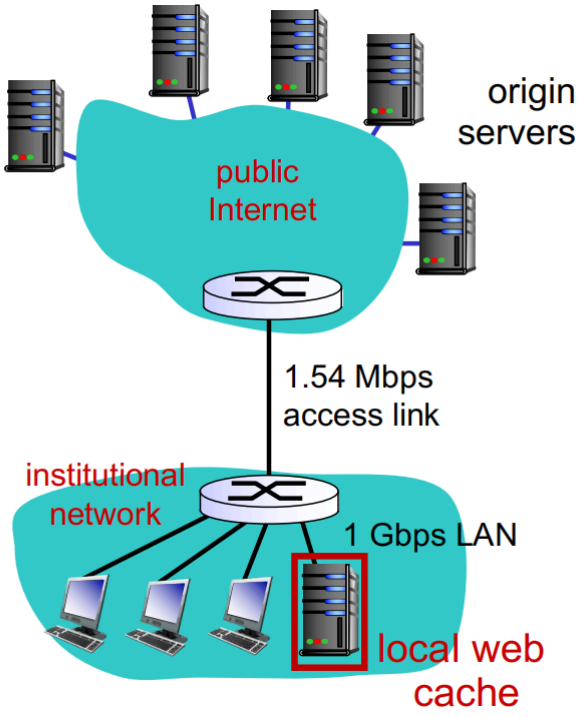


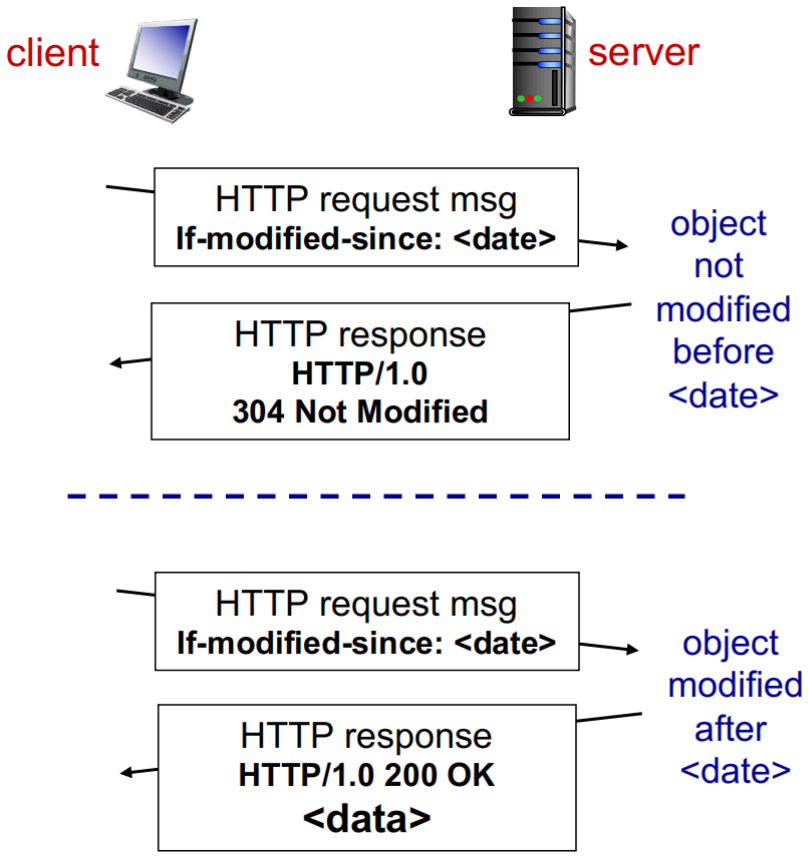
Calculating access link utilization, delay with cache: 计算访问链路利用率，缓存延迟：

- **Suppose cache hit rate is 0.4**
  - 40% requests satisfied at cache, 60% requests satisfied at origin
- **Access link utilization:**
  - 60% of requests use access link

- **Data rate to browsers over access link = 0.6*1.50 Mbps = 0.9 Mbps**
  - utilization = 0.9/1.54 = 0.58
- **Total delay**
  - = 0.6 * (delay from origin servers) +0.4 * (delay when satisfied at cache)
  - = 0.6 (2.01) + 0.4 (~msecs) = ~ 1.2 secs
  - less than with 154 Mbps link (and cheaper too!) 低于 154 Mbps 链接（而且也更便宜!)

Conditional GET

- Goal: don't send object if cache has up-to-date cached version
  - no object transmission delay
  - lower link utilization
- cache: specify date of cached copy in HTTP request
  - If-modified-since:
- server: response contains no object if cached copy is up-to-date:
  - HTTP/1.0 304 Not Modified



Question

- Does HTTP == Webpages?