Scalability of web applications

Overview

- Scalability questions
  - What's important in order to build scalable web sites?
- High availability vs. load balancing
- Approaches to scaling
  - Performance tuning, horizontal/vertical scaling
- Multiple web servers
  - DNS based sharing, hardware/software load balancing
- State management
- Database scaling
  - Replication
  - Splitting things up

Scalability related questions

- Where is your session state being stored? Why?
- How are you generating dynamic content? Why?
- Are you regenerating things that could be cached?
- What is being stored in the database? Why?
- Could you be lazier?
  - Do you need exact answers? e.g. page 1/2063
  - Queue up work if it doesn't need to be done right now
    - e.g. Do the user really need that video thumbnail right now?
- What do you care about?
  - Time to market, money, user experience, uptime, power efficiency, bug density, …

High availability / load balancing

- High availability
  - Stay up despite failure of components
  - May involve load-balancing, but not necessarily
    - Hot standby = switched to automatically if primary fails
    - Warm standby = switched to by engineer if primary fails
  - Easy component updates
    - e.g. Avoid maintenance windows in the middle of the night
- Load balancing
  - Combining resources from multiple systems
  - Send request to somebody else if a certain system fails
  - May provide high availability, but not necessarily
    - e.g. Adding a single-point of failure load balancing appliance

Availability 9s

Availability %		Downtime per year
90%	"one nine"	36.5 days
99%	"two nines"	3.65 days
99.9%	"three nines"	8.76 hours
99.99%	"four nines"	52.56 minutes
99.999%	"five nines" "carrier grade"	5.25 minutes
99.9999%	"six nines"	31.5 seconds
99.99999%	"seven nines"	3.15 seconds

Approaches to scaling

- Make existing infrastructure go further
  - Classic performance tuning :
    - Find the bottleneck
    - Make faster (if you can)
    - Find the new bottleneck, iterate
  - How are you generating dynamic content? Why?
  - Where is your session state being stored? Why?
  - What is being stored in the database? Why?
  - Can you be lazier?
    - Do you need exact answers? e.g. page 1/2063
    - Add work to a queue if it doesn't need to be done right now
      - e.g. Do you need that video thumbnail before proceeding?

Approaches to scaling

- Vertical scaling (scale up)
  - Buy more memory, faster CPU, more CPUs, SSD disks
  - Quick fix, use existing software/network architecture
  - But there are performance limits
    - Also a price premium for high end kit

ABMX server, 1u
1 core @3.1 Ghz, 1GB memory, 80GB disk
$397

. . .

Oracle Exadata X2-8, 42u
160 cores @ 2.4Ghz, 4TB memory
14 storage servers, 168 cores, 336TB
1.5M database I/O ops/sec
$1,650,000

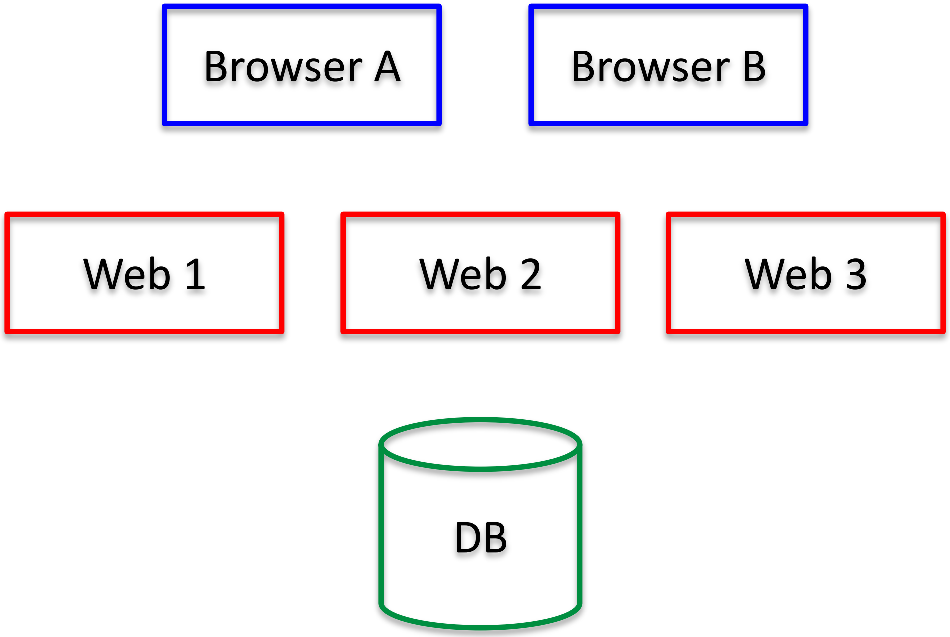
Approaches to scaling

- Horizontal scaling (scale out)
  - Buy more servers
  - Well understood for many parts
    - Application servers (e.g. web servers)
    - But may require software and/or network changes
  - Not so easy for other parts
    - Databases

http://www.flickr.com/photos/intelfreepress/6722296265/

One web site: many servers

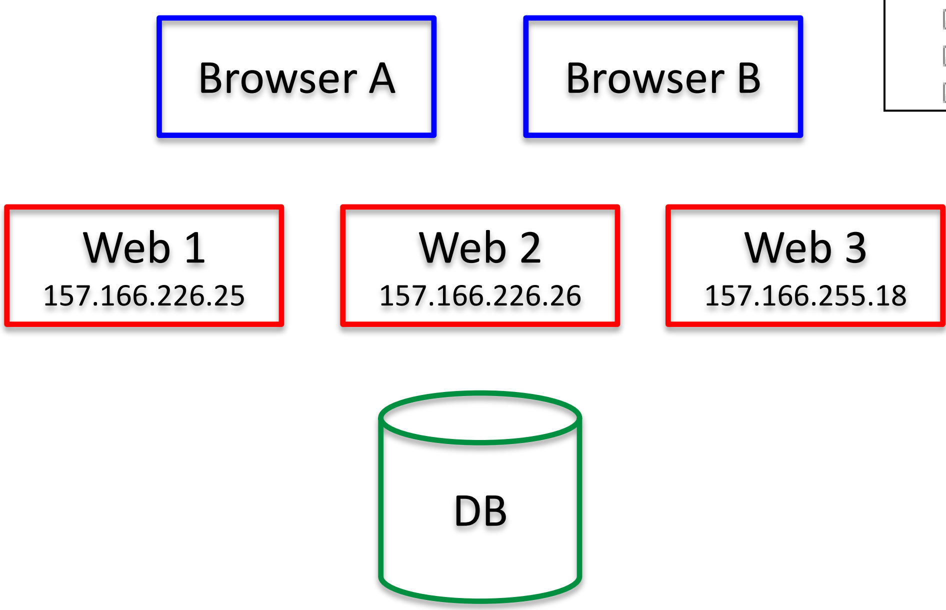
- How does the user arrive at a particular server?
  - Does the session need to "stick" to same web server?
    - Very important depending on how app manages state
    - e.g. using PHP file-based session state
  - What happens if web server crashes?
  - Users would prefer a geographically nearby server



Round robin DNS

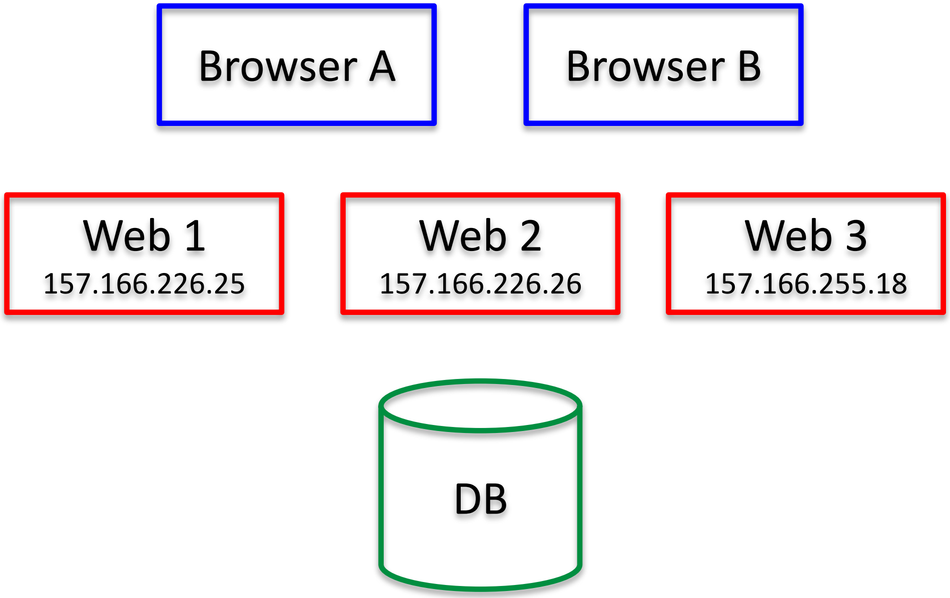
- Round robin DNS
  - Multiple IP addresses assigned to a single domain name
  - Client's networking stack chooses which to connect to

```
⊟ Queries
  ⊟ cnn.com: type A, class IN
      Name: cnn.com
      Type: A (Host address)
      Class: IN (0x0001)
⊟ Answers
  ⊞ cnn.com: type A, class IN, addr 157.166.226.25
  ⊞ cnn.com: type A, class IN, addr 157.166.226.26
  ⊞ cnn.com: type A, class IN, addr 157.166.255.18
```



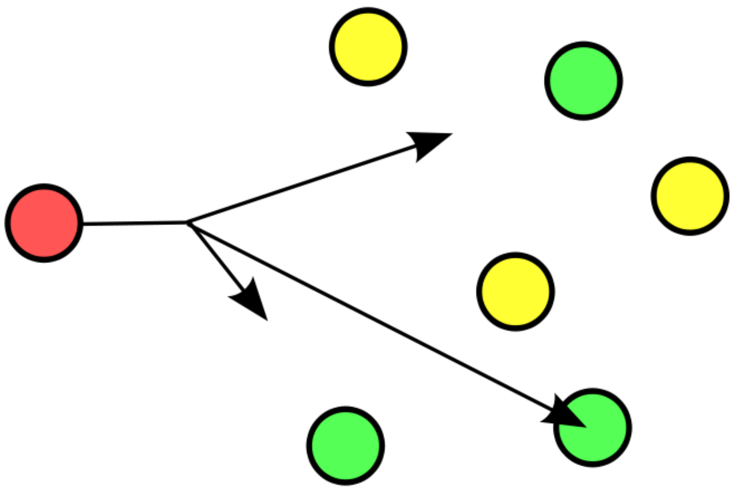
Round robin DNS

- Round robin DNS
  - Simple and cheap to implement
    - No specialized hardware, using existing DNS infrastructure
  - Problems:
    - DNS has no visibility into server load or availability
    - In simplest configuration, each web server requires an IP address
    - Users may end up on a distant server with high latency



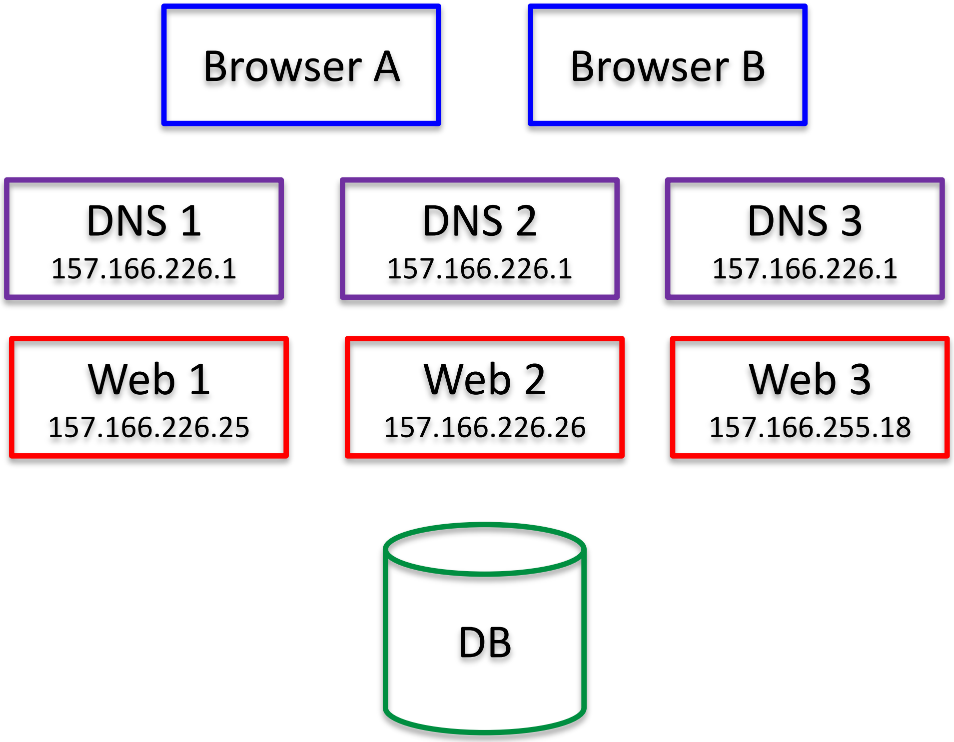
Anycast + DNS

- Goal: Get users to the "closest" server
- Anycast = multiple servers with same IP address
  - Routing protocols determine best route to shared IP
  - Best suited for connectionless protocols
    - e.g. UDP



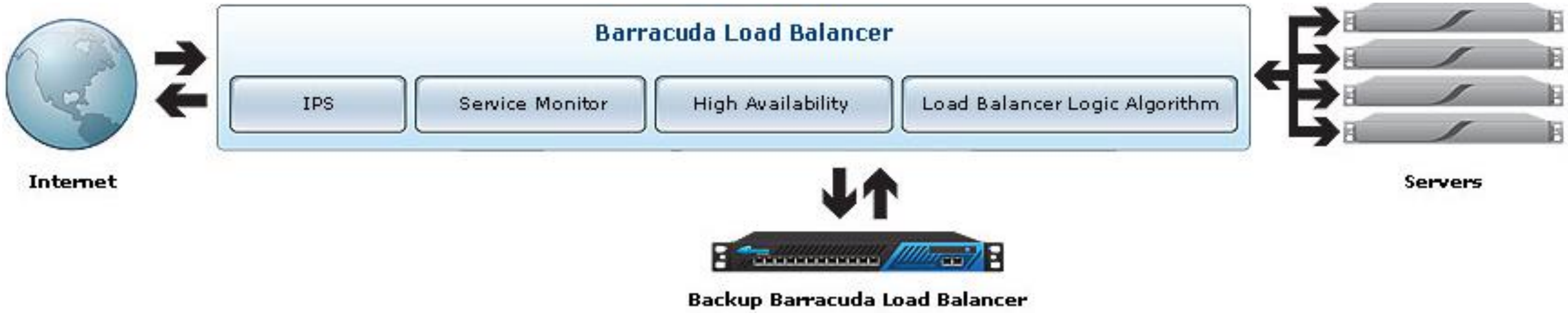
Anycast + DNS

- Multiple clusters
  - Place a DNS server next to each web cluster
    - Each DNS server has same IP address via IP Anycast
    - DNS gives out IP addresses of servers in its cluster
  - Anycast routes client to "closest" DNS server
    - DNS servers routes client to "closest" server farm

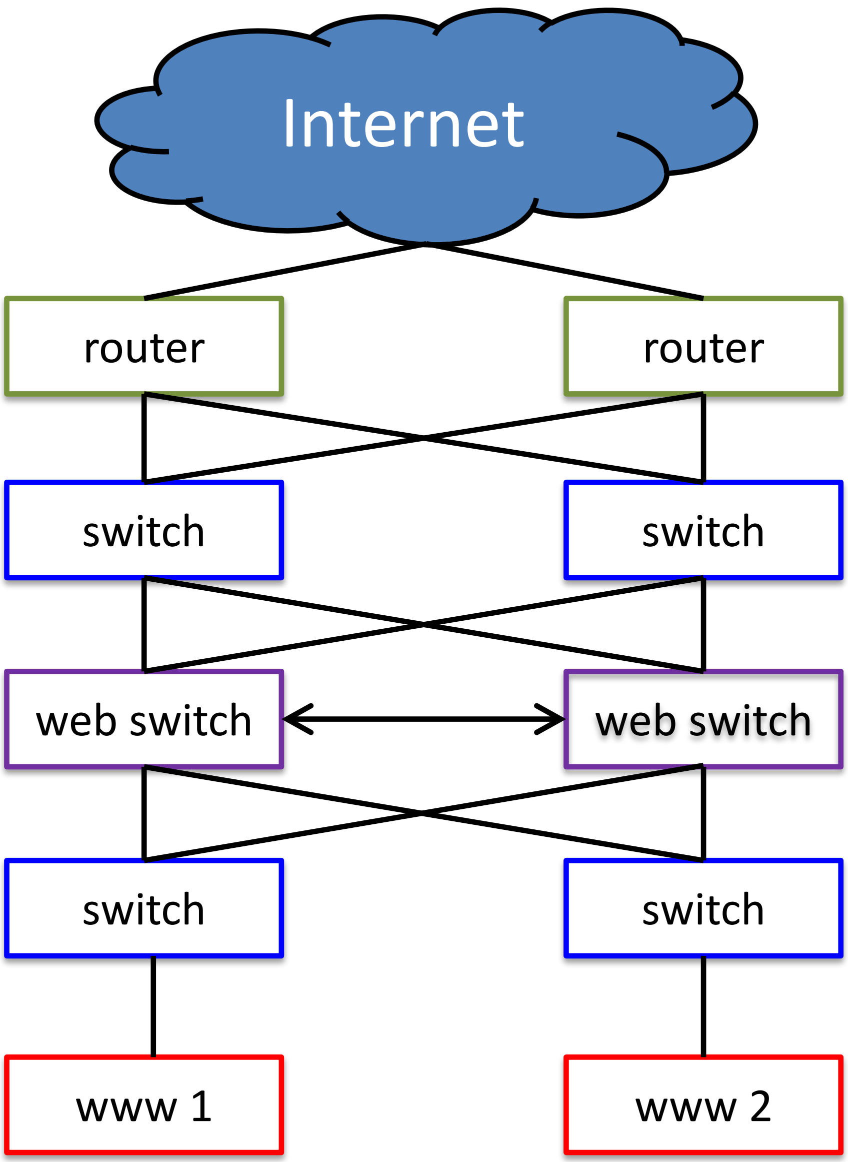


Load balancers

- Load balancers (web switches)
  - Hardware or software (e.g. mod_proxy_balancer, Varnish)
  - Like a NAT device in reverse
    - People hit a single public IP to get to multiple private IP addresses
  - Introduces a new single point of failure
    - But we can introduce a backup balancer
    - Load balancers monitor each other via a heartbeat
  - How to distribute load?
    - Round robin, least connections, predictive, available resources, random, weighted random



Load balanced, no single point of failure



Load balancer, some features

- Session persistence
  - Getting user back to same server (e.g. via cookie/client IP)
- Asymmetric load
  - Some servers can take more load than others
- SSL offload
  - Load balancer terminates the SSL connection
- HTTP compression
  - Reduce bandwidth using gzip compression on traffic
- Caching content
- Intrusion/DDoS protection

Software load balancer

- Apache server running mod_proxy_balancer
  - One server answers user requests
  - Distributes to two or more other servers

```
<Proxy balancer://mycluster>
BalancerMember http://192.168.1.50:80
BalancerMember http://192.168.1.51:80
</Proxy>
ProxyPass /test balancer://mycluster
```

Example configuration without sticky sessions.

```
Header add Set-Cookie
"ROUTEID=.%{BALANCER_WORKER_ROUTE}e; path=/"
env=BALANCER_ROUTE_CHANGED
<Proxy balancer://mycluster>
BalancerMember http://192.168.1.50:80 route=1
BalancerMember http://192.168.1.51:80 route=2
ProxySet stickysession=ROUTEID
</Proxy>
ProxyPass /test balancer://mycluster
```

Example configuration with sticky sessions.

State management

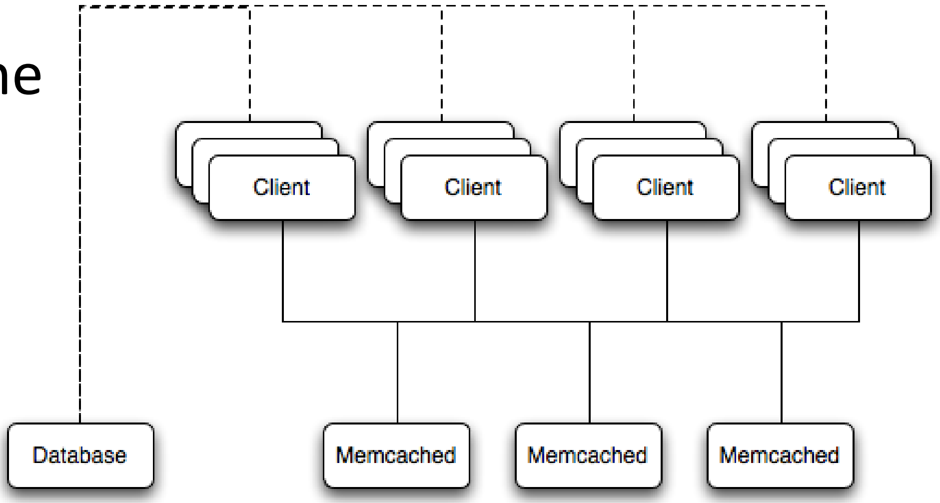
- HTTP is *stateless*, but user interactions often *stateful*
- Store session state somewhere:
  - Local to web server
  - Centralized across servers
  - Stored in the client
  - Some combination
    - Centralized but cached at closer level(s)

Local sessions

- Stored on disk
  - PHP temp file somewhere
- Stored in memory
  - Faster
  - PHP:
    - Compile with --with-mm
    - session.save_handler=mm in php.ini
- Problems:
  - User can't move between servers
    - Load balancer must always send user to same physical server
  - User's session won't survive a server failure
    - Switching to new server results in loss of client's state

Centralized sessions

- User can move freely between servers
  - But always need to pull info from central store
- Web servers can crash
  - User gets routed to another web server
- Approaches
  - Shared file system
  - Store in a database
  - Store in an in-memory cache
    - e.g. Memcached



No sessions

- Put all information in the cookie
- Browser "nodes" scale with your users
- Concerns:
  - User may delete cookie
  - User may modify cookie
  - Limits on amount of data
  - Local to the browser, user may use multiple browsers

Database scaling

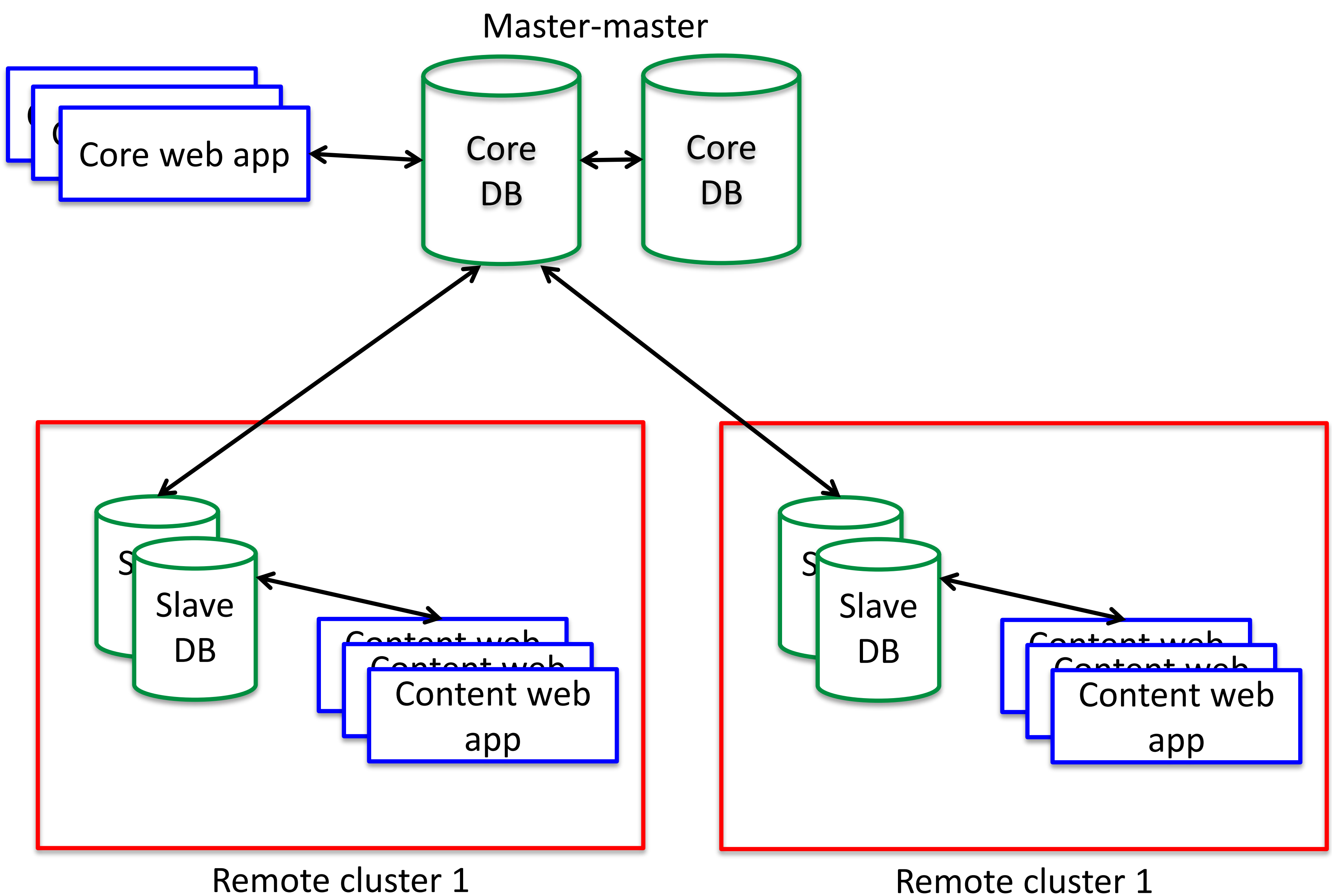
- Scaling databases is hard
  - Distribute among many servers and maintain performance
  - DB must obey ACID principles:
    - Atomicity - transactions are all or none
    - Consistency - transactions go from one valid state to another
    - Isolation - no transaction can interfere with another one
    - Durability - on failure, information must be accurate up to the last committed transaction
  - ACID isn't too hard/expensive on a single machine:
    - Shared memory, interthread/interprocess synchronization, shared file system
    - Facilities are fast and reliable
  - Distribute over a LAN or WAN, big performance problems!

Database replication

- Multimaster replication
  - The "holy grail" of distributed databases
  - Group of DBs, updates can occur on any DB
  - BUT: doing this without loosening ACID, very expensive
    - Two-phase commit between all the nodes
      - Node attempting transaction notifies peers it is about to commit
      - Peer prepare transaction and notify node they are ready to commit
      - If everybody ready, node informs peers to commit
- Master-master replication
  - For high-availability, not scalability
  - Two servers connected via a low latency network

- Master-slave replication
  - Mods only occur on master, changes propagate to slaves
  - Can offer read-intensive applications linear speedups

Database example



Other database options

- Horizontal partitioning
  - Separate rows into separate tables
  - Spreads read/writes, improves cache locality
- Vertical partitioning
  - Split rows into multiple tables with fewer columns
  - Allows queries to scan less data
    - Unless you end up needing to do a join across tables
- Sharding
  - Separate rows onto separate databases
    - e.g. All customers west of the Mississippi
  - Must determine which shard customer belongs to
  - Trouble for queries/transactions involving multiple shards

Summary

- Scaling web sites
  - High availability != load balancing
  - Scale vertically
  - Scale horizontally
    - More application servers
    - Balanced via DNS/hardware/software
    - Session management becomes harder
  - The database is usually the big problem
- Possible paper topic:
  - Web farms at extreme scale
    - "The Datacenter as a Computer", Google
  - Alternatives to SQL, "NoSQL"
    - e.g. Google Bigtable, Amazon Dynamo, MongoDB