LARGE SCALE COMPUTING SYSTEMS OVERVIEW

2110414 Large Scale Computing Systems

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Outline

- Course Introduction
- Overview and Examples of Large Scale Systems
- Problems and Solutions
- Architecture Patterns

Course Introduction

What is this course all about?

- Focus on the architecture of large systems
- Answer the following questions
  - How can we provide service for millions of users?
  - What are the issues the we should consider?
  - How can we expand our systems to support more users?
  - What are the current trends in this area?
- No textbook, we are talking about the state of the arts of many issues

3 Pillars of this Course

Large-Scale Computing Systems

Large-Scale Architecture	High-Performance Cluster	Scalable Algorithms
• Large-Scale Internet Services • Cloud Computing • Scalable Data Services • Content Caching	• Cluster Architecture • Cluster Usage • Cluster Administration • Cluster Programming	• Distributing Algorithms • Map Reduce Framework • Volunteer Computing • Case Studies

Scores and Assignments

- 3 exams (30 each) = 90%
- Assignments = 10%

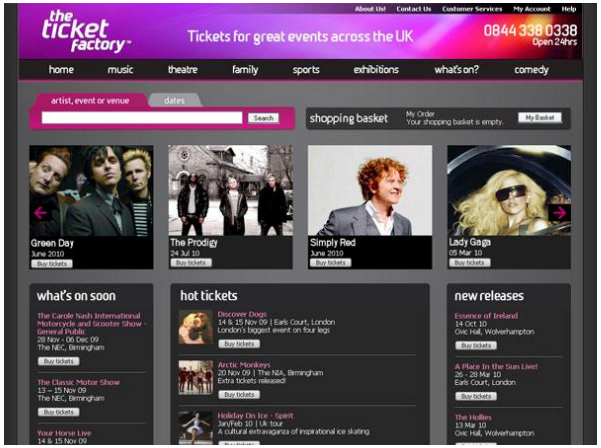
Overview and Examples

What is large-scale computing?

- A computing system that can
  - support large amount of workloads
    - user requests / submitted tasks / service requests
  - provide reliable services
    - guarantee SLA (Service Level Agreement)
  - manage large amount of data
    - data for search engine / data mining / business intelligence
  - Involve in large sets of (distributed) resources
    - 10,000+ computing resources
  - Some or all of the above

Why do we need large scale system?

- Online services are mandatory
  - Online Registration system
  - Online Ticketing system
- Internet allows business to reach more customers at all time
  - Internet banking
  - eGovernment

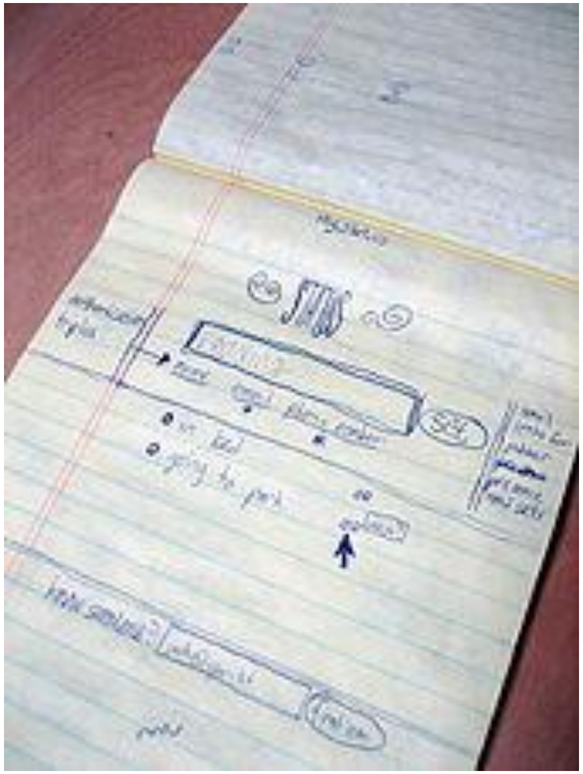


Why do we need large scale system?

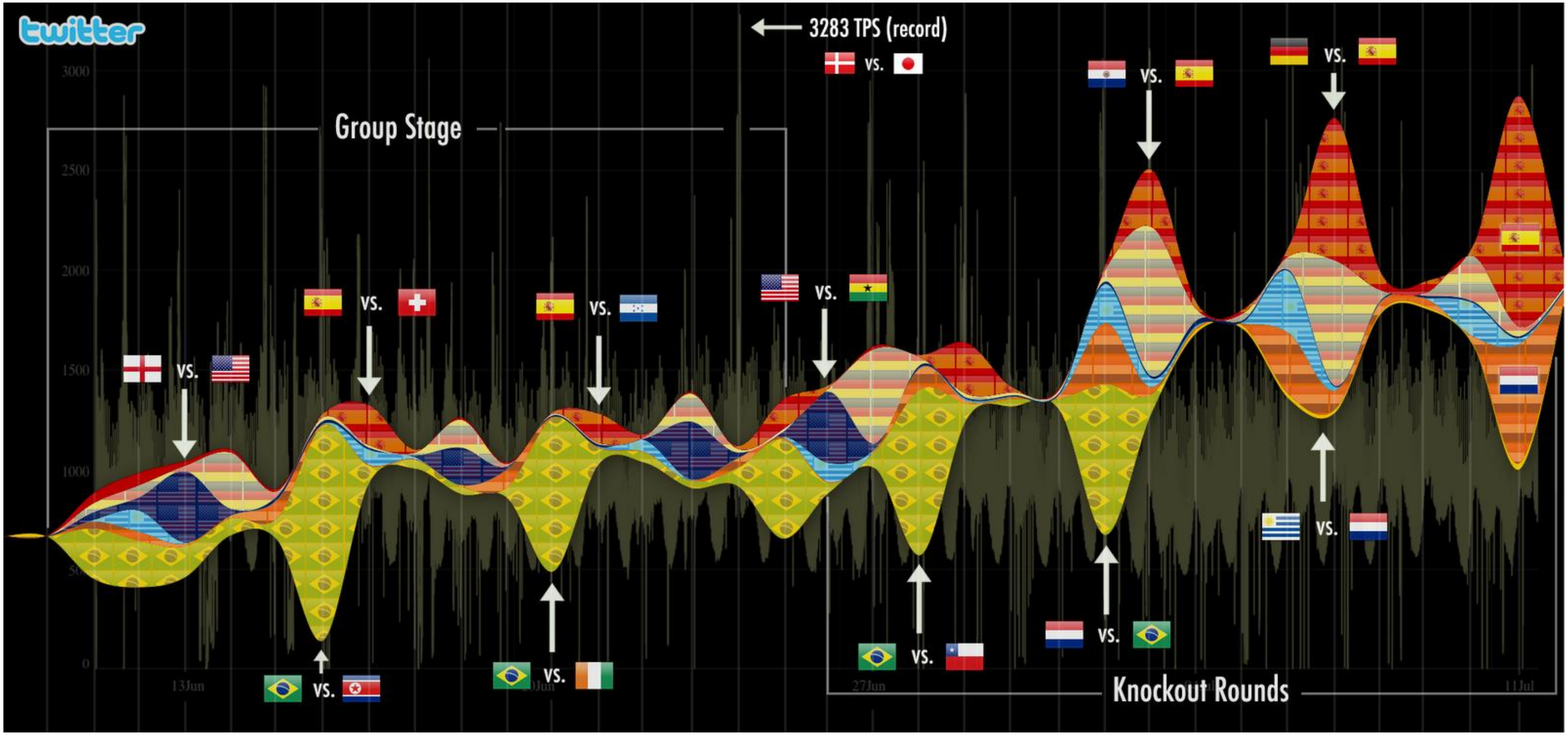
- The booming of social networks and online services
  - Facebook serves 570 billion page views per month
  - YouTube reaches 1 billion viewers per day (>10,000 views per second)
  - Amazon has more than 55 million active customer accounts
  - Playfish has more than 10 million players a day

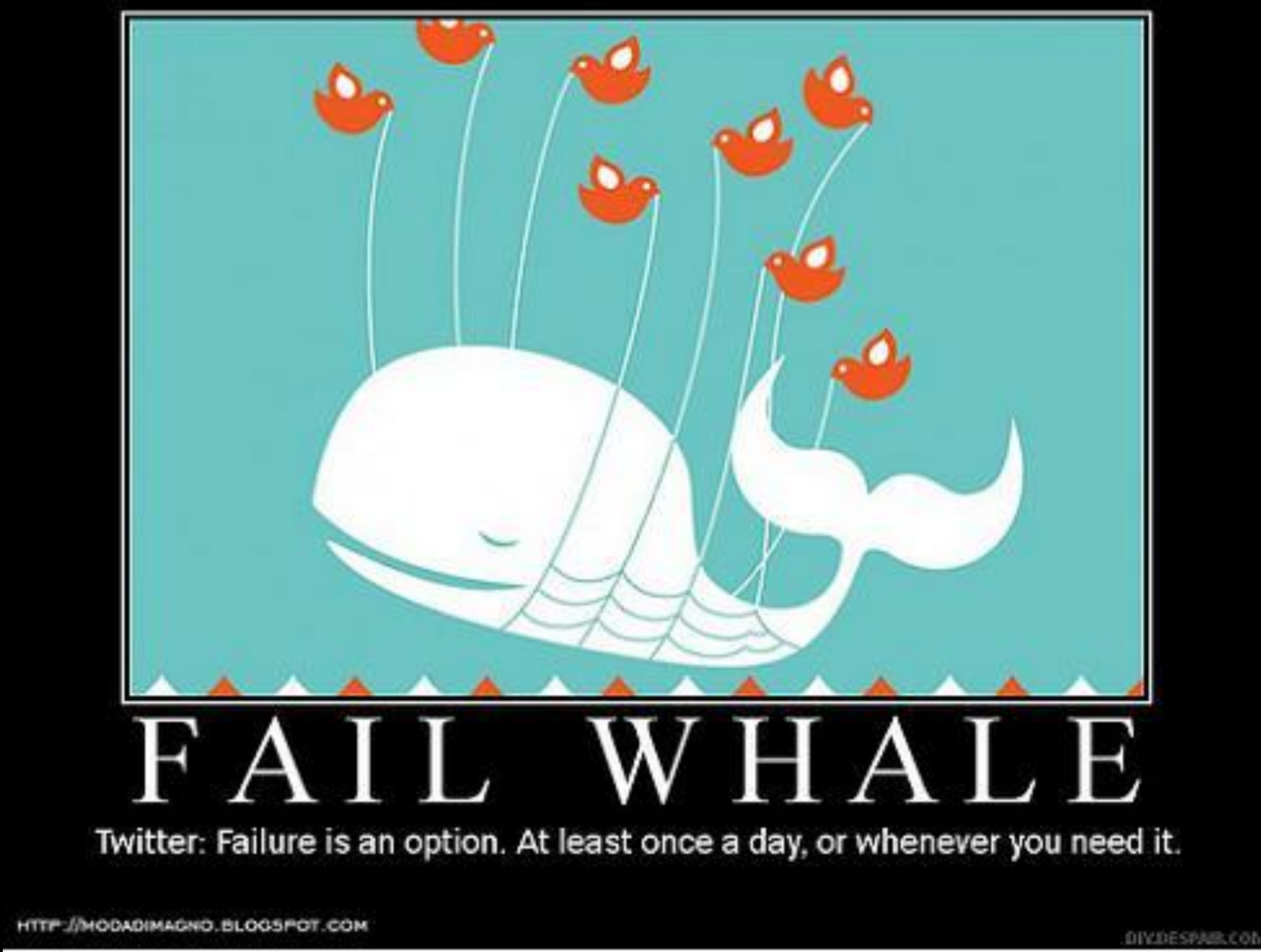
Real World Example: Twitter

- SMS of the Internet
- Sending short 140-character message to followers
- Start in 2006
- From 120,000 tweets/month (in 2007) to 1,500,000,000 tweets/day (in 2010) - 750 tweets/second
- 300,000 new subscribers a day
- Just reach 20,000,000,000 tweets in July 31st, 2010 (a Japanese graphic designer)



Twitter vs. World Cup 2010




FAIL WHALE
Twitter: Failure is an option. At least once a day, or whenever you need it.
HTTP://MODADIMAGNO.BLOGSPOT.COM
DIY.DESPAIR.COM

Real World Example: Fastest Computer in the World

- Tianhe-1A (China)
  - 2.5 petaFlops (sustained)
  - CPUs
    - 14,336 Xeon X5670
    - 7,168 Nvidia Tesla
    - 2,048 NUDT FT1000
  - Memory: 262TB

Problems and Solutions

Requirements of Large Scale Computing Systems

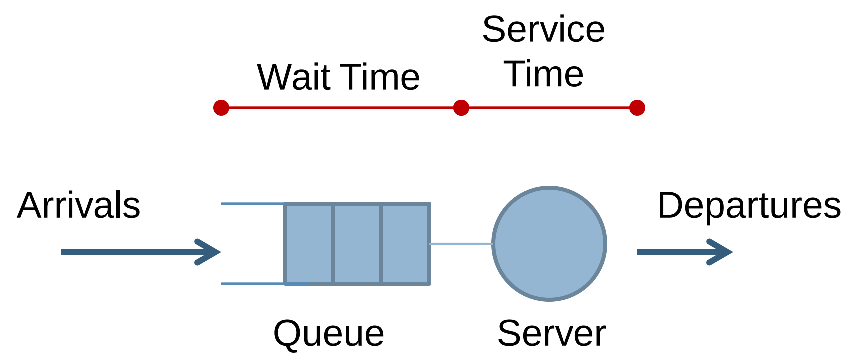
- Focus on throughput
- Need high-availability
- Must be scalable
- Simple to manage

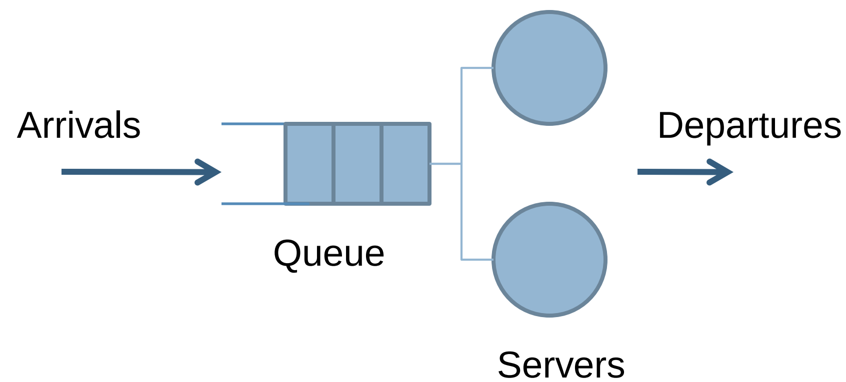
Throughput Oriented

- When you have many users, throughput is as important as service time
  - Upgrading systems allows system to serve requests faster (shorter service time + more throughput)
  - Adding more resources allows system to serve more requests (same service time + more throughput)
  - Similar to pipeline technique

Delay vs. Throughput

- Example: customers using ATM service
- Suppose there are 2 workloads
  - light = every 5 mins, 1 custs arrive
  - heavy = every 5 mins, 2 custs arrive
- 2 server types
  - slow = each customer spends 2 mins
  - fast = each customer spends 1 min
- Consider 3 cases
  - Case 1: single slow ATM
  - Case 2: single fast ATM
  - Case 3: two slow ATMs





Delay vs. Throughput

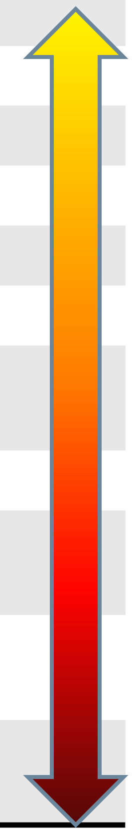
Case	Light Workload			Heavy Workload		
	Wait	ATM	Total	Wait	ATM	Total
1. One slow ATM	1m 20s	2m	3m 20s	8m	2m	10m
2. One fast ATM	20s	1m	1m 20s	40s	1m	1m 40s
3. Two slow ATMs	5s	2m	2m 5s	23s	2m	2m 23s

Availability

- System must be able to provide services for certain period of time
- There are 2 possible status: uptime and downtime
- Downtime includes any time that user cannot use or access the system
  - Any failures
  - Maintenance period
- Availability = uptime / (uptime + downtime)

Availability

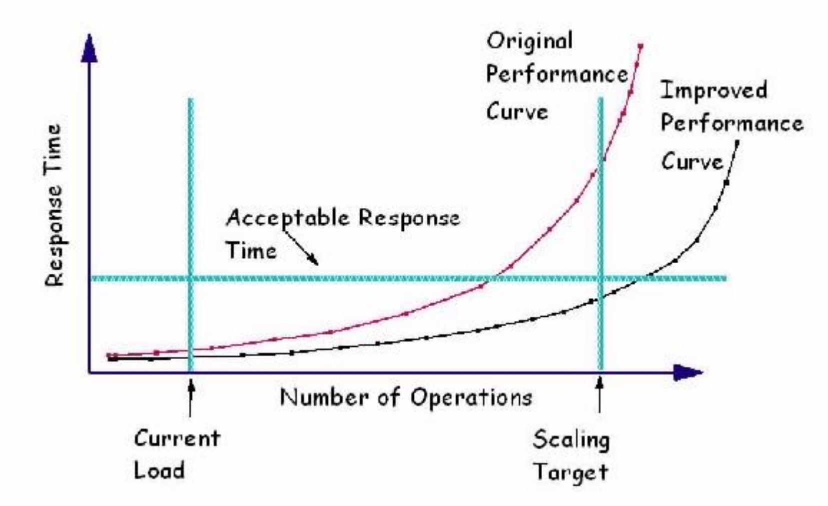
Availability %	Downtime per year	Downtime per month*	Downtime per week
90%	36.5 days	72 hours	16.8 hours
95%	18.25 days	36 hours	8.4 hours
98%	7.30 days	14.4 hours	3.36 hours
99%	3.65 days	7.20 hours	1.68 hours
99.5%	1.83 days	3.60 hours	50.4 min
99.8%	17.52 hours	86.23 min	20.16 min
99.9% ("three nines")	8.76 hours	43.2 min	10.1 min
99.95%	4.38 hours	21.56 min	5.04 min
99.99% ("four nines")	52.6 min	4.32 min	1.01 min
99.999% ("five nines")	5.26 min	25.9 s	6.05 s
99.9999% ("six nines")	31.5 s	2.59 s	0.605 s

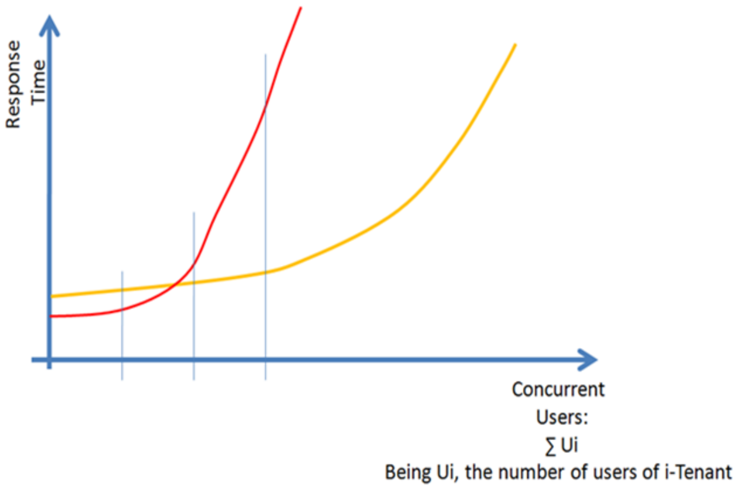


Budget

Scalability

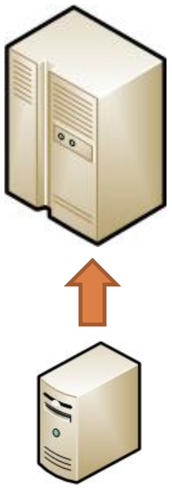
- The ability to either handle growing amounts of work in a graceful manner or to be enlarged
  - If we have more users, can we add some resources to the system to support the user's growth ?





Scalability Approaches

- Scale-Up (Vertical scale)
  - Adding more resources without changing number of servers
  - Simple, but can be expensive (sometimes)
- Scale-Out (Horizontal scale)
  - Increase number of servers
  - All servers are usually identical
  - More cost effective, but require the right design + hardware support



Manageability

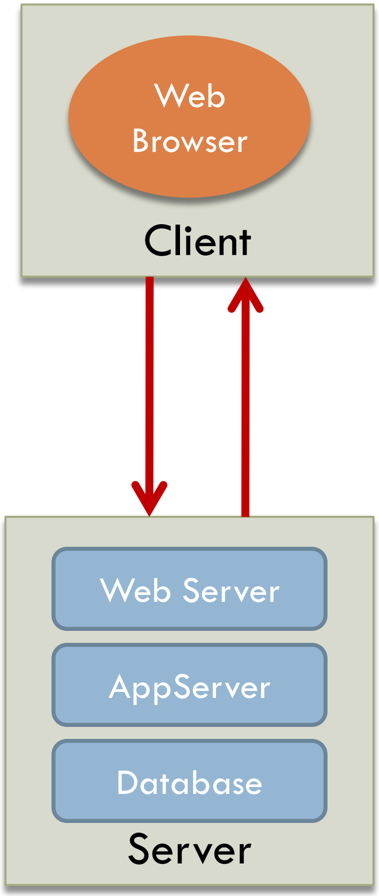
- Operational
  - Monitoring
  - Cooling issues
- Cost
  - Electricity
- Maintainability
  - How difficult is it for the admin to deploy, maintain, and upgrade the system ?

Design Principles

- Workload Partitioning
- Relaxed Data Consistency
- Effective Resource Management
- Memory/Storage Hierarchy

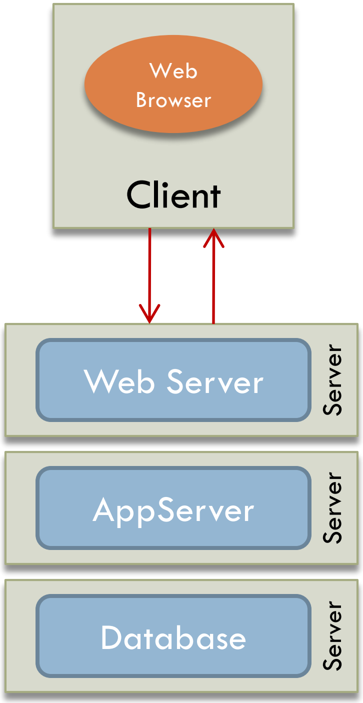
Workload Partitioning

- We can improve performance by distributing workloads to many servers
- Two possible approaches
  - Vertical partitioning
  - Horizontal partitioning



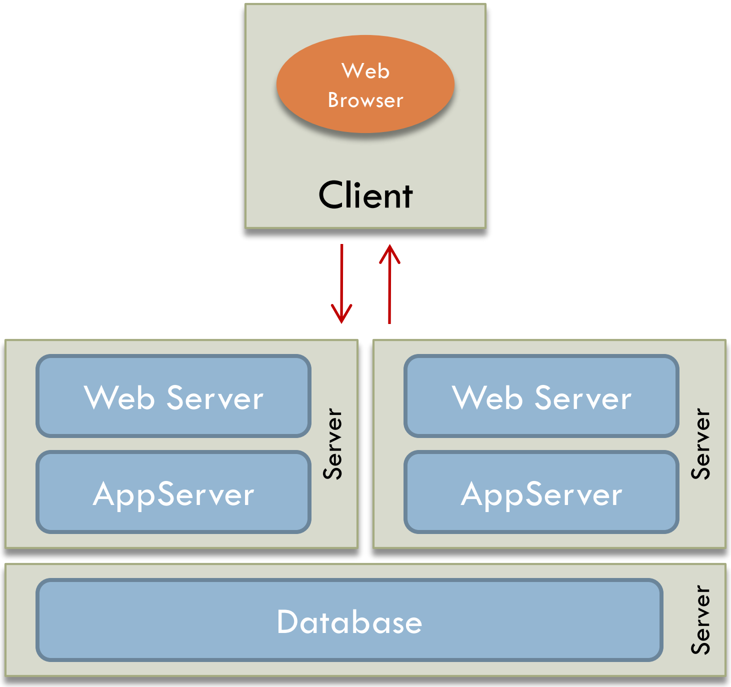
Vertical vs. Horizontal Partitioning

Vertical Partitioning



Simple, but limited

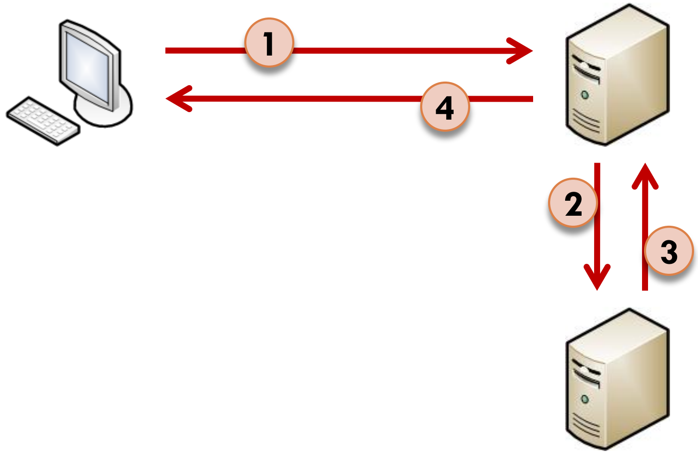
Horizontal Partitioning



Improve availability, may require special hardware

Relaxed Data Consistency

- Systems with multiple data sources usually require strong consistency
  - All servers must have the same data (user can send request to any server and expect the same result)
  - Consistency algorithm slows down the entire system



What if we have 10,000 servers?

Relaxed Data Consistency

- Some services can rely on relaxed data consistency
  - Data on all servers are not require to be exactly the same at all time
  - Still perform data consistency algorithm, but at less frequent periods
  - Google search engine (400,000 servers)
- Some services utilize data partitioning (data shards)
  - Data are distributed across multiple servers
  - Each data resides on only one server
  - Require intelligence hardware to distribute requests correctly
  - Used by many high-end relational databases

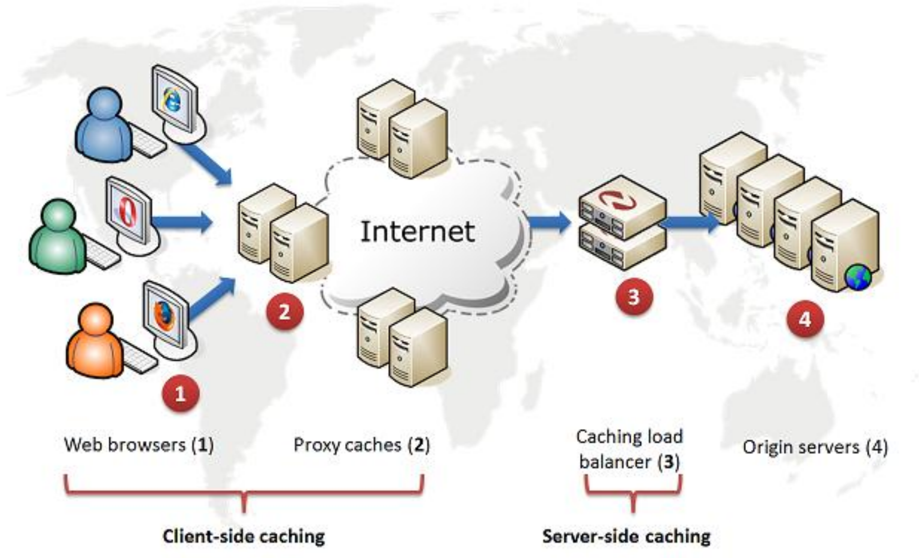
Effective Resource Management

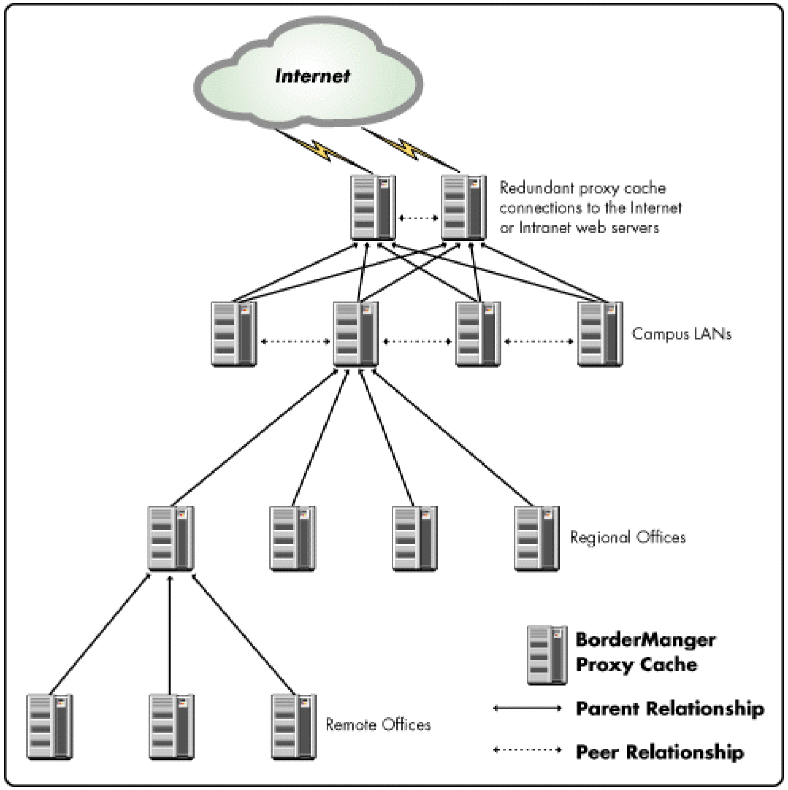
- Traditional transaction systems are synchronous and stateful operations
  - Synchronous operation holds server's resources until the operation is complete
  - Stateful operation occupies server's resources until user logouts
- Modern architectures rely on
  - Asynchronous operations
  - Stateless operation

Memory/Storage Hierarchy

- Large scale systems require data transfer across the networks
- Network latency is non-uniform by nature
  - Client usually has to connect to servers via WAN
  - LAN has shorter latency and more bandwidth than WAN
- Utilize caching system for latency reduction and bandwidth saving
  - Web Caching
  - Memcached (to be explained in other session)

Web Caching Structure



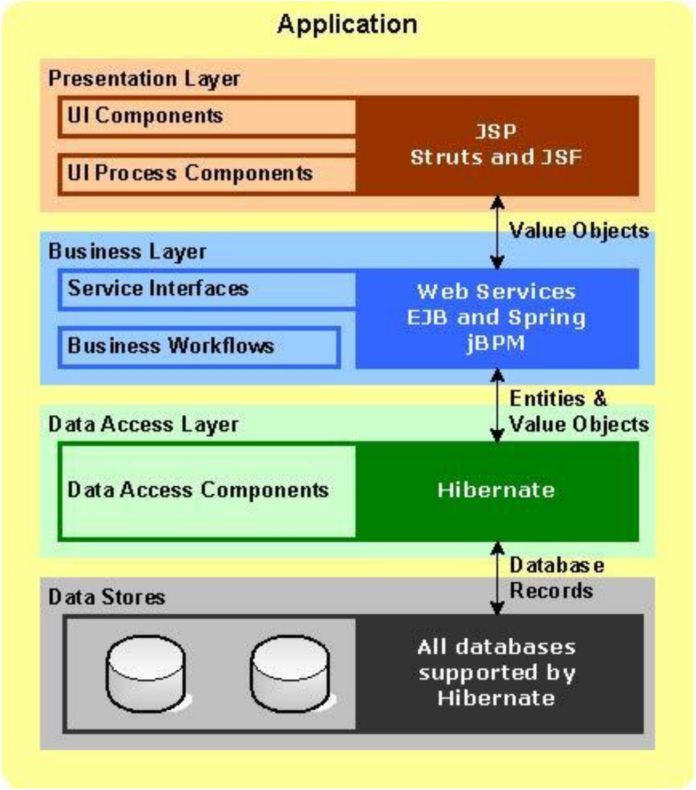


Architecture Patterns and Case Study

Popular Architecture Patterns

- Web Based Architecture
- Cluster Computing
- Peer-to-Peer Architecture
- Service Oriented Architecture
- Cloud Computing

Web Based Architecture

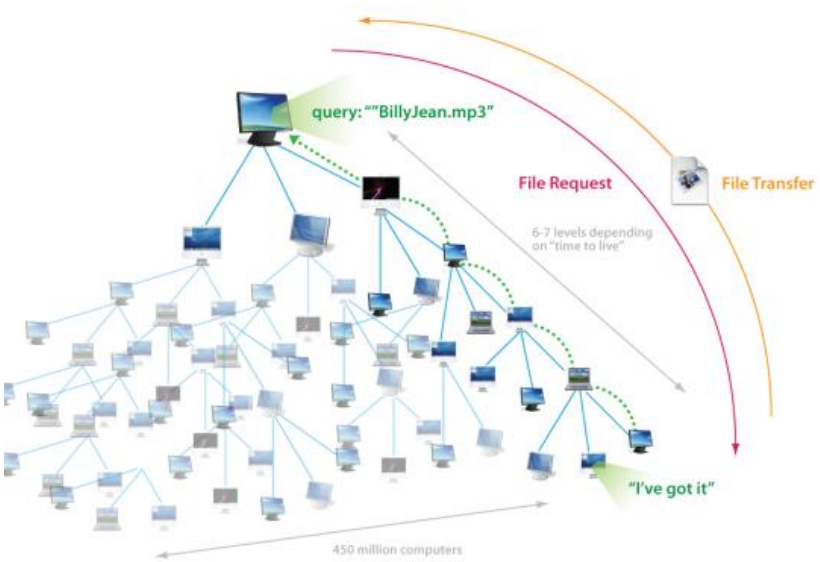


- Based on multi-tier architecture
  - Presentation
  - Business
  - Data Access
- Very popular and standard
  - A lots of frameworks

Cluster Computing

- Group of computers working together via network as a single computer
- Very popular and cost effective
  - Utilize COTS
  - Dominate top500

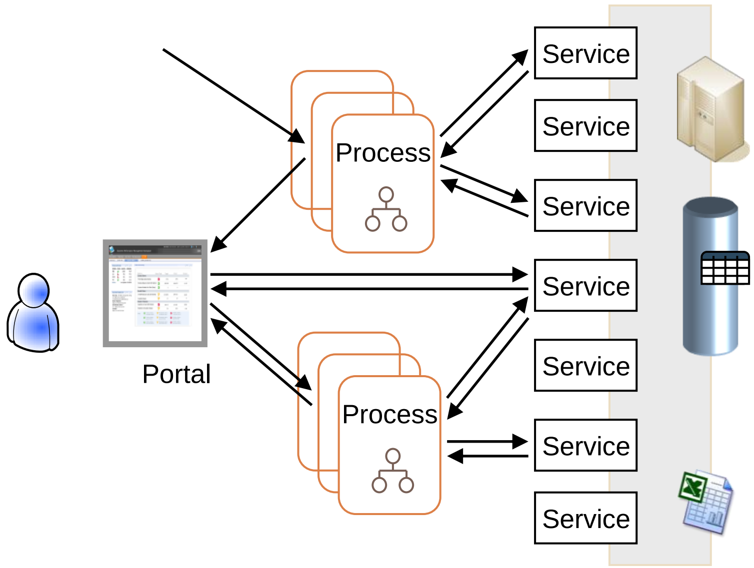
Peer-to-Peer Architecture



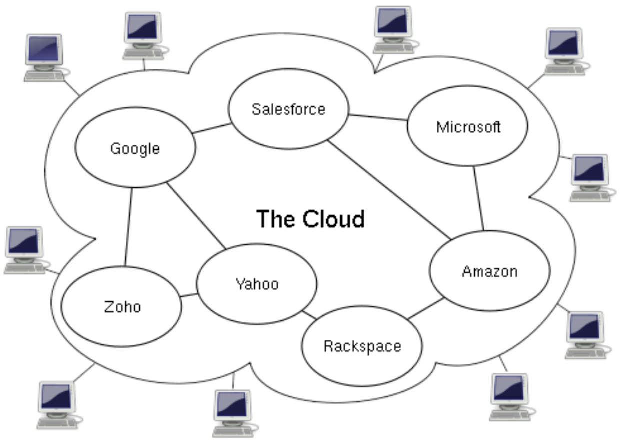
- All participants become both clients and servers
- Popular among data sharing
  - Napster
  - Bittorrent
  - P2P IPTV
- Require special P2P algorithms and structures

Service Oriented Architecture

- Very vague but popular architecture
- Everything is "service"
- Promise a lot of great things
  - Flexible
  - Extensible
- Not really deliver
  - Too complex

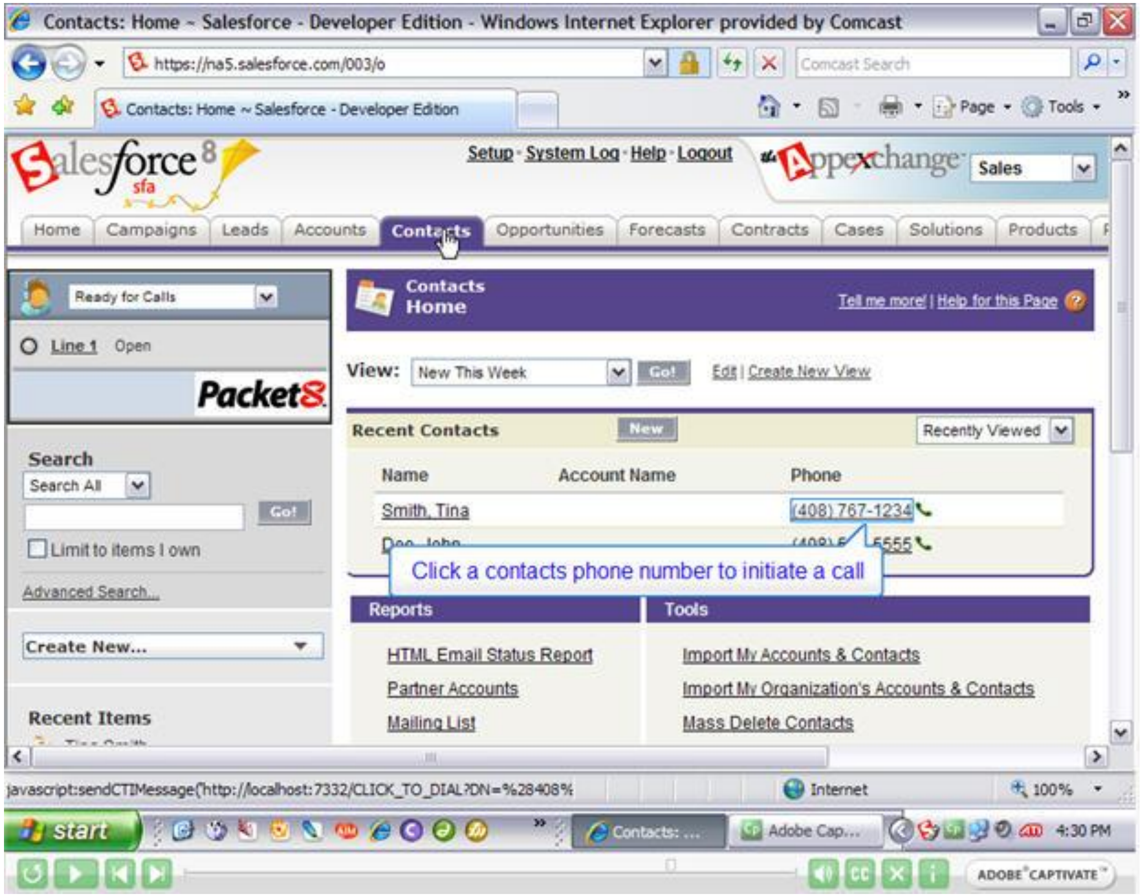


Cloud Computing

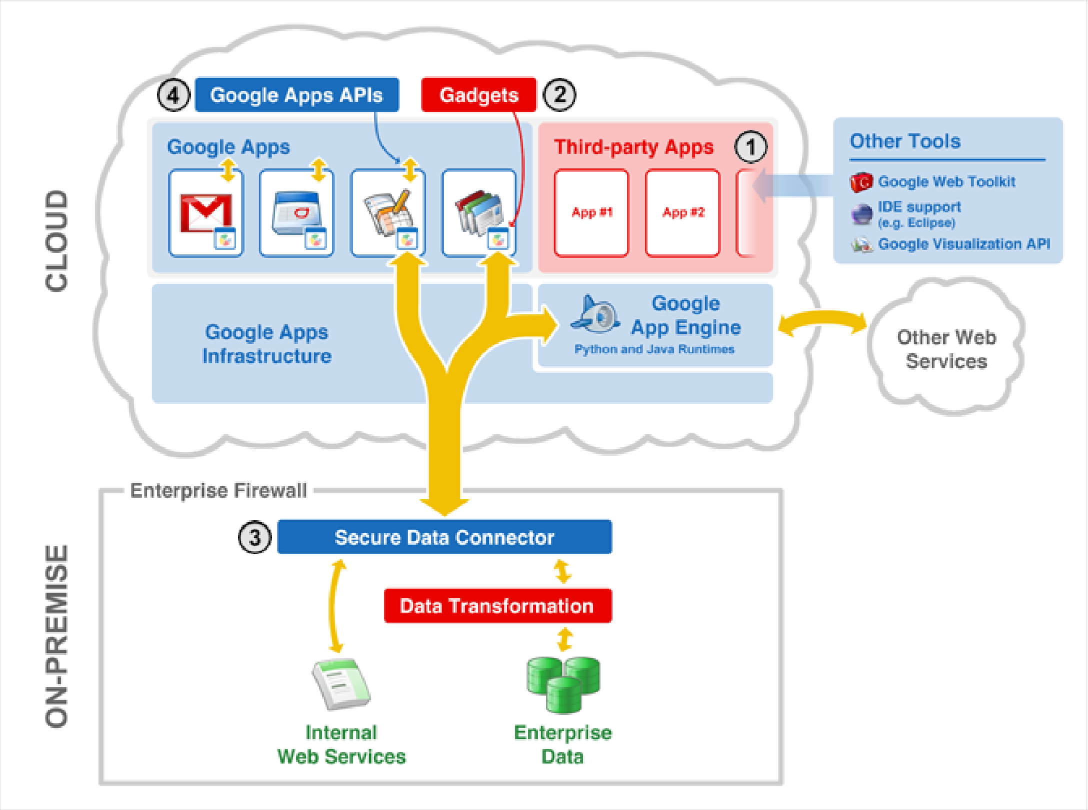


- Current trends
- Provide all infrastructures, resources and services via the Internet technology
  - (mostly) use web browser as a front-end
- Utilize resource sharing based on virtualization concepts
- Allow cheap "on-demand" resources and dynamic scalability

Sample Cloud Services



Sample Cloud Services



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