Cloud Computing

Stony Brook CSE 356

Author: Michael Ferdman and co.

Institute: Stony Brook University

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Go Seawolves!

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Preface

This is a collaboratively edited collection of notes from the CSE356: Cloud Computing course from the Department of Computer Science at Stony Brook University.

Chapter 1
Cloud Computing Basics

Topics

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- ❑ Server Hardware
- ❑ IP and NAT
- ❑ IaaS
- ❑ Security Groups

1.1 Servers and Clients

Definition 1.1. Server

A server is a computer/software that processes requests (i.e., receives data from a client or another server) and delivers data based on those requests. ♣

Definition 1.2. Client

A Client is a piece of computer hardware or software that accesses a service made available by a server. ♣

1.2 Server Hardware

Server hardware runs a piece of software called a ’server’. Usually dedicated machines designed to run 24/7, because if it’s powered down then access is gone. Nowadays, bigger companies are able to host backups in various data centers to provide for all possible contingencies.

It used to work as follows: designate space in a closet put a machine in plug in a network cable Nowadays, we have more secure and reliable rooms called datacenters but they are prohibitively expensive for individuals.

To overcome this, we have the “cloud” computing model, where a large service provider builds and maintains the datacenter, including purchasing the server hardware, and handles the networking. then the service provider rents out server hardware to organizations that want to host online services, deciding pricing on the amount of resources used (and for how much time they are used).

economical model for small organizations, because to start out they get “limitless” cloud infrastructure without CapEx. maybe good for large organizations too because OpEx of datacenter is high and requires expertise (that organizations may just be willing to pay for/rent instead of running themselves).

The way servers are stored in datacenters is by providing server racks (which originated from amplifier racks) to hold the servers in a compact space. The height of these servers would typically be described in U units in order to help with determining how many servers could fit in specified server racks.

1.3 IP and Network Address Translation

IPv4 is the old protocol (used to identify devices on a network), which is comprised of 32-bits. It is currently full, so there are two current alternatives:

Definition 1.3. IPv6

The newest protocol, IPv6 is made up of 128-bits. ♣

Definition 1.4. NAT

NAT maps a single IP address to a local network. This allow a single IP address to represent a whole entire network from outsiders and aid in security ♣

Public IPv4 address are separated into several different classes:

- Class A Addresses
  - default subnet mask: 255.0.0.0
  - Assigns first byte if IPv4 as the network address
  - Last 3 bytes are used for host addresses
- Class B Addresses
  - default subnet mask: 255.255.0.0
  - Assigns first 2 bytes if IPv4 as the network address
  - Last 2 bytes are used for host addresses
- Class C Addresses
  - default subnet mask: 255.255.255.0
  - Assigns first 3 byte if IPv4 as the network address
  - Last byte are used for host addresses
- Class D & E Addresses
  - default subnet mask: Reserved for Multicasting
  - Address with the first byte of 224 - 255 are reserved for Class D & E
  - Class D (244-239) are used for multi-cast addresses
  - Class E (240-255) are used for scientific purposes

IPv4 uses broadcast very prolifically, which means communication within a network can potentially be clogged down by broadcast hell since all machines can't communicate thru the wires simultaneously.

Routers, switches and hubs were created to alleviate this issue.

Routers will drop any broadcasts if it does not need an machine in its vicinity

The benefits of IPv6 other than more addresses:

- More Efficient Routing
  - IPv6 reduces the size of routing tables and makes routing more efficient and hierarchical. IPv6 allows ISPs to aggregate the prefixes of their customers' networks into a single prefix and announce this one prefix to the IPv6 Internet. In addition, in IPv6 networks, fragmentation is handled by the source device, rather than the router, using a protocol for discovery of the path's maximum transmission unit (MTU).
- More Efficient Packet Processing
  - IPv6's simplified packet header makes packet processing more efficient. Compared with IPv4, IPv6 contains no IP-level checksum, so the checksum does not need to be recalculated at every router hop. Getting rid of the IP-level checksum was possible because most link-layer technologies already contain checksum and error-control capabilities. In addition, most transport layers, which handle end-to-end connectivity, have a checksum that enables error detection.
- Directed Data Flows
  - IPv6 supports multicast rather than broadcast. Multicast allows bandwidth-intensive packet flows (like multimedia streams) to be sent to multiple destinations simultaneously, saving network bandwidth. Disinterested hosts no longer must process broadcast packets. In addition, the IPv6 header has a new field, named Flow Label, that can identify packets belonging to the same flow.
- Simplified Network Configuration
  - Address auto-configuration (address assignment) is built in to IPv6. A router will send the prefix of the local link in its router advertisements. A host can generate its own IP address by appending its link-layer (MAC) address, converted into Extended Universal Identifier (EUI) 64-bit format, to the 64 bits of the local link prefix.
- Support For New Services
  - By eliminating Network Address Translation (NAT), true end-to-end connectivity at the IP layer is restored, enabling new and valuable services. Peer-to-peer networks are easier to create and maintain, and services such as VoIP and Quality of Service (QoS) become more robust.
- Security
  - IPSec, which provides confidentiality, authentication and data integrity, is baked into in IPv6. Because of their potential to carry malware, IPv4 ICMP packets are often blocked by corporate firewalls, but ICMPv6, the implementation of the Internet Control Message Protocol for IPv6, may be permitted because IPSec can be applied to the ICMPv6 packets.

Definition 1.5. NAT

Network address translation (NAT) is a method of remapping one IP address space into another by modifying network address information in the IP header of packets while they are in transit across a traffic routing device. ♣

Definition 1.6. SNAT

Source NAT ♣

Definition 1.7. DNAT

Destination NAT ♣

NAT is one of the ways, humans have tried to circumvent the very limited public IPv4 address available. North American pool was already depleted on September 24, 2015.

NAT uses "private" address ranges, allowing multiple LANs all connected to the same WAN to coexist, because all public internet routers are configured to drop packets with private IP address.

Note *ZeroTier is a convenient free/low-cost VPN solution.*

- *http://ifconfig.co/ is a convenient service to figure out one's own IP. Run it from the Linux command line with* `# curl ifconfig.co`*.*
- *To check if two machines are on the same network you need the ip address and netmask of each machine. You would take the logical AND of the IP address and netmask for both machines. Then compare that value for the two machines. If those values are the same, then they're on the same network.*

1.4 Infrastructure as a Service (IaaS)

Definition 1.8. IaaS

Infrastructure as a service (IaaS) are online services that provide high-level APIs used to dereference various low-level details of underlying network infrastructure like physical computing resources, location, data partitioning, scaling, security, backup etc. A hypervisor, such as Xen, Oracle VirtualBox, Oracle VM, KVM, VMware ESX/ESXi, or Hyper-V, LXD, runs the virtual machines as guests. Pools of hypervisors within the cloud operational system can support large numbers of virtual machines and the ability to scale services up and down according to customers' varying requirements. ♣

Definition 1.9. "Running X on the cloud"

Running X in someone's data center on machines owned by else, and the customers are renting these machines ♣

Origins:

- People used to have servers under their beds.

- Moved to closets to protect them, then cooled with CRAC (computer room air conditioner)
- People starting renting other peoples closets + using their electricity
- These closets got bigger (Stadium sized)
- The "closets" got inconvenient: people would be coming in and out too often
- People eventually starting owning these "closets" AND the servers inside, and renting out use of the servers themselves

Examples:

- Amazon EC2
- Google Cloud Platform
- Microsoft Azure
- Rackspace Managed Cloud

Definition 1.10. Public Cloud

Public cloud is a pay-per-usage model where infrastructure is given on typically shared hardware. The advantage of public cloud is that companies do not have to worry about having to purchase, maintain, or manage onsite hardware – the cloud service provider is responsible for that. ♣

Definition 1.11. Private Cloud

Private cloud is a model where services are provided by private infrastructure (hardware, storage, network), which is managed by internal resources (the owning company). The main advantage of a private cloud is that the managing company maintains a greater control over the environment and management of resources. ♣

Definition 1.12. Party Line

A party line was used in an earlier time for cloud providers. A party line was a group of servers that were all provided access to the internet on one shared network. These servers would belong to multiple organizations or companies and provided a way for all the servers to access the internet. However, this posed a security issue because all of the traffic on the network was visible to all the other servers on the network. Cloud providers remedied this issue by giving each organization their own private network and having a gateway for that network that connected to the internet. ♣

1.5 Security Groups

Security groups are a way of filtering traffic coming in and out of an instance. More specifically (like in our OpenStack case), security groups are a set of rules that allow you to specify what protocol, port range, source, and direction (inbound/outbound) packets can pass through. If there is no rule that matches a particular packet, then it will be dropped.

Chapter 2

Online Services

Topics

- ❑ Web Development
- ❑ HTTP protocol (GET, POST)
- ❑ URLs and URIs
- ❑ SOAP/WSDL/REST
- ❑ JSON
- ❑ WebSockets

2.1 Web Development Basics

Typically files placed on a server, requested by client.

- HTML(+Images) for content
- CSS (+Images) for styling
- Javascript for client-side code

Images for content vs for styling - ALT parameter:

- In the old days, many websites were designed to be simple, unresponsive static pages. Many html websites were made using table tags. Image Maps were used for hyperlinking the images. There was no dynamic content on the webpage Used to be sliced images and tables Markup used for presentation, difficult to create and edit New way: Blueprint, Boostrap, Material (used to pick a target width, now "responsive" design) Now: Table tags not as heavily used in modern day webpages. CSS files are now used to separate content and layout. Lots of div tags are used now but it still beats tables. Today there are many predefined css layouts and frameworks such as Bootstrap, Blueprint, and Pure.css

Definition 2.1. Responsive Design

Modern day websites adapt to the viewport of the device and adjust the layout accordingly, which is called Responsive Design. ♣

dynamic web services:

technique that generates the content on the fly, typically from templates

2.1.1 HTTP History Overview

- 1989 - Proposal of World Wide Web project. -Tim Berners-Lee and his research team at CERN -Only GET and HTML

- 1991 - HTTP V0.9 - First documented version of HTTP
- 1996 - HTTP V1.0 - Officially published in RFC 1945 -Adds POST and HEAD methods
- 1997 - HTTP V1.1 - Officially published in RFC 2068 -Adds PUT and DELETE methods -Updated in 1999 in RFC 2616 -Updated again in 2014 in 7230
- 2015 - HTTP V2 - Officially published in RFC 7540 Anecdotally, 1.1 still seems the most common version in use. Most browsers and servers support HTTP 1.1 and 2
- Currently, there is work on HTTP/3. -Will operate over UDP instead of TCP.

2.2 HTTP Protocol

The HTTP(Hyper Text Transfer Protocol) is the foundation of any data exchange between a web client and a web server. Terribly inefficient protocol, but convenient because it's human readable.

2.2.1 Web Page Composition

- web page consists of objects
- object can be HTML file, JPEG image, Java applet, audio file,...
- web page consists of base HTML-file which includes several referenced objects
- each object is addressable by a Uniform Resource Locator URL, e.g.,

URL/URI

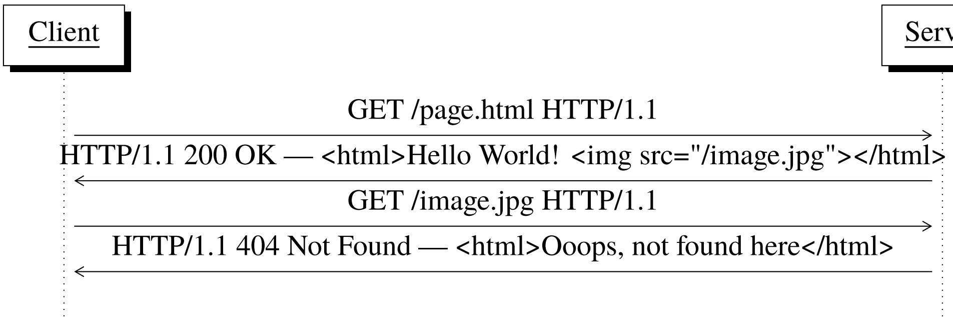
- A URI is an identifier (Uniform Resource Identifier) of a specific resource. Like a specific car, or book, or website.
- A URL (Uniform Resource Locator) is an identifier that also tells you how to access it. , such as https, ftp, etc.âĂŤlike a specific car located at a specific address.
- If the protocol (https, ftp, etc.) is either present or implied for a domain being discussed, itâĂŹs a URL, and thatâĂŹs the label you should use even though itâĂŹs also a URI.

HTTP Protocol

Web browsers and Web servers communicate mainly via the HTTP protocol. HTTP stands for the Hyper Text Transfer Protocol The client (browser) starts it off by sending the server a command such as GET or POST. The server then sends a response back with a status code like "200 OK". HTTP supports multiple parameters such as "Host" which stores the domain name the site. It also supports cookies.

Note *Lots of these parameters violate your privacy.*

Note *Use the* Network *tab in your web browser's* Web Developer Tools *to examine HTTP requests and responses to the server.*


Client
Server
GET /page.html HTTP/1.1
HTTP/1.1 200 OK — <html>Hello World! <img src="/image.jpg"></html>
GET /image.jpg HTTP/1.1
HTTP/1.1 404 Not Found — <html>Ooops, not found here</html>

```
GET /courses/cse356-f19/ HTTP/1.1
Host: compas.cs.stonybrook.edu
Connection: keep-alive
Cache-Control: max-age=0
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537...
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,...
Referer: https://compas.cs.stonybrook.edu/wordpress/wp-admin/
Accept-Encoding: gzip, deflate, br
Accept-Language: en-US,en;q=0.9
```

```
HTTP/1.1 200 OK
Server: nginx
Date: Sat, 31 Aug 2019 21:02:14 GMT
Content-Type: text/html; charset=UTF-8
Transfer-Encoding: chunked
Connection: keep-alive
Keep-Alive: timeout=20
Vary: Accept-Encoding,Cookie
Expires: Wed, 11 Jan 1984 05:00:00 GMT
Cache-Control: no-cache, must-revalidate, max-age=0
Content-Encoding: gzip
```

So when a client makes a request for a webpage, the server finds that HTML page given by the URL. The server sends the HTML file back, and the client receives it. Based on the HTML file, the server will make more requests for CSS/JS files, which go through the same workflow.

HTTP Response Codes

In general, HTTP response codes all fall under the following numbers:

- 1xx Informational (Continue, Processing, ...)
- 2xx Success (OK, Created, ...)
- 3xx Redirection (Page Moved, Redirect, ...)
- 4xx Client Error (Bad Request, Unauthorized, ...)
- 5xx Server Error (Service Unavailable, HTTP Version not supported, ...)

Common HTTP Response Codes are:

- 200 (OK success)
- 404 (Page Not Found)
- 307 (Temporary Redirect message)

GET and POST HTTP requests

POST requests are basically the same as GET requests, however POST requests can send additional information not visible in the URL.

This is a way to send sensitive information,like password, SSN,etc. Sending data using the URL is not secure. In addition, the things that actually distinguish the POST and Get request is that POST has a request body, which is the place to put the data you want to send to the server.

2.2.2 HTTP Connection Overview

uses TCP:

- client initiates TCP connection (creates socket) to server, port 80
- server accepts TCP connection from client
- HTTP messages (applicationlayer 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

aside protocols that maintain "state" are complex!

- past history (state) must be maintained
- if server/client crashes, their views of "state" may be inconsistent, must be reconciled

2.2.3 HTTP connections

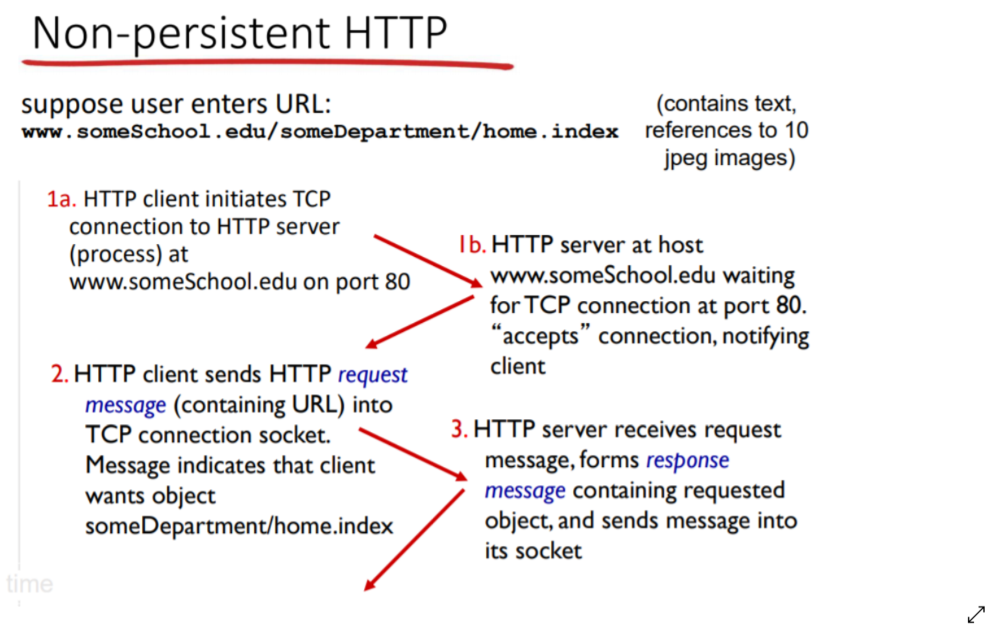
non-persistent HTTP

- at most one object sent over TCP connection, connection then closed
- downloading multiple objects required multiple connections

persistent HTTP

- multiple objects can be sent over single TCP connection between client, server

2.2.4 None Persistence Http



Non-persistent HTTP

suppose user enters URL:
`www.someSchool.edu/someDepartment/home.index`

(contains text, references to 10 jpeg images)

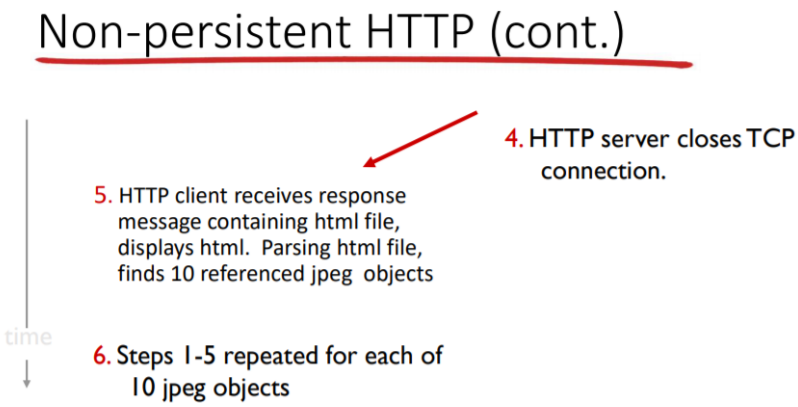
1a. HTTP client initiates TCP connection to HTTP server (process) at www.someSchool.edu on port 80

1b. HTTP server at host www.someSchool.edu waiting for TCP connection at port 80. “accepts” connection, notifying client

2. HTTP client sends HTTP *request message* (containing URL) into TCP connection socket. Message indicates that client wants object someDepartment/home.index

3. HTTP server receives request message, forms *response message* containing requested object, and sends message into its socket

Figure 2.1: process step one



Non-persistent HTTP (cont.)

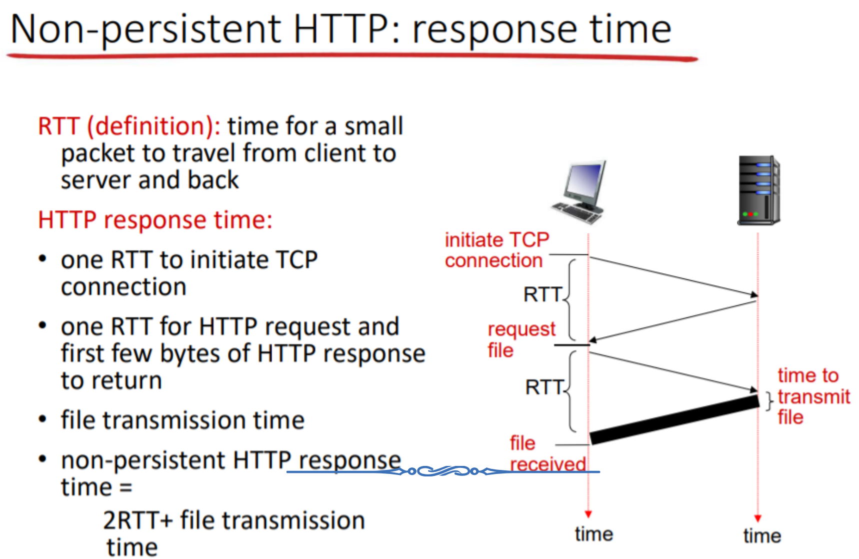
4. HTTP server closes TCP connection.

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

Figure 2.2: process step two

None Persistence Http: Response Time



Non-persistent HTTP: response time

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

HTTP response time:

- 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

2.2.5 Persistent HTTP VS Non-Persistent HTTP

Non-persistent HTTP issues:

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

Persistent HTTP

- 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, plus one RTT to start the connection, which you can also see in the Non-persistent http section above.

It seems that persistent HTTP is better than Non-persistent which is not true. The combination of the two will be the best. Example will show in the next subsection: Web Applications

2.2.6 Web Applications

Web Browsers:

- Netscape Navigator, Internet Explorer,
- Firefox, Chrome,
- Opera, Edge, Safari
- Lynx (a text-based browswer)

Web Servers

- Apache
- Nginx
- Microsoft Internet Information Server

2.2.7 N ways to make the Web Applications faster

- 1.CDN (CDN makes the request more efficient by sending the request to the closest server for the client)
- 2.Proxy (A server that received the request and forward to the root server, if it can't serve the request itself, which means it can't find the page in its cache)
- 3.Local server (server that host in your local private network), this is the fastest server, because the connection to the public network have a bottleneck(Speed limit for the network), but local servers have a much higher limit, but it may not have all the thing you want. But this is best we can do.
- 4. Using persistent HTTP: total RTT will be: N+1 , where N is the number of reference objects it needs.

- 5.Using parallel Non-Persistent HTTP/without pipelined: Nowadays, normally a browser can open 10 TCP at in the same time. So it will be 2 RTT, if there are 10 object.
- 6. Using pipeline,so we can send everything in One RTT ideally. However, this may not be the choice, so we compress the object and sends a portion together in one response.
- 7. Browser cache the object. This may have different cache strategy in different browsers.

In conclusion, we can use parallel persistent HTTP + pipelining and compressing to get the object more faster. Using Web caching to decrease the number of time we need to send the request to server. Using CDN + Proxy + Local server to handle the request much faster and efficient and robust.

	GET	POST
Restrictions	Only ASCII characters allowed. Has limited info it can send	Binary data allowed
Security	Less secure since data is in URL	More secure. Not stored in browser history or logs
Usability	Not for sensitive information	Used when sending passwords or other sensitive information.
Visibility	Visible to everyone (in address bar/URL)	Not displayed in address bar/URL
Cached	Can be cached	Not cached

REST

Traditional web - full page reload, mostly owner-generated content New world: lots of small requests, interaction within a page, mostly user-generated content A “page” dynamically fetches content pieces to incorporate into view Extends to little things like gradual load of content while typing (google instant) or scrolling (facebook, google image search - “progressive scroll” or “infinite scroll”.)

At first, people tried to get JS to fetch small pieces of html from servers and put it somewhere on the page. The problem however was that the server and client were still exchanging html only. The client did not have control of the representation of the data it received and it could only then pass the resulting html to a certain a part of the page.

Definition 2.2. AJAX

Asynchronous Javascript and XML (AJAX) is a technique which allows browsers to make asynchronous requests. What this means is that server requests are non-blocking, and code will continue running until the request comes back, in which a callback will be called. ♣

XML-RPC... SOAP... were attempts at creating a standard of requesting content from servers. Used XML on both the server and the client. The server would have to parse the request, send the data in an XML format and have the client parse the response. This failed initially. So WSDL was created as an extension of soap. WSDL allowed the programmer to know what function calls were available on the server. Now, SOAP is successfully used in large industries.

REST = Representational State Transfer People came up with this to get away from the XML syntax. The mechanism is simple: The client sends a request to the server and the server responds back with raw data. Implemented via HTTP protocol verbs. Examples: GET, POST, PUT, DELETE...

Definition 2.3. RESTful

Services following REST approach are called RESTful services. ♣

JSON = Javascript Object Notation The lack of structure in rest made people realize that some structure is good as a response they came up with JSON as an alternative to XML. It’s advantages include it being a very easy to learn and to write. Also since it is using Javascript, most modern browsers can natively parse JSON.

Note *jQuery, vue.js*

COMET

COMET is a model where a HTTP connection is held between the client and server. The connection is unidirectional – the server can only send data to the client. The main problem with comet is that the client has to open new connections if it wants to send the server more information. The upside is that the server only needs to maintain one connection instead of opening multiple to send data over time, which is less expensive.

Note *Comet was named after a dish soap brand just like Ajax...*

WebSockets

Note *Traditional HTTP request Client sends a request and wait Server does not respond until new data is available Server sends back data Client receives the data and send another request*

COMET - problem: web browsers limit number of connections Work around: domain sharding Since limitation is based on domain name, just use multiple domain names to open more connections + one way

Want two way communication between client and server - WebSockets Provides a persistent connection and both can start sending data

2.3 Cookies and Web Sessions

Data about the user is stored on server A session id is sent to client and stored on client Client passes session id to server Server uses this id to get data from the database Persist through user's interaction with the website Example: Google Docs What file was being edited where the cursor was

Definition 2.4. Cookies

Small files sent from the server to be stored on client side Used to track the client's activities and remember stateful information First visit? Logged-in user? Updated on every request ♣

Cookies can be sent to the server by setting the Set-Cookie HTTP Response header. This will alleviate the problem of having to write convoluted GET requests with tons of parameters in the URL. Instead, we can put all the relevant data in a cookie.

Typically when cookies are created by the server, the information is cryptographically signed. This prevents the client from tampering with the cookie, because the server will notice the change in the signature and will ignore all the information sent if the cookie is invalid.

Definition 2.5. JWT

JSON Web Token (JWT) is a standard that defines a way to transmit information between parties using a JSON object. The JWT token structure is xxxxx.yyyyy.zzzzz, which is the header, payload, and signature (respectively), separated by a dot. ♣

An example of JWT:

1. When a user logs in, a JWT Token will be created server-side and saved locally in the client (cookies are also an alternative to JWT).
2. Whenever the user wants to access a resource, the user will send the JWT token back to the server to authenticate (the token usually goes in the header).

One of the differences between JWT and Cookies is that the JWT mechanism is stateless – the server never stores user state. With cookies, the user's session must persist in the server.

We can actually store JWT tokens in cookies – there are many implementations available on their website for most popular languages.

Server Handling of Cookies

The server typically stores cookies in a database (see the Database section). Session information and related data gets put in a database, which the server will reference when the client sends information back (for both information selection and updating).

Web Sessions

Web sessions were created to prevent malicious users from manipulating cookies. A web session is created on the server that holds a history of past connections with the client. A session is fetched by a hashed session ID which is stored on the user's client as a cookie. A single user can have multiple sessions stored on the server or even share sessions between processes. Typically modern browsers will share sessions between tabs (unless the user decides to go incognito

If you use different browser(Edge,Chrome,Firefox) into login to blackboard, each of the browser will open a session. If you only use one of them and open multiple tab, all the tab will have the same section, every time the session gets update. It will synchronize other tab too.

2.4 Browser Caches and Request Ordering

Caching / HEAD requests Performance impact due to caches and request ordering (js serialization, css FOUC) GET vs PUT implications on caches.

Developer tools - Waterfall

2.5 Domain Name System (DNS)

Definition 2.6. Domain Name System(DNS)

The Domain Name System translates domain names to IPs addresses. For example, to go to Stony Brook's website, rather than typing out the IP (http://129.49.2.176), DNS allows you to simply use http:///www.stonybrook.edu. ♣

DNS is convenient for human beings, since it's easier to remember a URL composed of words than an IP address. The process of getting a IP address from a domain name is called DNS resolution (also known as DNS lookup).

Definition 2.7. DNS Resolution/DNS Lookup

DNS resolution is the process of translating an IP address to a domain name, or vice-versa. Also known as DNS lookup. ♣

Names can be pointed to new IP if server changed. DNS records primarily A (and AAAA), but also has other helpful ones like CNAME and MX.

DNS can be fast because of lots of caching. (Explain how DNS caching works) Problems with caching - updates are slow (minimum 10 minutes typically enforced by public DNS servers).

DNS can also be used for geographic load balancing across datacenters.

2.6 Content Delivery Network (CDN)

CDNs are used to reduce round trip time, usually used by websites with large amounts of traffic.

Definition 2.8. Round-trip time (RTT)

The amount of time it takes in milliseconds for a network request to get from its starting point to its end point. For example, the amount of time it takes for a response to be received by a client from the server after sending a request. ♣

The closer a server is to a client the shorter the RTT will be, and vice-versa. A CDN will typically consist of a network of servers in various geographical locations, where a website's data would be copied to each of these servers. The website's main server would then utilize DNS to redirect each client to the CDN server that would provided the shortest RTT, which is usually the closest server geographically.

Chapter 3
Virtualization

Topics

❑ Virtualization

The key technology behind the cloud Ironically, avoided by the “biggest” cloud systems Software-only virtualization VMware+qemu, long history of performance challenges Xen “paravirtualization” overcame hardware limitations

Hardware-assisted virtualization (for OS+Arch savvy: fix CPU bugs,nested page tables,SR-IOV,IOMMU) KVM+qemu emerged (and became adopted by everyone) Although qemu is really not a good fit... Resurgence of paravirtualization (for performance) On most-often used components: NIC and disk

```
char * mem = malloc[4gb]
while true {
    run(inst)
}
run(inst) {
    switch () {
        add: (do x using registers)
        sub: (do y using registers)
        ...
        ld/st
    }
}
```

One of the other problems with emulation in the beginning is that emulating the ADD/SUB commands took many commands on the software (so there was lots of overhead, making it slow) and instances competed for memory

Breakthrough 1: typervisor aka virtual memory monitor (vmm) and virtual machine emulator (vme): look at chunks of assembly instructions, maybe they can be run on physical hardware - if they dont touch memory or registers then no switch statement needed!

Breakthrough 2: another breakthrough: instead of mapping to actual hardware, come up with virtual things! virtual disk! (with virtual driver) These work as an adaptor for the actual hardware? "Xen" came up with this.

Then, Intel came up with "vmenter" "vmexit" instructions. Super fast: can’t even tell you are running in vm most of the time. All vm's are run this way now.

3.1 Virtualized Resources

Definition 3.1. Flavor

A Flavor of virtual machines has a certain amounts of the resources below (VCPU, Memory, Disk).Providers do this in order to simplify the VM selection process. OpenStack (and other provides) actually has flavors for not only different network options, but also memory, compute, storage options.. ♣

- latency - amount of time it takes to transfer data. generally imperceptible, and non-configurable. On the order of ms. Limited by distance (solvable with a CDN) China: 300ms. NYC: 30ms. SBU: 0ms.
- bandwidth - amount of data can be transferred per unit of time (order of 1-100 Gb/s) Typical cloud providers will give you 10 GB/s (or maybe 25). Servers have to have more bandwidth than the client. Not selectable in flavors: peak times = low bandwidth available, non-peak times = high bandwidth available. Torrents and porn can take up infinite bandwidth: providers will charge you for it, instead of throttling the connection
- aggregate transfer - GB/TB. total amount of data transferred. providers will charge you for this
- jitter - the variance in time delay between packets (important for interactive services like Skype – matters less for one way videos)

VCPU

VCPU - Virtual CPU dedicated to the virtual machine This is "virtual" because CPU cores are time shared and not space shared; you can not physical dedicate cores from your machine to the virtual machine and never be able to access them outside your machine. In most case, 1 vCpu implies 1 thread not a actual CPU or a CPU core

Memory

Memory is partitioned from the host machine

Also has the key characteristics of latency (ns), bw (GB/s), and capacity (GB). Nowadays, no one cares about latency and bw because the cpus can't keep up with the memory. We are typically limited by the computing power and bandwidth of the machine. Memory capacity is the most expensive component of a server – it is measured in GB (typically 64 to 256). This is one of the key bottlenecks. ECC memory Error-correcting code memory (ECC memory) is a type of computer data storage that can detect and correct the most common kinds of internal data corruption. ... Most non-ECC memory cannot detect errors although some non-ECC memory with parity support allows detection but not correction.

Disk

Diskspace (Ephemeral vs Block) - Ephemeral - Content is lost once machine is turned off Block - content is persistent but more expensive as a result

Disk Space is partitioned from the host machine

There are two main types of space allocation - Thick provision - you write 0s to all the space you are allocating to make sure you actually have that much space physically - Thin provision - you are given an "OK" (there is no check); once you run out of space, virtual machine freezes until disk space frees up

Reasonable ranges for disks:

	Range	SSD	HDD
Latency	1 to 20ms	1ms	10ms
Bandwidth	100 to 1000MB/s	1GB/s	100MB/s
IOPS	200k	200k	20k
Capacity	4 to 12000GB	1TB	12TB
Capacity/$		10GB/$	33GB/$

Network

There are three main connection networks for a VM. - Direct/Bridge - use your own network card or a physical connection - Virtual Network - doesn't let you connect to the outside world; you can still connect to other virtual machines within your physical machine - NAT (Network Address Translation) - Routers proxy connections from connected devices to servers (that translate source packet) and sends back responses using a lookup table

Server to Server Typically private (different schemes on different providers, Amazon EC2, Digitalocean, Linode, ...) Public IPs Typically NATed (SNAT+DNAT)

3.1.1 VM History

```
int pc;
while(true){
inst fetch(pc)
run(inst)
pc++;
}
run(init){
switch(instr opcode){
   Add: Regst[inst.dest]= Regst[inst.source1] + Regst[inst.source2]
```

```
    sub:
    Imp:
    cmp:
    ld:Regst[inst.dest] = Regst[inst.source]
    st:
}
}
```

In this time the VM is very slow, because emulate one instruction is slower than running on physical hardware. So graduate student in Stanford decided that run instructions that other than LD(load),ST(store) directly using the pysical hardware. So it will be much faster, because those instruction didn't touch the memory,and not affect anything.

however it is not fast enough for people to use. University of Cambridge led by Ian Pratt, a senior lecturer in the Computer Laboratory, and his PhD student Keir Fraser to start the project on Xen.

3.1.2 Server on VM

Many servers are run on the cloud provider's VM, and every new instance has four key features: CPU, memory, disk (OS) and net.
Cloud provider doesn't let you choose those feature directly but the limited types of flavor of a VM.
Ex.
1 CPU 1024M 20G 1T
2 CPU 2G 40G 2T
4 CPU 4G 80G 4T

NET:
Latency - the amount of time to transfer data
Bandwidth - the speed of data transfer per unit time
Aggregate Transfer - the actual amount of data that you transferred on your server

Cloud provider usually doesn't show you their info about heir network since they have "good network" because most of the time you won't be downloading/uploading all the time (except when your server provides torrent and porn services).
DISK:

- HDD
- SSD

HDD Speed and Performance. Solid state drives (SSDs) are faster than conventional hard disk drives (HDDs) and they are also more reliable and use less power. Solid state drives have dramatically faster read and write speeds when compared with hard disk drives.

Definition 3.2. Over-provision

Cloud provider proves more storage than they actually have since most of time you don't use your all of space. ♣

Memory:
Normally, people do talk about latency for memory because it is fast enough to keep up with the CPU. Only people who want to over-clock or have fun, they will try to buy the "fast" memory.
bandwidth: GB/S
capacity:64GB-256GB, host:15 instance, some of the memory will be left for other software application that runs on the server.If you run out the memory in the server(over-provision/oversubscribe),it will write to the wrong file.
The memory you didn't use(all of them will be use as cache), the OS will be use as a cache to give you more convenient experience. So frequently use file will be cache inside it.

CPU:A chip that fits in your computer to run program.

3.2 Oversubscription of Resources

Resources on a VM (cont'd)

Oversubscription/Overprovision - “faking” more memory than you have. Example: allocating twenty virtual machines with 2gb RAM each when you only have 32gb of RAM on your physical machine) - Can cause problems when physical machine runs out of memory - Machine pages to disk when out of physical memory. This can cause massive slowdowns since performance on disk is very slow

3.3 VM Features

Lots of cool features
“Throw-away” VMs
Suspend/Resume
Checkpoint/Restore
Clone
Migrate (stopped or live)
Cloud “stacks”
EC2 - Amazon's proprietary cloud-for-rent (uses Xen)
Google - Google's proprietary (probably uses kvm++)

OpenStack - open-source choice (used by RackSpace)

Lots of smaller competitors (e.g., Eucalyptus, OpenNebula)

Cloud-specific terminology:

There are the terminologies used for Virtual Machines

Instance - a new virtual machine

- Flavor - defines specs such as disk space, memory, etc of virtual machine
- Zone - where the machine starts up
- Image - initial data injected into machine
- Migration - take one instance(disk image file) from one server move to another server
- live migration - slowly copy the data into another instance, and keep track the new data that is writing to the first instance. Then after the that data has been move into second instance. you will start to move the new data that is writing when you do the live migration, and repeat the sam process until all the data is copy to the second instance.

You can upgrades softwares in your image to see if there would be any problem could occur so you can make sure your server won't crash.

Reasons to migrate include cloud providers who want to upgrade their own hardware – they do a live migration, and throw away the old instance.

VM makes it very easy to do migration of your image, cloud provider copies your disk image into another physical host.

Live migration uses double resources while its process, but cloud providers usually make sure only few live migrations are happening at certain time so it won't be an problem.

In practice, large company like Google and Amazon prefer to live migrate its cloud servers

One of the key feature of the VM is that, unlike physical machine, it's easy to increase size of the disk, same thing to memory.

It's hard to downsize your disk, because it is complicated to do that, you need to concatenate the date together, shrink it, and downsize the favor. So cloud provider typically not allow you to do that.

Google and Microsoft use KVM for their cloud instances, while Amazon uses Xen.

linode:

-the biggest fish in the small fish.(cloud provider)

-allow your to resize up and down for your favor.

Digital Ocean:

- does not allow to downsize.

SkySilk:

-the second biggest fish in the small fish.

- throw away data when resizing.

-does not allow you to downsize your favor.

Zone/Jail/Container/Serverless server: Instances are basically resources (disk, memory, net, etc) that runs softwares.

Container restrict the resources on application running inside the container.

Most container are associated with part of the directory tree, and you can't see anything that's outside your container's directory.

Container starts from parent process(init, systemd) which sets up system. Then, it launches all other softwares by forking. Container is easy to use because it's much lighter than VM and can manipulate the container easily. Deleted, add files, and set the limit on how many resources they can use.(CPU,memory,disk,etc).Everything is isolated from each other. You can modify your container from outside of your container root. It is flexible on oversubscription.

Issues of container:

It consumes some of your CPU

It needs a file management -> Docker is one of the solution.

Drawbacks of container

- less secure than VMs.
- Fixed OS and kernel.

Serverless server: Cloud provider names it server-less server, because it is cooler in sounding(dumbest naming):, but in fact they're actually selling you a container. The main advantage of this is that they're cheaper for consumers (pricewise).

Init is a system used to bootstrap the user space and manage user processes.

3.4 Containers

What containers do is restrict the resources (e.g., cpu and memory limit) given to any given container. Typically OSes restrict users from using some amount of memory. The processes and files in the container are limited to itself.

The main advantage of a container is that you can treat them as light-weight VMs, which means you can freely destroy and do whatever you want in them.

Note *Docker is a platform which allows users to host multiple containers in a resource-efficient manner. Kubernetes helps facilitate the deployment and management of such containers. These two services can be used both independently of each other or together.*

3.5 Software development in cloud

Unlike software designing class (CSE 308), this class will do everything pretty much the opposite. Big(O) notation isn't important in cloud software as in a normal development. Scripting language (NodeJs, Python) makes it easy to do thing,because they have a lot of third party plugins and libraries to do most of the things you want. But in the same time it lost its efficiency.
Companies like Facebook, WordPress and still using PHP as their major language to develop new projects.
Perl - please don't read me language
Companies encourage people to finish their tasks ASAP, no matter what languages they use. The result for it is that within a project there might be many languages mixed together. To make different languages work together, you make the function call to become an HTTP request and two parts of the software can communicate. If you're writing JavaScript and needs to use Python, then you can do it by starting a web server in python and accept the HTTP request from JavaScript, and use JSON to pass parameters.In this way, it also makes things easy to maintain, and replaceable. If any part break, other parts still works, if you want to rewrite part of the software you can just rewrite it in a different language. It is also faulted tolerance.
SOA - Server Orientated Architecture(Microservices)

Message broker: allows for communication between microservices through messages

- Every Microservices connected to the message broker, and send the thing to it and declare the type of it. Then message broker will forward it to other Microservices.
- It also can queue up the message and can handle faulted tolerance, and also handle the intensive request.

This way it's easy to add and update a feature you provided
Microservices are running in private ip address and it's very limited so only few people can access for safety concern.

It's easy to get caught up in a multitude of microservices who talk to each other (in an extremely dense graph). Netflix has a good video on it, where they demonstrate how easily it is to do so.

A common message broker is RabbitMQ – it primarily uses the AMQP protocol for messages, but it supports the very popular (and simple) STOMP protocol. HTTP isn't really a messaging protocol, but RabbitMQ still provides support for it.

Message broker normally has a "backup instance" also running in case one that is operating crash, the second one can take care of the work and the user will not feel anything.

3.6 Microservice Application Architecture

Each microservice is independent of each other, so they need to have their own database, which that no one can touch it. So when you need to change anything or rewrite the entire microservice. Everything will still work well, and you don’t need to collaborate with other microservice. So each microservice will hold its own database. To avoid the overhead, you don’t want a bunch of MySql/MongoDB in your instance. They will use (CDBMS) is a database management system to take care of it.

Instead of having states in microservices, the general practice is to use a centralized microservice to maintain the states of the user objects, and keep other microservices stateless.

In order to have a good performance server from low-performance code, there was an easy solution - buy better and more and big instances so it can handle the user’s request. If you need more performance buy more and big server.

Chapter 4

DevOps

4.1 About DevOps

Definition 4.1. DevOps

DevOps is a set of practices that automates the processes between software development and IT teams, in order that they can build, test, and release software faster and more reliably. The concept of DevOps is founded on building a culture of collaboration between teams that historically functioned in relative siloes ♣

- Another horribly abused term, DevOps is essentially a combination of software engineering and system administration.
- Usually used by startups that can't afford sysadmins and DBAs, or testers
- It's true, they can't
- A new kind of developer environment
- Lots of automation
- Code deployment
- Rollback
- No official version numbers or release dates
- Bug fixes and new features are gradually phased into production
- Lots of clever tools
- Containers for "local" development (Vagrant)
- Continuous integration (and delivery)
- Many commits and merges, constant unit testing, frequent code roll-outs
- Jenkins
- Configuration Management

Note *Ansible, Salt, Chef, Puppet (+git)*

Chapter 5
Object Storage

Topics

❑ SQL Databases ❑ NOSQL Databases

5.1 SQL Databases

SQL databases are the traditional approach to databases. They support the SQL query language, which is declarative.

With databases, we typically do not want to expose the database to the public. We want to make sure we never open up a database port to the public, or give it a public IP. Attackers will scan ports like 3306 (MySQL default port) to dig out your data.

Examples of popular databases:

- MySQL: the most popular (free, simple, fast during conception)
- Postgres
- IBM DB2

Advantages of SQL:

- Referential integrity
- Tables of structured data
- No duplicate key,which makes the query much faster and less things to check

Frameworks of SQL:

- Mostly standard: DML/CRUD (INSERT, SELECT, UPDATE, DELETE)
- Slightly standard: Data-definition Language (DDL) (CREATE, ALTER, DROP)
- Non-standard: DCL - determine permissions for various objects (GRANT, REVOKE)

MySQL (still) wildly popular

- Once was fast, but didn't always preserve data
- When you use it for a long time, it is hard to switch to other one for all kind of reason(don't want to pay for other database), like the example that some company still using soap(xml kind),and today we are using JSON in most of the time.
- "It was lacking everything that made databases good"
- Caught up in features (triggers, referential integrity, etc.)
- Lost the performance advantage even on simple cases

5.2 NoSQL Databases

5.2.1 Why use NoSQL?

For cases where tables were constantly being changed (columns being added or updated), it would cause the table to freeze and prevent users from accessing it. The temporary workaround was to just have one column that contained XML or JSON, but at the point at database table started looking like HashMaps (key-value pairs). And that's exactly what NoSQL is.

Examples:

- MongoDB
- CouchDB
- S3
- Riak
- Redis
- HyperDex

NoSQL Traits:

- Schema-less (or mostly so), allows for non-uniformity and iterative development
- None of the cool/advanced SQL features
- Mostly proprietary interfaces
- Simple, typically less efficient (makes it "easier" to scale, more on this later)
- Several categories: key-value, document-storage, column-storage
- All use indexes for fast(er) retrieval
- Typically adapting JSON for storage and queries
- Many adapt HTTP/REST for communication

Chapter 6
Messaging

Topics

- ❑ Message Brokers
- ❑ Brokerless Messaging
- ❑ Efficient Messaging

Simple REST services HTTP as back-end protocol Synchronous Serialization (a.k.a., “RPC”) JSON (pretty wasteful and inefficient, but simple) Protobuf (the Google way) Thrift (the Facebook way, greater language support) Versioning of message format is important Allows upgrading parts of the system

AMQP services Special protocol for messaging Asynchronous Typically requires “broker” software RabbitMQ, Kafka Lots of options “Durable” queues Consumer “Acknowledge” Publisher “Confirm” “Response” messages via “callback” queues Advanced message routing options Typically uses publish/subscribe (pubsub) architecture Can subscribe to specific messages or message types

Note *Thrift, Protobuf*

Note *Robot.txt for not crawling, only google honors it.*

Chapter 7

Scale-Out

7.1 Scale-Out/Scale-Up

Definition 7.1. Scale-Up

Add more hardware, vertical ♣

Pros:

- Possibility to increase CPU/RAM/Storage virtually or physically.
- Single system can serve all your data/work processing needs with additional hardware upgrade being done.
- Minimal cost for upgrade

Cons:

- When you are physically or virtually maxed out with limit, you do not have any other options.
- A crash could cause outages to your business processing jobs

Definition 7.2. Scale-Out

Add more servers, horizontal ♣

Pros:

- Load is distributed to multiple servers
- Even if one server goes down, there are servers to handle the requests or load.
- You can add up more servers or reduce depending on the usage patterns or load.
- Perfect for highly available web application or batch processing operations.

Cons:

- You would need additional hardware /servers to support. This would increase increase infrastructure and maintenance costs.
- You would need to purchase additional licenses for OS or required licensed softwareâĂŹs.

7.2 Consistent Hashing

Definition 7.3. Consistent Hashing

Consistent Hashing is a distributed hashing scheme that operates independently of the number of servers or objects in a distributed hash table by assigning them a position on an abstract circle, or hash ring. This allows servers and objects to scale without affecting the overall system. ♣

7.3 Sharding

- Spread data across multiple servers

- Either client knows the home, or nodes forward request to home

- Increases read/write performance with more shards

- Spread load by horizontal scaling

- - static sharding - "everyone a-m then everyone n-z" creates imbalances. SOLUTION: Hashing

- hashed sharding - simple: hash(key)/numShards. If numShards increases, we have an issue: reassigning shards means needing to re-hash everything. SOLUTION: consistent sharding

- consistent sharding - circle of shards - each shard is responsible for a range of the keys. add or remove –> adjust the key range. replication of shard X is shard X+1 (next shard in the circle). makes copying easier, number of keys = number of slots

7.4 Replication

-Multiple copies of data to increase read performance

-And reliability / fault-tolerance

-Writes always take place on the master

-Choice of master may depend on data

-Systems with multiple masters for data are possible

-data might not be the latest update

-Will eventually consistent but burden to maintain

-automatic fail-over

7.5 Coordinate system

-Master Slave relationship: Master write, slave read

-Write records in binary logs when write to master shard (Ex. MySQL) Then, slaves read from binary log(master), copy to local log, execute queries on log

-SQL uses SQL thread to update DB in many threads without interference and parallel, and uses IO thread to read log from master

-To change master of slaves, set a slave as master and add slaves under it

ORM - Object Relation Mapping, Ex. MySQL, NoSQL

MySQL uses Circular replication to enforce replication from only one other master, avoid time-order conflicts (two server update at same time), no conflict resolution, slow MySQL Replication Delay âĂŞ slow query in master cause delay in slaves Solve Replication Delay - divide into small queries, or delete in slave then delete in master MongoDB manage shards using proxy: detect new requests, send requests to all DB(broadcast), ensure operations are consistent, good to read heavy load, bad to write(have to add shards) MongoDB problem: not load balanced, use Hashing to determine which shard to go to (shard: f(key)%N)

7.6 Other

What if you want to scale MySQL? Master/slave replication Read from slave, write to master master writes to disk and writes to a binary log slave reads the log and performs all the queries itself To add more capacity you, create more slaves Difficult to manage in large scale-out deployments Led to NoSQL (MongoDB, etc.)

Object storage (persistent key value storage) (NoSQL) Sharding and replication out of the box Cassandra, CouchDB, MongoDB, Redis, Riak CAP âĂIJtheoremâĂİ Applies to any system that performs writes Consistency, Availability, Partition tolerance Must choose two of three Partition tolerance: split brain Consistency: Strong, Eventual Disconnected operation and merging conflicts Intra-server transient failure Offline client operation

Consistent hashing Why not simple hashing? H(A) mod N (where N is number of nodes) If a machine is added or disappears, all data must move Nodes organized as a ring Hashes distributed on ring

Distributed Filesystems/Databases Ceph, HDFS, Cassandra

- optimized for larger objects (non-img media such as videos)

- Sharding and replication out-of-the-box. Pretty much needs this for high performance reads and writes for large items

Chapter 8
The CAP Theory

8.1 What does CAP standards for?

C: Consistency - if all replicas have same values
A: Availability - system is available
P: Partition tolerance - If connection within network is lost suddenly, client must still be able to reach any node

Considering all three properties, performance is slow. Can only apply two of the three properties.

8.2 types of commonly used databases

relational database:
AC: MySQL

NoSql:
CP:Cassandra(more CP rather than AP,better performance than MongoDB in medium size application), MongoDB
AP:CouchDB

Cassandra VS MongoDB:
Cassandra is good at storing data and okay at accessing data (ex. facebook use Cassandra to store those posts that nobody reads)

Chapter 9
Distribute file system

9.1 HDFS and Ceph

Definition 9.1. HDFS

Hadoop Distributed File System ♣

Definition 9.2. Ceph

Ceph replicates data and makes it fault-tolerant,[7] using commodity hardware and requiring no specific hardware support. As a result of its design, the system is both self-healing and self-managing, aiming to minimize administration time and other costs. ♣

HDFS and CEPH Allow us to work on partial objects HDFS assumes that files are run inside the same server

CEPH: a bit easier to bring up because the people develop ceph creates many ansible playbooks to deploy ceph.

Cases you want to store large objects:

- Media files such as videos,pictures, musics

- Binary files such as docker images, snapshot, and virtual machine

when to use HDFS

- User has more control, can optimize more, and therefore can make more mistakes
- User knows where the information is
- uses Hadoop scheduler. Take job, run job on the correct instance (user can know where this instance is), then notify the scheduler
- better build in error handling

when to use Ceph

- "Youll never know where your data is. the system will find it out automatically"
- You'll never have the ability to optimize. Ceph cluster is an all-knowing god
- used to be very difficult. first cloud section ever - none succeeded. Now, ansible playbooks!! so easy yay (see below) used for backing storage for VM
- https://github.com/ceph/ceph-ansible

Data locality is a benefit and a burden - HDFS embraces it, Ceph (mostly) abandons it

- Directory/metadata storage - Centralized: Easy, but not easy to scale (HDFS NameNode) - Decentralized: Hard, but effective (CRUSH)

all key-value based database are kinda complicated when they're distributed

Chapter 10
Logs and Timestamp

You only care about logs when there's error on your program, and you want to be able to search from your log. The common practice for people to fix bug in their programs are add more and more print statements, but this is not readable and inefficient. Writing logs is very performance-intensive; it consumes a lot of RAM.

2 things should be in log: What module produces the message, and the severity of the log.

10.1 Log severity levels

- Very Verbose - VVERB
- Verbose - VERB
- inform - INFO
- Warning - WARN
- Debug - DEBUG
- Error - ERROR
- Critical - CRIT
- Fatal - FATAL
- Emergency - EMERG

Note *Severity can be misleading – some people use CRITICAL for application startup*

10.2 Log Rotation

log rotation for handling old logs by compressing or deleting them. So you will not run out of storage.you can set the time to handle your log. If logs are getting too big, you can compress it.

10.3 The importance of timestamp

in linux, syslogd controls what is sent and to where based on '/etc/syslog.config'. Syslogd âĂŞ receive log msgs, write into corresponding file, include Timestamp indicate when event happened Severity: WARN, DEBUG ERROR, INFO, CRIT, FATAL, VVERB, VERB Log rotation: old logs get compressed, deleted, or renamed Some systems categorize the log and write them into different log files based on the severity of the log, so you can look at different logs for

different levels or types of logging.
For example, checking log.error will show you log messages from error, crit and fatal. That is, it will show things more severe than your viewed "log level"

On a scaled out architecture, reading logs becomes much more tedious and difficult. As you read the logs on different machines, you look at the timestamp of the logs to see which logs correlate with each other. However, the timing of each machine may be different from each other.

Synchronizing timestamps across multiple machines

- centralized time - dedicate one machine to being a timer
    - time keeper has to notify all machines what time is it, machines receive the time and set it to their local time
    - latency becomes an issue
- a latency solution - send a ping, get response with latency, local datacenters to minimize latency, send many requests and asynchronously collect response, garbage collector makes app slow
- Software to measure performance: Apache bench, Faban, K6
- If one of the machine is running a little bit faster than the other machines, it will synchronize its timestamp with the source(centralized time) machine by slowing down its time. Moving backwards in time could break a program.
- Every body should run a Network Time Protocol (NTP) service in their instance to synchronize the time.
- Most of the world government runs the NTP server, they are the absolute truth of time. You can't connect directly to them, because you can mount things to attack them.
- normally, people have multiple upper time instance to synchronize the time.
- you want your NTP server to be as close as to you. (ping 0.us.pool.ntp.org)

Definition 10.1. NTP

The Network-Time-Protocol (NTP): A networking protocol for synchronizing clocks between computer systems ♣

Once you have your timestamps synchronized, when you have many machines set up or a randomized load balancer, it becomes too tedious to SSH into each to read the logs. The solution is to centralize your logs into a single location. Create a single machine or micro-service to store all logs so you only have to look at one machine for your logs. Another solution is to use search indexes. Aggregate all logs to one machine on a search index.

- Splunk (Costs money)
- Logstash with Elasticsearch + Kibana (free)
    - Elastic Search : 20min to bring up Elastic Search + 5 weeks to learn Kibana.

    - Search is pretty much build in everything that we use today.
    - Convenient to assign unique ID to each request
    - Pass ID and log it everywhere
    - Many cool visualization tools to search and analyze quickly
    - FTP âĂŞ File transfer protocol
    - Gopher protocol âĂŞ extract web documents stored on web servers, page with everything
    - HTTP âĂŞ client traverse between servers

10.4 Writing Logs

Logs are critical in all deployments

- Troubleshooting of individual events
- Troubleshooting of aggregate events
- Insight into performance and behavior aka analytics

Possible downfalls:

- Variable verbosity requires care
- Too little logs –> cannot trace back to event of interest
- Not enough data to trace security incidents
- Too much logs –> looking for needle in haystack
- Too much data to find things conveniently
- Negative impact on performance
- Logs are big and consumes a lot of disk space.
- Logs will permanently grow and grow
- Reading over scaled out architectures

Possible solutions:

- Consuming too much disk space; solved with log rotation - the process of taking old logs, and compressing or deleting them.
    - have to determine how long our "rotation" is. maybe 1 month?
    - functions something like a cache: rotate out old logs into compressed, then rotate some compressed logs into deletion
    - rotated out log file gets compressed
    - if logfile name is "logfile", others will be "logfile.1" etc
- Scaled out logs
    - Timestamp in UTC with NTP
    - Centralize logs in one place

Splunk âĂŞ a software to search, monitor, index logs, âĂIJlog managementâĂİ

10.5 Summary

- Exists in two flavors: centralized (syslog) and roll your own
- Traditionally disconnected among services and machines
  - Need timestamp sync to make sense of multiple logs (NTP, UTC)
  - Cloud based system have to configure UTC Time Zone(default), NTP(synchronize clock)
  - Store in centralized place (Log aggregation)
    - Logstash (centralize) + Elasticsearch and Kibana (Search index)
    - Splunk
- A common failure mode: disk full of logs
  - Need to make sure rotation enabled

Chapter 11

Web Searching

11.1 About

Instead of scaling up, google decide to scale out to save money on servers. These "servers" are just a bunch of CPUs and memory put together.

Even before Google, searching in the cloud index is challenging due to the amount of data that relates to a search.

What page should appear first and how to rank them?
primitive search result ranking is depended on:

- whether that html page has a description tag in the html header section that matches the key word;
- The words in the title

some people begin to cheat, to add those popular word into their title or description so they can gain the popularity in this way.

Yahoo is the largest directory sites, host a list of urls

Google âĂŞ greater capacity, scale out and sharding(many cheap machines), search index, copies all websites, most relevant search result, index pages, many physical location, good recall

Some Search Engine Examples: Inktomi(bad user experience, bad page rank, no snippets, no caching), Hotbot, Altavista(first to index full text page)

How do you identify the content is relevant to what the user search?

search engines started to use website's reputation to arrange their ranking in the searching result.
ways to determine the reputation of a website:

- traffic of the website
- number of links pointing to it from other websites. Popular site will have many link point to them
- if reputable sites link to other sites, those sites are deemed more reputable

about 10 years ago, Google start to crack down on people who sold their site's reputation by manually adding those site into their black list.

selling reputation requires some semi-illegal actions, absolutely not ethical according to ACM codes link to the ACM codes: https://www.acm.org/code-of-ethics

People in US normally will not do this, but they will pay the people in the "East" to do that.

ways to cheat today:

- take contents from wiki to increases reputation

the most important consideration of why Google is on top today: their search results are the most relevant. Smaller search engines cannot index huge amount of data because they don't have enough money

location is one of the priority factor that's going to be consider during your search in order to provide more relevant result to you.

How do you judge whether a search result is good or bad?

High precision and accuracy. In most case accuracy is prefer over precision, but if there is not enough precision accuracy is useless.

11.2 Precision and Accuracy

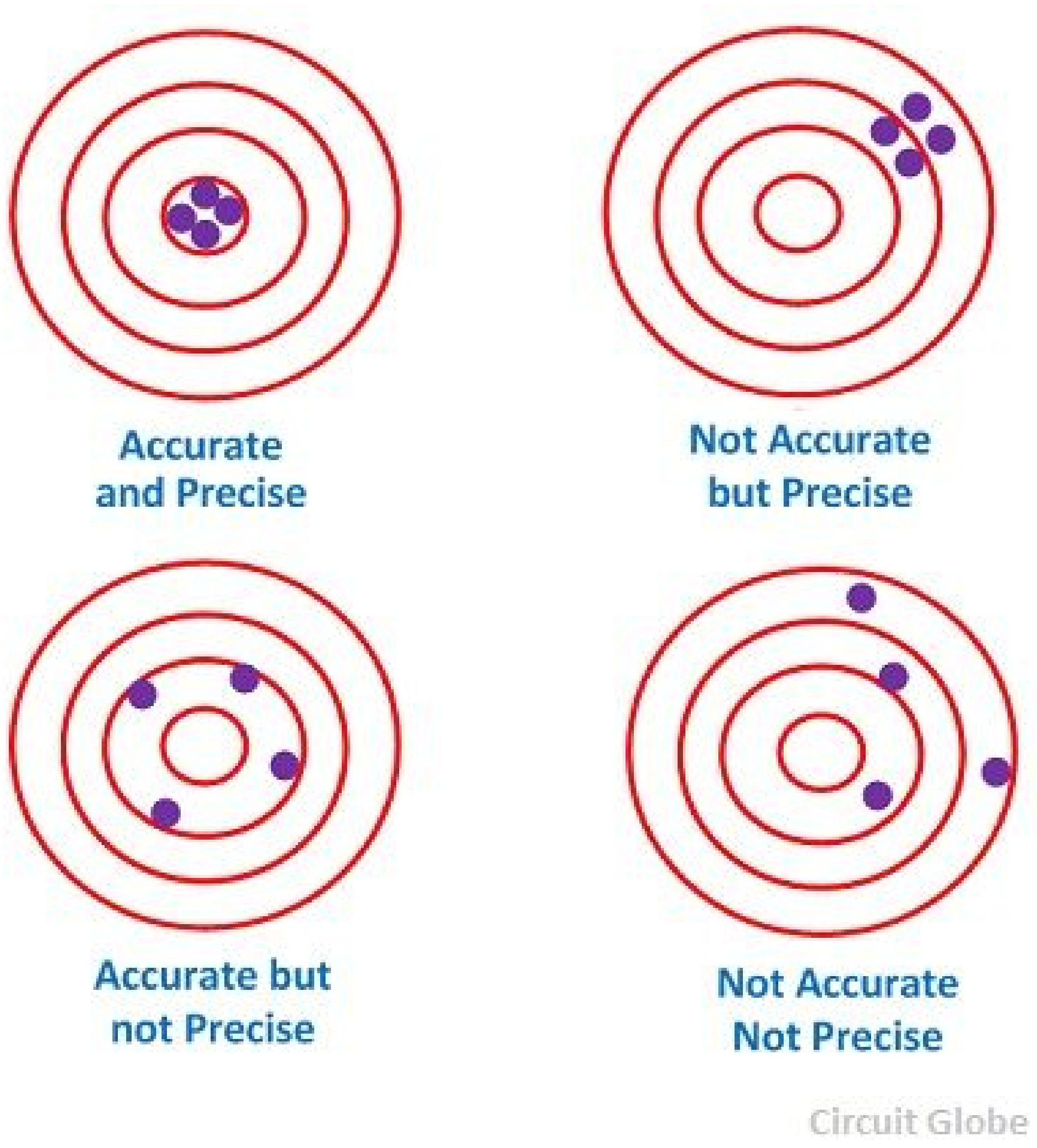


Figure 11.1: analogy

what makes a search engine good:

- index many things
- good at ranking
- precision of the searching result
- accuracy of the searching result

accuracy: Accuracy is how close a measured value is to the actual (true) value.
precision: Precision is how close the measured values are to each other.
from math is fun:https://www.mathsisfun.com/accuracy-precision.html

precision: how much of what we got was actually relevant?
recall: how close we are to what we want

true positive: things appear in the correct searching result
false positive: wrong records that appears in the searching result
true negative: things shouldn't be in the searching result and it exist
false negative: things should appear in the searching result which is not

expectation of a searching operation:

- for restaurant: as long as it return some relevant result on the top
- for email query: it's absolutely unacceptable when a email you want is not laid in the searching result

Google has generally better records than Bing, they index more site. On the other hand, Bing doesn't has that large data set and has better precision and page rank
If you search on Bing, chance are high the first page contains things that you care about
when a searching engine cross a web site, it need to create an index records all the links in the origin of that website. creating a lookup table with token(each unique word) as its key and URL as its value
In a database system, create index to make query faster.
full-text search(inverted index): performance on the data structure called invert index,using the word(key) to find the value(URL)

Search engines today will get the full list of results and then rank.
Google indexes all the pages in the internet, they're storing at least one copy (usually multiple copies) for all the pages they return in their search result.
Google has multiple copy of nearly all of the contents of the internet, not just their index.
Even if the internet were to die, you can still using Google to search.
Google estimates how frequently a website is going to update, they use a FIFO queue to store that relatively reputable sites will be recorded by Google once or twice a day.
webmaster tool : you can submit your website for indexing
If you don't want Google to index your site, add a robot.txt file to specify that you do not want

your site indexed. Normally, third party crawler don't care this file, but Google will. Incast Problem: Many people request to one server. Apply Node Hierarchy to load popular shards heavily, replicate more times, caching to improve performance, and queue requests

11.3 Prevision vs Recall

Precision and recall are two extremely important model evaluation metrics. While precision refers to the percentage of your results which are relevant, recall refers to the percentage of total relevant results correctly classified by your algorithm

11.4 web crawler

- WebCrawler, Lycos, AltaVista, HotBot, Google
- stored the whole page instead of just title, description, url
- Crawling to find content
- Done frequently to notice changes
- Official term: Inverted Index
- Fast-lookup map of all elements (words) to documents
- May also contain location information
- Need to combine results for multi-word queries
- Precision vs Recall (email needs perfect recall, web doesnâĂŹt)
- Need hierarchy to query index nodes
- Easy features: stop words, spell check, stemming
- Scoring results by relevance
- Needs to generate result snippets (separate request)

DEC make the best web search engine(miss management), was bought by compaq, bought by Hewlett-Packard.

Google's strength: system that could have the same capacity compared to alta vista without paying millions of dollars. They bought many many cheap machines instead of one big hunk with all the information. Scaling out was the way to go.

by extension, for the same price, they could create something with more capacity

11.5 Page rank

Why: prioritizes pages to show first

How does page rank algo work

- early on
    - simplistic

  - check for word in title, description tag
  - later on, also check for synonyms for search term eg. hat-> cap
  - could be gamed: invisible tag at bottom of HTML page, with random popular words at the bottom of the page
    - people tried to fix this by hiring people to blacklist the websites, then with algorithms. nothing worked
- page rank algorithm uses around 120 - 150 characteristics to rank websites. One characteristic they use is the reputation of the website
- reputation is calculated as follows:
  - number of links from other websites to our current website. The guy who started Baidu creator originally came up with this,"Google invent it 3 years afterward".
  - take into account the reputation of the linkers to a website
  - if 1000 disreputable websites link to you, not as meaningful as 1000 reputable websites
  - also take into account the number of websites you are linking to.
  - simplistically, take your websites reputation and distribute it among everyone you link to.
  - full algorithm is not public, has around 120 to 150 factors taken into account
- Abuse of page rank âĂŞ spam irrelevant keywords
- Sulution: consider reputation

Definition 11.1. Inverted index

An inverted index is an index data structure storing a mapping from content, such as words or numbers, to its locations in a document or a set of documents. In simple words, it is a hashmap like data structure that directs you from a word to a document or a web page. ♣

inverted index data structure :search value to get key (opposite of regular index approach)

insertion of document in inverted index data structure via hashmap:

- hash the content
- put hashed key as value and content as key into the hashmap
- if there’s any data prior to current operation in the hashmap, put the hashed key into the and of the list otherwise create a new list and insert current hashed key as its first child

prepossessing before the searching operation:

- stamping
- spell check

Precision is the relevant fraction. Recall is returned fraction vs total Importance depends on context E-mail: need perfect recall, good precision Web: want great precision, recall is useful Scoring is important Usually more results than desired Everyone wants relevance DonâĂŹt give me what I asked for, give me what I want

Search result precision

- Web search split into 2 part
- true positive:correct, false positive:false
- others are false negative:false, true negative:correct
- In ideal situation, search system wants true positive
- true positive (precise), false positive(not precise)
- If database of search engine isn't large enough->more false negative

Whats actually inside search engine

- create index for all of the words and store in some datastructure
- create lookup table for key and urls
- Not looking for exact value of keyword. Looking for document that value came from -> fulltext search

Definition 11.2. A/B testing

A/B testing (also known as bucket tests or split-run testing) is a randomized experiment with two variants, A and B. It includes application of statistical hypothesis testing or "two-sample hypothesis testing" as used in the field of statistics. A/B testing is a way to compare two versions of a single variable, typically by testing a subject's response to variant A against variant B, and determining which of the two variants is more effective. ♣

Note *morgan is a module for node.js to monitor the request (response time etc) https://www.npmjs.com/package/morga*

Chapter 12
Cloud Application Performance

Topics

12.1 Tail at Scale

Average latency of request is not important as tail of latency when we looking for the QOS. QoS dictated by the tail X% of requests complete in Y time Each processing step adds latency Client, WAN, Load Balancer, Broker, Backend, Data store The outliers create problems at tail QoS set at each step Scale-out services may compound latency Major problem for Search, MapRedce (“stragglers”)

You can use the log to track the place where the problem happens. If there are only a few slow transactions in 10000 transactions it is ok, but if 500 out of 10000 are slow, you have a problem.

long tail distribution: In statistics and business, a long tail of some distributions of numbers is the portion of the distribution having many occurrences far from the "head" or central part of the distribution. The distribution could involve popularities, random numbers of occurrences of events with various probabilities, etc.[1] The term is often used loosely, with no definition or arbitrary definition, but precise definitions are possible.

peaks in the long tail distribution of latency usually are irrelevant, but tails matter

Definition 12.1. QoS

Quality of service (QoS): refers to any technology that manages data traffic to reduce packet loss, latency and jitter on the network. QoS controls and manages network resources by setting priorities for specific types of data on the network. ♣

A system will always have a bottleneck, and it’s hard to find the real bottleneck. It is easy to throw hardware at it to fix the problem, but you don’t know where you need to "add the hardware".

Bottlenecks: there is only one real bottleneck in the system. Until you find the real bottlenecks and fix it, the performance will not improve.

Suppose you fix all your bottlenecks in the software, then hardware will be the problem.
Four type of hardware resources: Mem, CPU, net, disk.
Usually we don't have to worry about network bottleneck.
Disk bottleneck normally is causing by the log, you need to keep track of the log. Normally we avoid read and write from the disk. If we ran out of disk volume, it is easy to track.
CPU is the critical one

CPU utilization: A measure of how busy the CPU is right now.
Load average: number of process waiting for the CPU.

We intentionally keep CPU utilization low in order to provide good service.

12.2 Bottleneck

Definition 12.2. Bottleneck

he single component that holds back/slows an application ♣

Since systems always have one, and only one, bottleneck at any given time, bottlenecks are not removed, they are 'shifted' aka once one bottleneck is gone, there will be a new point in your application that causes the largest slowdown.
Two types of bottlenecks:

- Artificial Bottlenecks
- Hardware Bottlenecks

Definition 12.3. Artificial Bottleneck

n artificial bottleneck is essentially a performance problem that is a direct result of a difference between the production environment or workload and the performance test environment or workload. ♣

Definition 12.4. Hardware Bottleneck

hardware bottleneck is the result of performance limited by a single component of hardware ♣

Artificial (Ex.):

- OS kills an application once it exceeds the stack space
- Java: Garbage collector is slow, and as heap grows, it happens more frequently
- Node.js: Limited to only 1 CPU, so scaling-up can't help
- Flask: Also limited to 1 CPU, but isn't async like Node so each process handles requests one at a time while others wait
- Apache: can dynamically add/remove workers, so if initial workers too much or too little, Apache will waste time creating/killing workers

Hardware:

- Net: Generally will not be a bottleneck
- Mem: Typically causes catastrophic failure, so easy to notice
- Disk: Inherently slow. Most commmon issue is leaving vverb logging on. Solving disk space is easy, simply add hardware, but disk performance issues are harder to solve. Typically done with scale-out.
- CPU: Add CPUs if there is a consistent CPU utilization > 60% or Load average > the number of VCPUs

All complex systems have one bottleneck

Bottlenecks can shift... but there can be only one

Finding bottlenecks

Log times (and analyze them, maybe with ES)

Log worst-case times (and their details)

Monitor CPU, memory, swapping, disk, (network)?

“top” is surprisingly useful

Fixing bottlenecks

Improves performance

Fix algorithm (e.g., cache, queue, add index, rewrite code)

Artificial vs Hardware bottlenecks

Fix config (artificial limits [app, ulimit, sysctl], features [php accelerator, pypy])

12.3 Caching

Definition 12.5. Caching

Caching: Storing data in another location for faster read performance ♣

Mostly web static content

Expiration times important

Task can be pushed to CDN

Memcache: Most popular caching microservice. Easy to implement

Stores data in memory

Avoid redundant/duplicate computation/lookup

Sit in front of MySQL, ES, etc...

Requires invalidation on updates

Set expire date(usually 5 seconds)

Linux commands: vmstat(summary info of memory, processes, pages), iostat(cpu stat, io stat for devices)

12.4 Queuing Writes

1.when the user types a message it will appear in his/her screen, the message in the user screen may not be sent yet, the system will fix it's ordered later when it actually being sent.
Most online games would predict the user's action, and fix it later if it didn't happen.
When performing database insertion, the system would create new id when the write is entered the queue.
2.latency for a web is about 700ms is OK, but the fast the better.
3.for a phone call, the round trip time should be less than 700ms else no one can hear each other, but when they talk to each other, it will cut off each other.
Keep in mind:
sending multi-get query statements to the database requires both query statements to be independent of each other
You will need to wait for the entire query to finish,if you can't perform parallelism.
In practice, when we measure the performance of an system, we only cares about the tail of our performance graph.
Most of time when people look at the tail latency distribution.

tail latency: the slowest response time for your application
Look the logs from load balancer to find out who's being slow.

When we need/want to improve the QoS, we will like to find the bottlenecks of our application, so user can have a better experience.

Chapter 13
Security

Definition 13.1. XSS

Cross Site Scripting (XSS): An attack were the attacker injects client-side scripts into the webpage. ♣

Definition 13.2. CSRF

Cross Site Request Forgery (CSRF): An attack where the attacker tricks the browser into injecting a request into an authenticated session ♣

Definition 13.3. Botnet

Botnet: A network of private computers infected with malicious software and controlled as a group without the owners' knowledge, e.g., to send spam messages. ♣

13.1 Security Approach

- Password Hashing: Using a hashing algorithm such as md5 or sha256 to hash passwords and store them on the database. Use with a salt so passwords are not easily guessed by looking at the hashed passwords.
- Server Side Code Injection: injecting code into the server. Attack happens when the server does not sanitize inputs from the client. Example: SQL Injection.
- Salting: concatenate some random value then hash the password. This helps to defend against Rainbow table attack in which a precomputed lookup table is used.
- Dangerous Assumptions: Never make assumptions about your user inputs. E.g. If a request does not have username field, do not assume this is an admin simply because you hard code the front end website to not include username field for admin login.
- Botnet: To defend against botnet, make sure your machine is not compromised by code injection. Close off possible attack vectors like vulnerable ports. Do not run source files provided by the users. Professor Fredman was himself hacked this way for pulling a .php file supplied by an attacker.

Chapter 14
Scheduling and Job Placement

Have lots of machines and lots of jobs How to put the two together?

14.1 Old school Approach

Scale up as much as possible (stay on one machine) Run things manually across machines

14.2 new Approach

use a cluster manager Admission control, efficient task-packing, over-commit High-availability with automatic fault-recovery time Honors priority levels and quotas Schedules jobs to reduce probability of correlated failures Notable examples Mesos, Kubernetes (similar to Borg): containers and applications YARN: Hadoop-like resources - Monitor how quickly jobs are running, copy jobs to new machine to rerun - Wait for all jobs to finish before reduce , guess which is bottleneck - Decide which machine to run job - Less network comm, performance enhanced - Schedule jobs

Makespan: time from begin to terminate of jobs

Celery: simple jobs and shell scripts

Chapter 15
Hadoop vs Spark

Topics

❑ Map-Reduce
❑ Hadoop
❑ Spark

15.1 Map-Reduce

Another term for "Big Data" Process lots of data, produce a (small?) aggregated result Dominated by MapReduce pawradigm

- example: counting words in a book. you can count the words one by one OR you can take 20 people, give each a page, have these people count the words on their page, then take another page

Three phases: map, shuffle, reduce "grep" and "wordcount" are (useless?) easy examples Easy to scale out, very fault tolerant Many implementations Ex.: MongoDB, CouchDB, Hadoop

15.2 Hadoop

- only way to handle large data job
- Named after a toy elephant(author's daughter's toy)
- Can run in parallel(Distributed machine to run Job)
- Good for large-scale, not real time
- Comprises four main "modules"
- Hadoop Common, Hadoop Yarn, HDFS, MapReduce.
- data scientists prefer SQL, so things were made to allow SQL syntax layer above map-reduce

Libraries, GUIs HBase, Hive, Pig, ... Hive, Pig âĂŞ query files at higher level, write SQL, return SQL output

MapReduce is great, but it is not good at doing iteration process, because it needs to write the output to disk and read it back again for the next iteration.So this will be time consuming.(can't to pass data between stages) Typically used for long-running big-data batch jobs Typically on data that takes up lots of disk space Leverage memory and add bells and whistles Interactive queries, stream processing, iterative execution Careful not to step on Hadoop's toes "Different purposes, not competitors", no other way to handle huge data, but people tend to avoid using hadoop as much as possible.

15.3 Apache Spark

- reading data into memory, and process anything there
- memory is fast, so if data can fit into memory, using spark will be fast.
- It is design to doing things from memory, so it is very bad if you need disk I/O.
- cross-pollination between hadoop and spark.
- more likely to use this in a small company or startup.(less data)
- can pass output between each stage so it is very good at interactive process than Hadoop.

Chapter 16
Machine Learning

16.1 About

new approach of programming - machine learning

efficiency in algorithms: if rules are simple, human always do better, machine learning is good act generalization We can't figure out the algorithm to find the correct output, and as the input gets large and large it will not be possible to do it. So we train machine learning model by feeding it the input and output to let the model learn.

Each of the input is call "feature", and each of them we will multiply by a weight. we will learn this simple function: f(x)= w*x+b w is the weight vector, x is the input matrix, b is a generalization term to adjust the answer, so the model will not over-fit.

We want machines be able to learn because we can't come up with the correct algorithm.

overfiting : does not learn to generalize, model learns the detail that negatively impact performance and ability to generalize

type of machine learning algorithm:

16.2 Types of Machine Learning

- supervised: feed input with the output
- unsupervised: feed input without the output
- reinfoced,

16.3 CNN

CNN: In deep learning, a Convolutional Neural Network (CNN, or ConvNet) is a class of deep neural networks, most commonly applied to analyzing visual imagery. They are also known as shift invariant or space invariant artificial neural networks (SIANN), based on their shared-weights architecture and translation in variance characteristics. They have applications in image and video recognition, recommend systems, image classification, medical image analysis, and natural language processing.

Instead treating the entire matrix as giant input, CNN takes a piece of the matrix and performance computation on it, and it can learn from those pieces

CNN using sliding window technique, to traverse the input matrix.

Ex. Resnet, googlenet, VGG, etc.

Natural Language Processing:

16.4 Field in computer vision using CNN

- object detection is the process of identification
- object classification is the categorization of the object based on a previously defined classes or types.
- object segmentation is the process of splitting up an object into a collection of smaller fixed-size objects in order to optimize storage and resources usage for large objects.

16.5 Embedding

embedding in machine learning: A word embedding is a learned representation for text where words that have the same meaning have a similar representation. It is this approach to representing words and documents that may be considered one of the key breakthroughs of deep learning on challenging natural language processing problems. typical size of stack in a operating system is between 64 - 128 kilobytes, if something exceeds it, the operating system kills it

Chapter 17
Monitoring

17.1 Monitoring Programs

- Monitoring programs detect status and report failure of micro-services. The status of a process can be running, sleeping, stopped, or zombie. Typical monitor programs monitor network services by either pretending as an user to test the correctness, expectation of output and performance, of the network services or sending ping to specific micro-services to check whether or not a specific port is open.
- Monitoring as services
  - Some companies provide services that test whether or not the developing web API is functioning properly. They login to the machine and ask for data from the server. The machine runs something and send back respond either periodically or on demand.

Definition 17.1. Agent

An agent sends the data to users. Monitoring using an agent provides data regrading load average, CPU, memory utilization and network usage. ♣

Definition 17.2. Zenoss

A software for service monitor ♣

17.2 About top

- Top
  - The top program provides a dynamic real-time view of a running system. It can display system summary information as well as a list of tasks currently being managed by the Linux kernel. The types of system summary information shown and the types, order and size of information displayed for tasks are all user configurable and that configuration can be made persistent across restarts.
  - First column indicates the PID. Second column in top indicates how many tasks are in the system. Third column in top indicates the usage of the CPUs.
- htop
  - a colorful top like tool with IO monitor integral within it

Definition 17.3. Load Average

Reasonable percentage of load average: 60. Anything goes above 60, the tail will shift to the right. In a system that has 32 vCPUs, above 32 overloads the machine. ♣

- Three details regarding load average
  - id: idle, low load, high idle
  - us: how much cup time goes to the applications
  - If the idle percentage drop below 40 percents, some of the tasks may be queued, so the performance drop.

17.3 CPU Usage monitoring in Top

- System load/CPU Load âĂŞ is a measurement of CPU over or under-utilization in a Linux system; the number of processes which are being executed by the CPU or in waiting state.
- Load average âĂŞ is the average system load calculated over a given period of time of 1, 5 and 15 minutes.

17.4 Other

Simple Network Protocol (SNMP): a very simple protocol expose all kinds of statistics, such as CPU and Memory utilization, and collect data from bidirectional, both client and server.

Definition 17.4. SNMP

Simple Network Monitoring Protocol is an applicationâĂŞlayer protocol defined by the Internet Architecture Board (IAB) in RFC1157 for exchanging management information between network devices. It always has an UID associated with the statistics that it collected. ♣

Chapter 18

Homeworks

Homework 0 - Web Server

1. Create a new m.micro Linux server
2. Assign a public IP to it and log into it
3. Create a static web page in the server's document root called hw0.html that contains the string "Hello World" and one image

Homework 1 - Ansible/Git

1. Place your hw0 files into a public git repository (use a service such as github or bitbucket)
2. Create an Ansible playbook to deploy your hw0 on Ubuntu 16.04 servers, checking out the files from git and using âĂIJhw1âĂİ as the name for hosts: in your inventory
3. Place your playbook at http://yourserver/hw1.yml

Homework 2 - Mongodb

1. Install mongodb, configure it to listen to network connections
2. Create a database called "hw2"
3. Create a collection called "factbook"
4. Populate the collection with data from https://github.com/opendatajson/factbook.json (hint: write a script to do it)
5. Open TCP port 27017 from network 130.245.168.0/22 in the Security Group

Homework 3 - Kubernetes

1. Write a dockerfile that installs a webserver and hosts hw0 on it, then build a docker image from it and host it on dockerhub.
2. Create a single-node kubernetes cluster using minikube (m.milli instance) and deploy hw0 into it by creating a Deployment, and a Service that exposes port 80 to the Deployment. Make sure to disable virtualization with minikube by using the –vm-driver=none flag.
3. Write a Deployment YAML (if you haven't already in the previous step) that deploys a replica of hw0 into a Pod labeled "app: hw0".
4. Place your Deployment YAML at http://yourserver/hw3.yml.

Homework 4 - RabbitMQ

1. Install rabbitmq
2. Create a direct exchange called "hw4"
3. Create a REST service

   ```
   /listen { keys: [array] }
   ```

   Creates an exclusive queue, binds to “hw4” with all provided keys, waits to receive a message and returns it as

   ```
   { msg: }
   ```

4. Create a REST service

   ```
   /speak { key:, msg: }
   ```

   Publishes the message to exchange “hw4” with the provided key

Homework 5 - Load balancer

1. Install nginx
2. Configure it as a round-robin reverse proxy between three backends:
   http://grading.cse356.compas.cs.stonybrook.edu:9000/
   http://grading.cse356.compas.cs.stonybrook.edu:9001/
   http://grading.cse356.compas.cs.stonybrook.edu:9002/
3. Make sure failures of a backend server (e.g., timeouts or 50X responses) are not fatal and allow the other backends to handle requests

Homework 6 - Cassandra

1. Install Cassandra
2. Create “hw6” keyspace (replication factor 1)
3. Create a table "imgs" that includes a filename (string) and contents (blob) columns
4. Create a POST form target

   ```
   /deposit { filename: (type=text), contents: (type=file) }
   ```

   Uploaded files should be deposited into hw6/imgs in Cassandra
5. Create a GET service

   ```
   /retrieve { filename: }
   ```

   to get the previously uploaded image (make sure to respond with the appropriate image/âĂę content type)
   (note: use Cassandra 2.2 (22x) for this homework)

Homework 7 - Elasticsearch

1. Install Elasticsearch with Kibana (elastic version >=6x)
2. Create an index called “hw7”
3. Populate the index with IMDB data about some relatively recent movies (https://grading.cse356.compas.cs.stonybrook.edu/hw7/movies.json)
   (hint, use a script or logstash)
4. Create a visualization to chart the top rated movie for every year and the average movie earnings for each year.
   (note: don’t forget to open the appropriate default port(s) for both Elasticsearch and Kibana in the security group settings, as we will be accessing Elasticsearch and Kibana via your-website.com:port)

Homework 8 - MySQL/Memcached

1. Install a mysql variant (mysql, maria, percona, ...)
2. Create a database called "hw8"
3. Create a table called "assists" and import MLS 2017 data for assists by soccer players (https://github.com/jokecamp/FootballData/blob/master/MLS/2017/assists.csv)
4. Create a REST service to access the data and return the top assisting player for a given club in the given position, and the average number of assists by all players of that club in that position

   ```
   GET /hw8?club=HOU&pos=M
   ```

   to get { club:(string), pos:(string), max_assists:(int or float), player:(string), avg_assists:(int or float) }
   Note: Use a higher value of the goals scored (GS field) as a tiebreaker for players who have equal assists (A field).
5. Install memcached
6. Integrate memcached caching to speed up the REST-based service

Homework 9 - Machine Learning with PyTorch

1. Download the training script at:
   https://grading.cse356.compas.cs.stonybrook.edu/hw9/avg_model.py
   Note: The script is based off of: https://github.com/bentrevett/pytorch-sentiment-analysis/blob/master/3%20-%20Faster%20Sentiment%20Analysis.ipynb
2. Read through the repo’s README and the folder’s README to understand how the model is trained (and what neural network it decides to go for). Create an environment with the packages described in the repo’s README.
   Note: You may have an issue when following the original repo’s instruction in doing ’spacy download en’ (it outputs a Segmentation Fault). Just run the command again using ’sudo’.

3. Convert the training script into a webapp (e.g. by using a python web framework) with a POST endpoint "/predict" that queries the model to retrieve the sentiment value of a sentence.

   ```
   POST /predict {"sentence":(type=string)}
   ```

   The response should be in the form:

   ```
   {"result":(type=number)}
   ```

   Note: disable training when setting it up for the post request and re-enable to train the model. Be sure to use a m.standard instance for this homework.

   The repo's README mentions python 3.7, but python 3.6 will work fine.

4. For those using their own machines: Train the model on your own laptop and then copy the resulting file into the instance and proceed with the assignment normally. If you train on your own machine, you must make sure that you do not train with cuda enabled. (I personally haven't tested in this instance, proceed at your own risk)

Chapter 19
Warm-up Projects

Warm-Up Project 1

1. Create a front page at http://yourserver/ttt/ - the page must include at least one CSS file which changes the appearance of something on the page and a POST FORM that requests and submits a field called ’name’. (The FORM ACTION should point to this page’s own URL)
2. If the page receives a POST parameter called ’name’, it should output “Hello $name, $date” with the name and date filled in dynamically. (Do not use client-side JavaScript for this part)
3. Create a REST-based Tic-Tac-Toe service at http://yourserver/ttt/play that takes as input a JSON object including a ’grid’ property and returns a JSON object including a ’grid’ property and a ’winner’ property. The ’grid’ property is an array of 9 characters, each being a space (’ ’), ’X’, or ’O’. The ’winner’ property is a single character to indicate who won.
4. Integrate the REST-based tic-tac-toe service into your front page that starts operating when the page is loaded with a ’name’ specified. (Use client-side JavaScript for this part)

Warm-Up Project 2

1. Develop a user-creation system validated with email

   ```
   /adduser, { username:, password:, email: }
   ```

   creates a disabled user

   ```
   /verify, { email:, key: }
   ```

   key sent via email (backdoor key is “abracadabra”). The email should include the text

   ```
   validation key: <key_goes_here>
   ```

   (including the < and > characters). Optionally, IN ADDITION to a JSON POST request, you may also make this API call accept a GET request with the two parameters in the query string, to allow for a direct link from the verification email.
2. Add cookie-based session support

   ```
   /login, { username:, password: }
   /logout
   ```

3. Modify your Tic-Tac-Toe REST service at http://yourserver/ttt/play to take as input a JSON object including a 'move' property to indicate on which square (0-indexed, in reading order) the human is making a move in the current game. The server should respond with a JSON object that includes a 'grid' property and a 'winner' property as in WP#1. Making a request with move:null should return the current grid without making a move. Once a winning or tying move has been sent to the server, the server should consider the game completed and reset the grid.

```
/ttt/play, { move: }
```

4. Maintain the history of previously played games by each user on the server.

```
/listgames
to get { status:"OK", games:[ {id:, start_date:}, ...] }
```

```
/getgame, { id: }
to get { status:"OK", grid:["X","O",...], winner:'X" }
```

```
/getscore
to get { status:"OK", human:0, wopr: 5, tie: 10 }
```

Clarification: all of the above API calls must be POST requests with a JSON object for the request and JSON object as a response of either status:“OK” or status:“ERROR” (unless otherwise specified).

Chapter 20

Course Project

Twitter Clone

1. Milestone 1: Oct. 22
2. Milestone 2: Nov. 5
3. Milestone 3: Nov 19
4. Milestone 4: Dec 3

   Implement a Twitter clone. At a minimum, you must implement the API we provide. If you have comments or clarifying questions on the API, please leave them directly on the google doc.

Appendix

Linux Basics

Topics

□ Remote access

□ Permissions and privileges

□ Common commands

□ Directory structure

□ Popular server software

- remote access: ssh, scp, ssh keys
- permission and privileges: file rwx, sudo, chmod, chown, su
- file and directory operations: touch, mkdir, cd, ls, rm, cp, mv, cat, tail/-f, less
- package managers: apt, yum
- admin utils: systemctl
- common web server software: apache2, nginx
- popular web framework that works on Linux: Javascript nodejs/express, Python flask/Django, Java Spring MVC
- directory structure:
  1. /home is your user directory in which everything specific and private to only an user is kept. Everything else not in this directory are system directory and should have write permission restricted to root only. Inside home, there may be hidden .local, .etc, and other directories that perform the same functions as their system wide counterparts but specific to this user only.
  2. /etc is for storing system wide configuration files. This include application specific configuration across all users.
  3. /var/log is for keeping all the logs. Both system applications dump their logs here. E.g. nginx and apache.
  4. /tmp is a directory for storing temporary files and caches. These are usually gone after a reboot.
  5. /bin is for storing binaries that are needed by the operating system, most of which are preinstall, and necessary for it to be any useful. E.g. ls and mkdir should be found here.
  6. /sbin is like the /bin except /sbin binaries usually need root permission to do its jobs properly. E.g. iptables and iwconfig.
  7. /root is the home directory of the root user. Do not confuse this with the root directory

aka / which contains every other directories and files in the Unix operating system.

8. /usr contains many things which are system wide. These includes /usr/bin and /usr/sbin which are applications install by users and do the same things as /sbin and /bin except they are not needed by the operating system. Most of the applications install by the user from package managers should go inside here. There is also /usr/local which contains system wide user settings like desktop launchers in /usr/local/application (if you are running a Gui like gnome) and have yet more directories name /sbin and /bin. By convention /usr/local/bin and /usr/local/sbin are for storing binaries that are installed outside the package manager.
9. /opt is exactly the same as /usr/local/bin and /usr/local/sbin, it is meant for storing binaries not installed with package manager. I personally do not use these directories and prefer to dump everything in /bin in my home directory if installing outside the package manager.
10. /boot contains the kernel. Best to stay away from it. Advanced user will usually mount this directory on a separate partition in case a kernel update goes horribly wrong.
11. /lib, /lib32, /lib64 contains all the dynamic and static linked libraries. If you code C or C++, that's where the compiler link their libraries from.
12. /usr/inlcude contains all the header files for various libraries. I usually manually dump all the headers of the libraries installed outside the package manager here,

- bash basics:
  1. | is piping
  2. > is direct std to output
  3. < is redirect stdin from input
  4. » is append stdout to ouput
  5. « is append stdin from input
  6. && is chaining together commands
  7. & at the end of the command means to run command in the background
  8. fg is bring a background command to foreground
  9. jobs is to view all background commands

Appendix

User-Server Interaction: Cookie

As we know that an HTTP server is stateless. This simplifies server design and has permitted engineers to develop high-performance Web servers that can handle thousands of simultaneous TCP connections. However, it is often desirable for a Web site to identify users, either because the server wishes to restrict user access or because it wants to serve content as a function of the user identity. For these purpose, HTTP uses cookies. Cookies, defined in [RFC 6265], allow sites to keep track of users. Most major commercial Web sites use cookies today.

B.1 Cookie

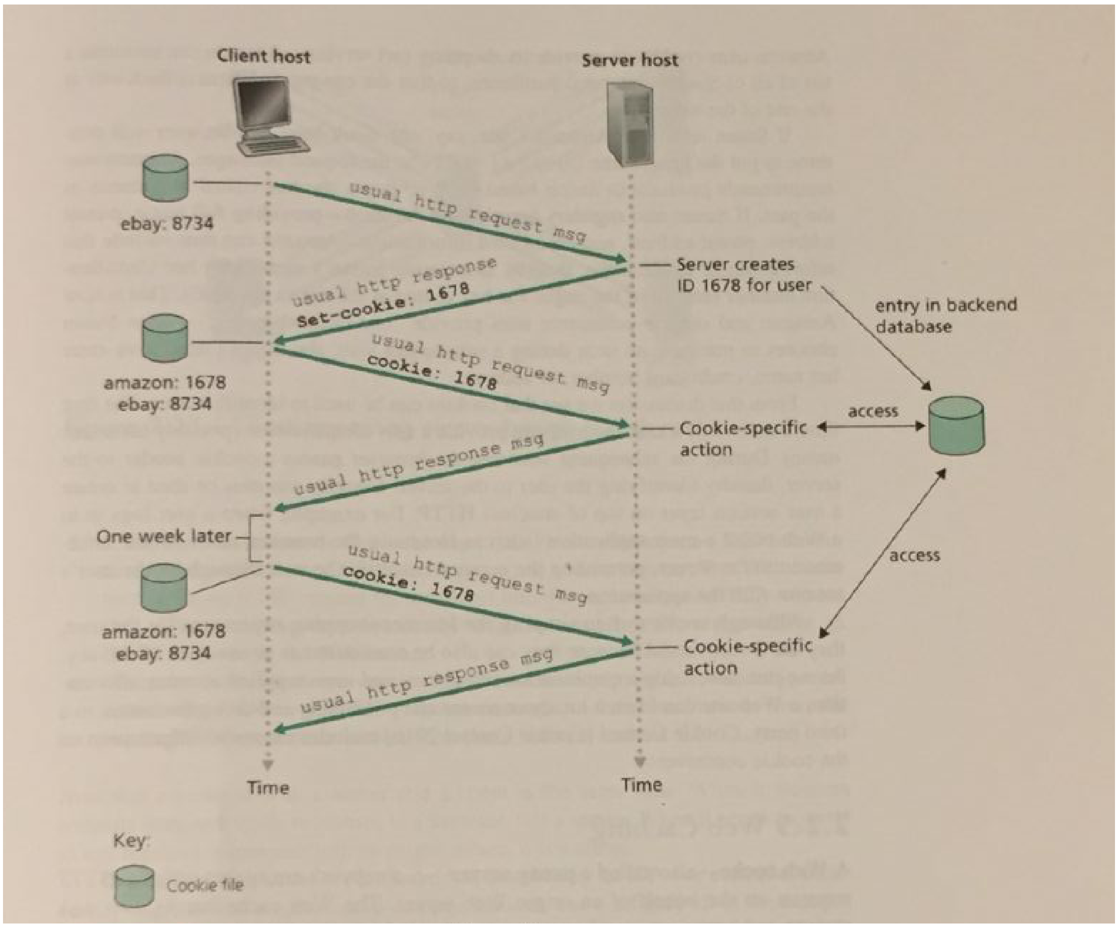


Figure B.1: cookie work flow

As show in the figure above, cookie technology has four components:

- 1. a cookie header line in the HTTP response message

- 2. a cookie header line in the HTTP request message
- 3. a cookie file kept on the user's end system and managed by the user's browser
- 4. a back-end database at the Web site.

So let's walk through an example to have a better understanding of how cookie works.

1. Suppose Tombird, who always accesses the Web using Internet Explorer from his home PC, contacts Amazon.com for the first time.Let us suppose that in the past he has already visted the eBay site.

2. When the request comes into the Amazon Web server, the server creates a unique identification number and creates an entry in its back-end database that is indexed by the identification number.

3. The Amazon Web server then responds to Tombird's browser, including in the HTTP response a Set-cookie: header, which contains the identification number. For example, the header line might be: Set-cookie:1678

4. When Tombird browser receives the HTTP response message, it sees the Set-cookie: header. The browser then appends a line to the special cookie file that it manages. 5. This line includes the hostname of the server and the identification number in the Set-cookie: header. Note that the cookie file already has an entry for eBay, since Tombird has visited that site in the past.

6. As Tombird continues to browse the Amazon site, each time he requests a Web page, his browser consults his cookie file, extracts his identification number for this site, and puts a cookie header line that includes the identification number in the HTTP request. Specifically, each of her HTTP requests to the Amazon server includes the header line: Cookie: 1678

7. In this manner, the Amazon server is able to track Tombird's activity at the Amazon site. Although the Amazon Web site does not necessarily know Tombird's name, it knows exactly which pages user 1678 visited, in which order, and at what times!

Too be continues...

Appendix

Ansible

What is Ansible?

- Ansible is an open-source automation tool, or platform, used for IT tasks such as configuration management, application deployment, intraservice orchestration and provisioning. Automation is crucial these days, with IT environments that are too complex and often need to scale too quickly for system administrators and developers to keep up if they had to do everything manually. Automation simplifies complex tasks, not just making developers' jobs more manageable but allowing them to focus attention on other tasks that add value to an organization. In other words, it frees up time and increases efficiency. And Ansible, as noted above, is rapidly rising to the top in the world of automation tools. Let's look at some of the reasons for Ansible's popularity.

Advantages of Ansible?

- Free. Ansible is an open-source tool.
- Very simple to set up and use. No special coding skills are necessary to use Ansible's playbooks (more on playbooks later).
- Powerful. Ansible lets you model even highly complex IT workflows.
- Flexible. You can orchestrate the entire application environment no matter where it's deployed. You can also customize it based on your needs.
- Agentless. You don't need to install any other software or firewall ports on the client systems you want to automate. You also donâĂŹt have to set up a separate management structure.
- Efficient. Because you don't need to install any extra software, there's more room for application resources on your server.

Why you should use Ansible

- reduce human errors.
- time saving, one script and you can deploy as much servers as you wish
- trackable, you can easily follow what the script is doing
- same setup/environment for all your servers, no more "it works on my machine" problem

Appendix

Kubernetes

- A Kubernetes cluster is a set of one or more machines running Kubernetes processes. A cluster has a master machine (i.e. a master node/instance) and potentially additional worker machines (i.e. worker nodes) that communicate with the master machine. All of these machines coordinate in order to manage a set of containers. For testing locally, running a Kubernetes cluster via a tool like minikube works well.
- A Pod is a simply a contained environment that runs a docker image, i.e. a container.
- A Deployment is for managing these Pods. it assures that a certain amount of them (i.e. an amount of replicas) are running in a certain way (e.g. what port they run on). In addition to this, you can make changes to a group of Pods via a Deployment.
- A Service allows exposing a network to containers, thus allowing you to give a container access to ports on your public IP, e.g. http of your public IP.
- Reference: https://kubernetes.io/docs/concepts/overview/what-is-kubernetes/

Appendix
LaTeX Examples

This template is based on the Standard LaTeX book class, so the options of book class work as well (Note that the option of papersize has no effect due to `device` option). The default encoding is UTF-8 while TeX Live is recommended. The test environment is Win10 + TeX Live 2019, either `PDFLaTeX` or `XeLaTeX` works fine.

E.1 Definitions, Theorems, and Propositions

sectionTheorem Class Environments

In this template, we defined four different theorem class environments

- *Theorem Environment*, including title and content, numbering corresponding to chapter. Three types depending on the format:
  - **definition** environment, the color is main;
  - **theorem, lemma, corollary** environment, the color is second;
  - **proposition** environment, the color is third.
- *Example Environments*, including **example, exercise, problem** environment, auto numbering corresponding to chapter.
- *Proof Environment*, including **proof, note** environment containing introductory symbol (**note** environment) or ending symbol (**proof** environment).
- *Conclusion Environments*, including **conclusion, assumption, property, remark, solution**[1] environment, all of which begin with boldfaced words, with format consistent with normal paragraphs.

E.1.1 Theorem Class Environments

Since the template uses the `tcolorbox` package to customize the theorem class environments, it is slightly different from the normal theorem environments. The usage is as follows:

```
\begin{theorem}{<theorem name>}{<label>}
The content of theorem.
\end{theorem}
```

[1] We also define an option `result`, which can hide the `solution` and `proof` environments. You can switch between `result=answer` and `result=noanswer`

The first parameter `<theorem name>` represents the name of the theorem, and the second parameter `label` represents the label used in cross-reference with `ref{thm:label}`. Note that cross-references must be prefixed with `thm:`.

Other theorem class environments with the same usage includes:

Table E.1: Theorem Class Environments

Environment	Label text	Prefix	Cross-reference
definition	label	def	`\ref{def:label}`
theorem	label	thm	`\ref{thm:label}`
lemma	label	lem	`\ref{lem:label}`
corrlary	label	cor	`\ref{cor:label}`
proposition	label	pro	`\ref{pro:label}`

E.1.2 Other Customized Environments

The other three math environments can be called directly since there are no additional option for them, e.g. `example`:

```
\begin{example}
This is the content of example environment.
\end{example}
```

The effect is as follows:

Example E.1 This is the content of example environment.

These are all similar environments with slight differences lies in:

- Example, exercise, problem environments number within chapter;
- Note begins with introductory symbol and proof ends with ending symbol;
- Conclusion environment and so on are normal paragraph environments with boldfaced introductory words.

Definition E.1. Left Coset

Let H be a subgroup of a group G. A left coset *of H in G is a subset of G that is of the form xH, where $x \in G$ and $xH = \{xh : h \in H\}$. Similarly a* right coset *of H in G is a subset of G that is of the form Hx, where $Hx = \{hx : h \in H\}$ $\hbar$*

♣

Theorem E.1. Lagrange's Theorem

Let G be a finite group, and let H be a subgroup of G. Then the order of H divides the order of G.

♡

Proposition E.1. Size of Left Coset

Let H be a finite subgroup of a group G. Then each left coset of H in G has the same number of elements as H.

♠

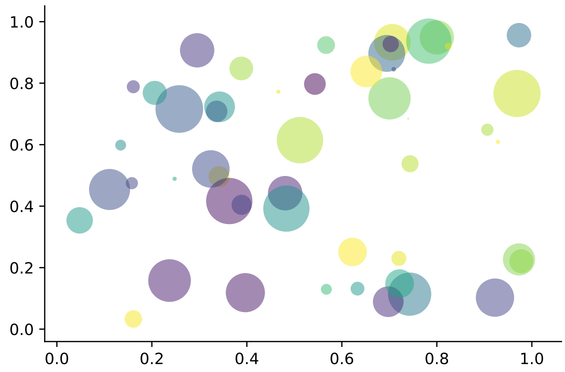


Figure E.1: Matplotlib: Scatter Plot Example

Table E.2: Auto MPG and Price

	(1)	(2)
mpg	-238.90***	-49.51
	(53.08)	(86.16)
weight		1.75***
		(0.641)
constant	11,253***	1,946
	(1,171)	(3,597)
obs	74	74
R^2	0.220	0.293

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

E.2 Figures and Tables

You can add Figure E.1 and Table E.2 references into the text.

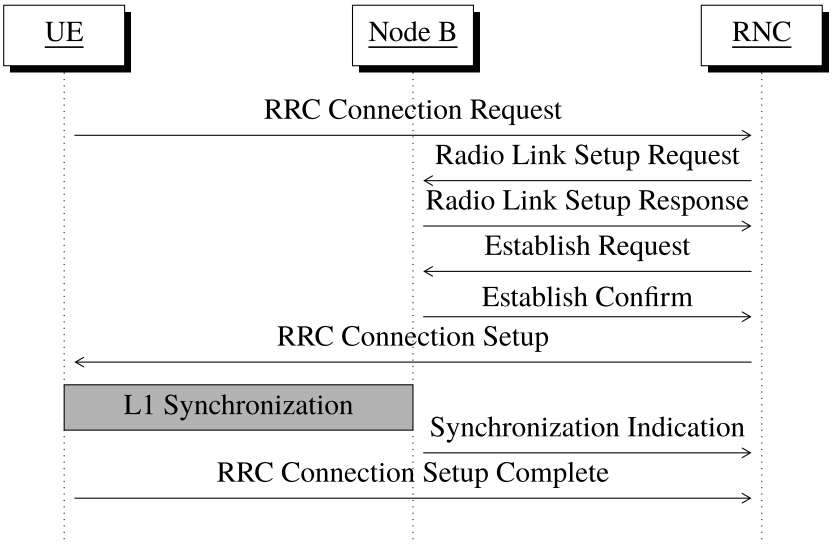
E.3 List Environments

This template uses `tikz` to customize the list environments, with `itemize` environment customized to the third depth and `enumerate` environment customized to fourth depth. The effect is as follows

- first item of nesti;
- second item of nesti;
    - first item of nestii;
    - second item of nestii;
        - first item of nestiii;
        - second item of nestiii.

1. first item of nesti;
2. second item of nesti;
    (a). first item of nestii;
    (b). second item of nestii;
        I. first item of nestiii;
        II. second item of nestiii.

E.3.1 Diagrams



Bibliography