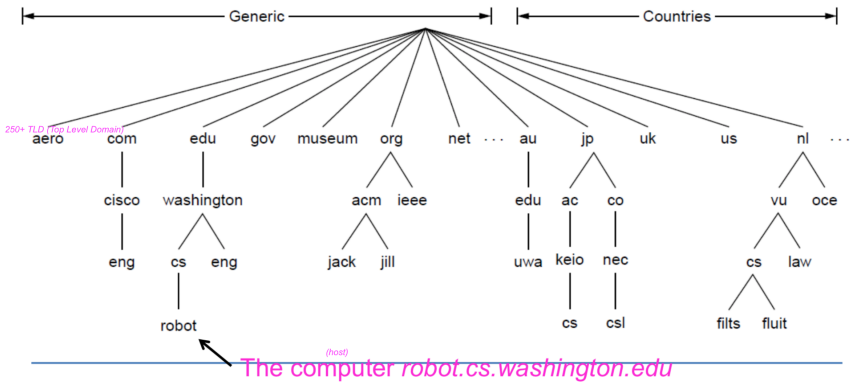
Week8: Application Layer

DNS (Domain Name System)

- DNS is an application layer protocol to allow host to query DNS server to translate name and IP address
- It has a distributed hierarchy database system stored name/IP address information
- It is used by other application layer protocol (http, ftp, smtp)

DNS Name Space



- The top of hierarchy (TLD) is managed by ICANN (Internet Corporation for Assigned Names and Numbers)
- Why the database system has to be distributed (cannot be centralized)?
  - Single point of failure
    - weak for being attacked 一旦挂了就全完了
  - Traffic volume
    - distributed system 分散 query volume
  - Distant centralized database
    - living far from the centralized system 的人就会很凉凉
  - Maintenance
    - 维护各个小 database 比较容易

DNS Services

- Hostname/IP address translation
- Hostname aliasing
  - find alias names for hostname
- Mail server aliasing
- Load distribution
  - 某个繁忙的网站(只有一个domain name, like www.google.com) 配有多个server(多个IP address), DNS 会把volume分配到不同的server (IP address).

Domain Name Property

- Case insensitive
- Each part max 63 char, total max 255 char
- Can be internationalized

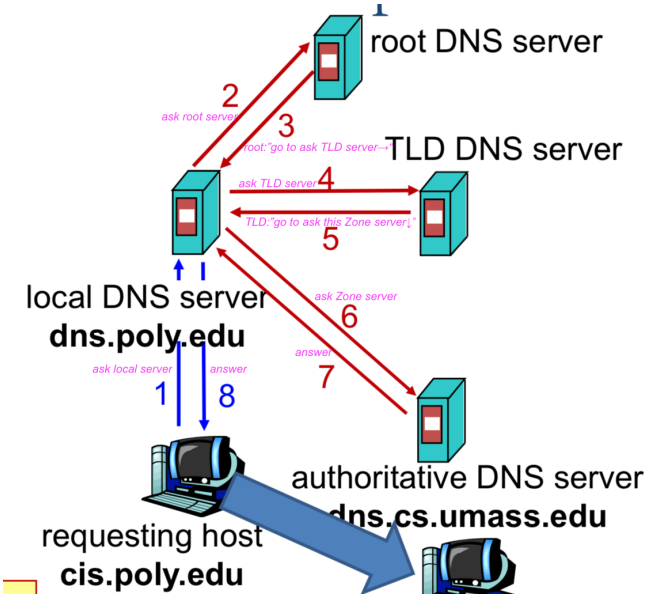
- **Absolute Domain Name**
  - end with a dot, 普通款: www.google.com.
- **Relative Domain Name**
  - In context of a absolute domain name, left-most part in an absolute domain name. (eg. computer1 and computer2 in cs.unimelb.edu.au)

Name Servers

- The DNS name space is divided into non-overlapping sub trees (called a zone).
- **Zone (authoritative) name server**
  - Each zone usually has one **primary name server** and one **secondary name server**. The domain name of the secondary name server may be outside its zone for reliability.
- **Root name server**
  - There are 13 root name server globally
  - used when local name server cannot resolve a domain name
  - 每个root name server有一个IP address, 但是实际上有cluster of servers behind it, 它们共用一个IP address. (anycast IP space)

Process To Resolving A Domain Name

- Firstly DNS protocol run on UDP port 53, if data lost, run on TCP



- Iterative query (red)
- Recursive query (blue)
- this process will cause a lot of network traffic load!

- **Caching**
  - Once a DNS name server/local computer known a mapping, it cache the mapping in its local memory.
  - Cache entities discard when timeout

DNS Software

- DNS server software
  - BIND
  - djbdns
  - Microsoft Domain Name Server
- DNS query toll
  - nslookup
  - dig

SMTP (Simple Mail Transfer Protocol)

Email (Electronic Mail)

- 3 main component
  - User agent
    - create message and send to mail server
  - Mail server - MTA (Mail Transfer Agent)
    - receive massage from user agent, and transfer it to receiver's mail server
  - SMTP
    - protocol used between sender's user agent and sender's mail servers, also used between sender's mail server and receiver's mail server

User Agent

- Basic function:
  - compose
  - report
  - display
  - dispose

- User agent compose:
  - **Envelop**
    - Encapsulation information about transport
      - destination address
      - priority of the email
      - security level
    - Mail server use these information to route
  - **Content**
    - **Header**
      - user agent control info
    - **Body**
      - human-readable message

- Data format (for user agent
  - (RFC 821) Envelop + (RFC 822) Header + Blank line delimiter + Body

- **RFC 822**: format for header
  - 只支持 English text, 如今已经不适用了

Header	Meaning
To:	Email address(es) of primary recipient(s)
Cc:	Email address(es) of secondary recipient(s)
Bcc:	Email address(es) for blind carbon copies
From:	Person or people who created the message
Sender:	Email address of the actual sender
Received:	Line added by each transfer agent along the route
Return-Path:	Can be used to identify a path back to the sender

- **MIME** (Multipurpose Internet Mail Extensions) **RFC 1341**
  - 支持多种语言
  - 支持 image, audio
  - Add 5 headers:

Header	Meaning
MIME-Version:	Identifies the MIME version
Content-Description:	Human-readable string telling what is in the message
Content-Id:	Unique identifier
Content-Transfer-Encoding:	How the body is wrapped for transmission
Content-Type:	Type and format of the content

Email Data Transfer

- **SMTP**
  - based on TCP port 25
  - RFC 821 (HELO) → RFC 2821(EHLO)
  - Basic step:
    1. create readable text command
    2. user agent sent data to its own mail server on port 587
    3. main server route data on port 25
    4. final delivery by using other protocols like POP3 or IMAP

Email Data Delivery

(from receiver's mail server to receiver's user agent)

- POP3 (Post Office Protocol 3)
- IMAP (Internet Massage Access Protocol)

Email Software

- user agent
- mail server
- agent middleware

WWW (World Wide Web)

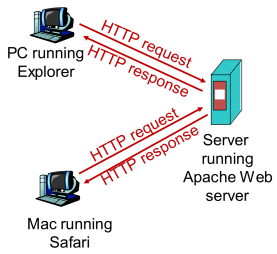
- Web page has a base HTML file and
- Web page also consistent of objects (include HTML file, JPEG image, audio file…)
- Each object is addressed by a URL (Uniform Resource Locator)

`www.someschool.edu/someDept/pic.gif`

host name　　path name

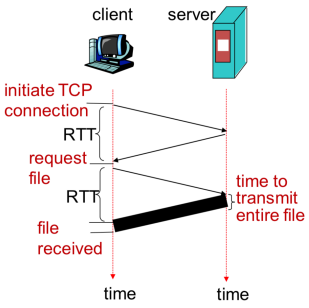
HTTP (Hypertext Transfer Protocol)

- An application layer protocol, build on top of TCP, use TCP port 80
- Has client/server model



Non-Persistent HTTP

- Client 和 server 建立 TCP connection 之后, 只能在这个 connection 中发送1个object
- 如果一个 web page (HTML file) 有10 张图片(image object), 需要建立11个connection
- Total Response Time = 2 Round Trip Time + object transmission time
- 缺点
  - 每次都要新建一个 connection
  - OS will be busy to establish many connections
  - 1 additional RTT delay than persistent HTTP for each object



Persistent HTTP

- Client 和 server 建立 TCP connection 之后, 可以在这个 connection 中发送好多个objects

- Server leaves connection open after sending response. Server terminate a connection if it hasn't been used for some time.
- **Pipelining**: client send a request once it discover a referenced object
- Default HTTP is persistent HTTP with pipelining.

HTTP Request Methods

Method	Description
GET	Request to read a Web page
HEAD	Request to read a Web page's header
PUT	Request to store a Web page (write a new page / resource)
POST	Append to a named resource (e.g., a Web page)
DELETE	Remove the Web page
TRACE	Echo the incoming request
CONNECT	Reserved for future use
OPTIONS	Query certain options

Cookies

- Web is stateless (no user information remain after connection terminated)
- Cookies are small info (<4KB) store on client/server computer, and be reused (RFC 2109)
- 5 field:
  - domain: the domain name of web page that the user visited
  - path: which path will use the cookies
  - content: user info
  - expiry
  - security
- 当一个用户用一个 browser 第一次访问一个 domain name, web server 会创建一个 cookie ID, store the ID at server database, 并且告知 browser 这个 ID 是多少. 这个 browser 以后每次访问这个 domain name 都会带上此 ID. Server will perform cookie-specific action
- 优点
  - Authorization: stay log in
  - Shopping cart
  - Recommendation
  - User session state: (eg. Email)
- Cause problem of privacy, can use it to learn user's behavior.

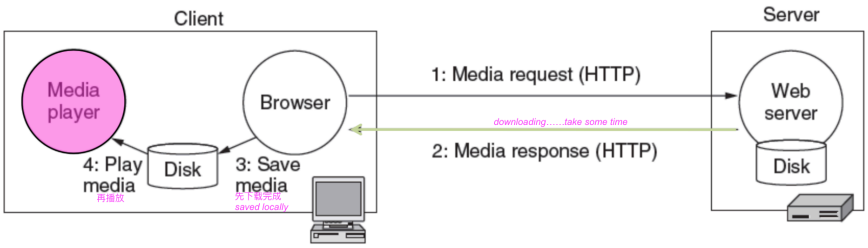
Web Cache (Proxy Server)

- Proxy server has a cache stored some objects, it may satisfy client's request without using the origin server.
- Client browser request a web to proxy server. If the proxy server (cache) has the objects, it will sent the object directly to client browser. If the cache do not has, it will request to the origin server and then transfer the object to client browser.
- Cache act as both client and browser
- Cache is typically installed by ISP
- 优点
  - reduce response time
  - reduce traffic on origin server

Multimedia Network

- Multimedia network transfer multiple type of data, include some large object like video and audio. Video and audio dominate the traffic load right now
- Required higher bandwidth and higher QoS (eg. delay sensitive)
- Need separate **multimedia server** from (text-only) web server. Streaming service provider are often separated and highly specialized (compare to traditional server host)

Basic Model To (Download) Multimedia Via Web



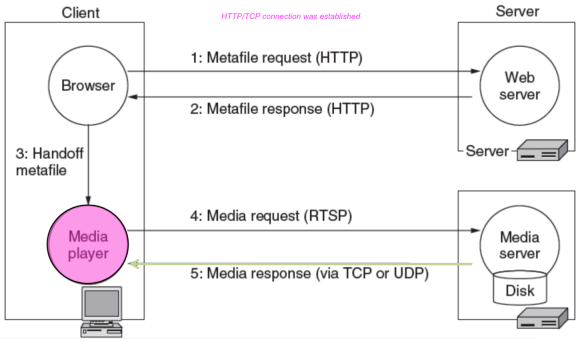
- 完全下载→本地储存→开始播放
- Too basic, not used in real world
- 缺点
  - have to transmit the entire large file (may take a long time), then be able to have a look of the content (do not scale, cannot deal with huge file)
  - assume point-to-point media distribution model rather that point-to-multipoint (broadcast) media distribution model (eg. used in live video直播)

Protocols Used In Multimedia Network

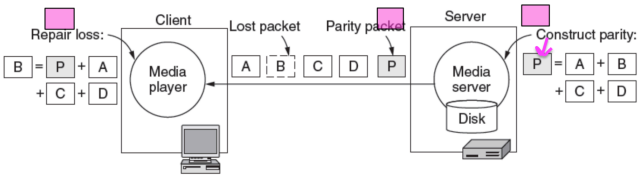
- Transport protocol
  - **TCP**
  - **UDP**
- Open protocol
  - **HTTP**
    - used in on-demand video (eg. YouTube, video stored in YouTube server)
    - based on TCP
  - **RTP** (Real-time Transport Protocol)
    - used in 直播live video
    - based on UDP
  - **RTSP** (Real Time Streaming protocol)
    - for flow control (start and stop flow)
    - based on TCP
  - **MPEG-4** (ISO)
- Closed protocol
  - Real Network's RealAudio
  - Microsoft's Windos Media
  - Apple's QuickTime

Media Playback Software

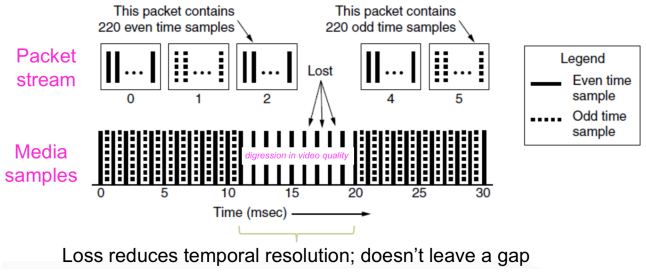
- 4 main task
  - Manage user interface
    - eg. volume, next, playback
    - ↓↓↓request to web server→request to media server



- Handle transmission error with transport protocol
  - error is likely to occur using RTP/UDP (no retransmission). Playback should manage them gracefully.
  - Methods
    - **Use reliable protocol** (eg. TCP)
      - fix all errors
      - but increase jitter significantly
    - **Add FEC** (Forward Error Correction)
      - eg. parity packet
      - fix most error
      - but increase overhead, increase complexity to decode, increase jitter

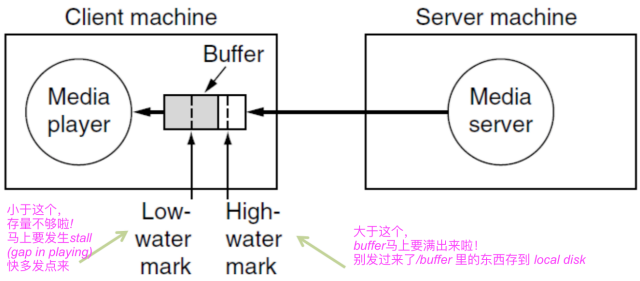


    - **Interleave media**
      - mask most error, will not leave a gap in playing
      - but significantly increase complexity to decode and significantly increase jitter, and will have digression in video quality



Loss reduces temporal resolution; doesn't leave a gap

- Decompress 解压 media file
  - server 发送过来的可能是compressed文件
- Eliminator jitter
  - has small buffer: quick to start playback but sensitive to jitter/delay
  - has large buffer: delay at the start of play but less sensitive to jitter/delay



Real Time Streaming (RTSP)

- Method that client used to control (start and stop) the flow of media streaming
- Defined in RFC 2326
- RTSP command is sent by client to server

Command	Server action
DESCRIBE	List media parameters
SETUP	Establish a logical channel between the player and the server
PLAY	Start sending data to the client
RECORD	Start accepting data from the client
PAUSE	Temporarily stop sending data
TEARDOWN	Release the logical channel

ADC (Analog-To-Digital Converter)

- ADC produce digital audio from a microphone
- Telephone: take 8000 8-bit samples per second
- Computer: will have better quality

Audio Compression

- **Frequency masking**
- **Temporal masking**

Image Compression

- Lossy compression
  - **JPEG** (Joint Photographic Experts Group)
    - compression ratio about 20:1
    - symmetric, encoding and decoding take same time
- Lossless compression

Video Compression

- **MPEG** (Motion Picture Experts Group)
  - MPEC can compress video and audio together
  - Evolutions
    - MPEG-1: VCR quality 40:1
    - MPEG-2: broadcast quality 200:1
    - MPEG-4: DVD quality 1200:1

VoIP (Voice Over IP)

Conventional phone network (**PSTN**, Public Switch Telephone Network) become insufficient.And data networks developed fast. People start to provide phone services based on data network.

VoIP Benefits

- Consolidated infrastructure
- Financial saving
- Flexible infrastructure
- Mature standards based on voice and data

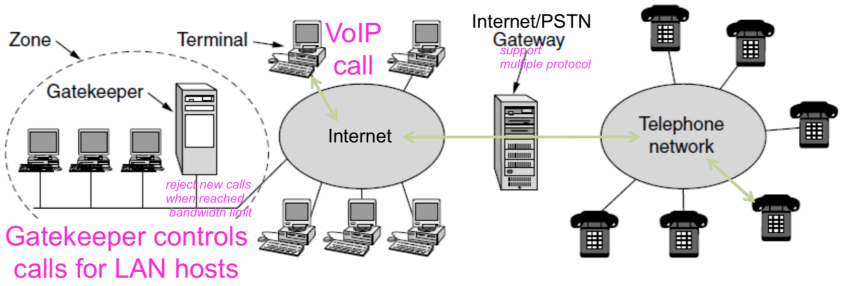
VoIP Technologies

- 3 distinct model
  - infrastructural (PSTN/PABX integration)
  - virtual (media gateway, virtual directory)
  - value-added (voice mail)
- Other protocols
  - **SGCP** (Simple Gateway Control Protocol)
  - **SIP** (Session Initiation Protocol)
  - **H.323**

VoIP Protocols

H.323

- Guideline that support call between **Internet computer** and **PSTN phone**. It involved multiple protocols.



- H.232 protocol stack

Audio	Video	Control			
G.7xx	H.26x	maintain quality of the call, congestion control RTCP	talk to gatekeeper registion H.225 (RAS)	call establishment and termination Q.931 (Signaling)	H.245 (Call Control) control flow, bitrate, compression method
RTP					
UDP				TCP	
IP					
Link layer protocol					
Physical layer protocol					

SIP (Session Initiation Protocol)

- A protocol used to **setup** and **terminate** call session
- 功能
  - callee location
  - callee capability
  - call setup
  - call termination
- Addressing
  - URL type schema (can contain IPv4/IPv6 address or actual phone number)
- SIP methods:

Method	Description
INVITE	Request initiation of a session
ACK	Confirm that a session has been initiated
BYE	Request termination of a session
OPTIONS	Query a host about its capabilities
CANCEL	Cancel a pending request
REGISTER	Inform a redirection server about the user's current location

- How is SIP working process?