# Cloud Computing Is In Your Future

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# Cloud Computing is Utility Computing

Illusion of Infinite Computing Resources on Demand

- No up front commitment
- Pay for resources as needed

# Utility Computing Scenarios

- Outsource Your Infrastructure
- Occasional Need for Massive Computation
- No Need to Build to Peak Capacity
- Cloud-Bursting
- Software as a Service
- Data Close To Your Customer
- Internet Scale

# Flavors of Vendors

Platform as a Service

Software as a Service

Application as a Service

Cloud Appliance Vendors

# Platform as a Service

Google App Engine

Amazon EC2

Microsoft Azure

Force.com

Rackspace  Intensive

…

# Cloud Operating System

Abstracts the underlying infrastructure

Manages resources

# Classes of Platform Vendors

Scalability, Failover, Recovery

- Amazon
- Google / Force.com
- Microsoft

# Software as a Service

SQL Azure

Google Big Table

Amazon Simple DB

SharePoint Services

Azure Tables and Blobs

# Application as a Service

Hosted Exchange

Salesforce.com

Facebook

Gmail

Mozy

# Cloud Appliance Vendors

- Cisco Uniform Computer Service
- EMC ?
  - VMWare vCloud
- Dell PAN System

# Application as A Service

Hosted Exchange

Gmail

Salesforce.com

Mozy

# Economics

# Compelling Case

SMB Applications

Massive Computation Needs

No Need to Build to Peak Capacity

Cloud Bursting

Software as a Service

~~Data Close To Your Customer~~

~~Internet Scale~~

# Economic Conditions

Pricing

Service Level Agreement (SLA)

# Azure Platform Pricing

- Compute $0.12 per hour
- Storage $0.15 per GB month
- Storage Transactions $0.01 per 10K
- Bandwidth
  - $0.1 in per GB
  - $0.15 out per GB
  - Within the datacenter is free

# SQL Azure

Up to 1 GB database $9.99 /month

Up to 10 GB database $99.99 / month

Bandwidth

- 0.1 in per GB
- 0.15 out per GB

# SMB Data Costs

10 GB SQL Database

2 GB a month data in, 4 GB a month data out

$100.77 a month

A SAN can cost from $30-40,000

25 year equivalent

Infrastructure employee costs about $500,000 /year

Does not consider cost of software licenses.

# SMB Compute Costs

$1051 per year for one compute process with no idle time

$31.53 if you did a storage save every second

$3600 per year 2 TB of disk storage

About $5000 / year

Employee and licensing costs not considered

# Utility SLA

| | | 2007 | | 2008 |
|---|---|---|---|---|
| | Goal | Actual | Goal | Actual |
| Calls Answered Within 30 Seconds | 80% | 84.64% | 80% | 85.47% |
| Average # Service Interruptions Per Customer | 1.373 | 1.027 | 1.373 | 1.051 |
| Average # Min Without Power Per Customer | 168.69 | 82.61 | 168.69 | 78.55 |
| Service Appointments Met | 87.78% | 98.52% | 88.37% | 98.73% |
| Actual Meters Read "on cycle" vs estimate | 93.15% | 98.75% | 93.15% | 99.05% |
| Complaint Cases Per 1000 Customers | 1.496 | .974 | 1.496 | 1.080 |

Utility Availability: 99.98%

# Outages

Google Asia

Gmail Outages

Amazon Outages

# Announced Azure SLA

Computation: 99.95% up time

SQL Azure: 99.9% up time

Penalties not announced

Google, Amazon, have no real penalties

# Technology

# Utility Computing Scenarios

Outsource Your Infrastructure

Occasional Need for Massive Computation

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# Latency Exists

Speed of light in fiber optic cable: 124,000 miles per second

A ping Japan from Boston takes 100 ms.

Real number is about 250 ms.

Fetch 10 images for a web site:  1 second

Ignores Latency of the operation

# Bandwidth is Limited

Shannon's Law: $C = B \log_2 (1 + S / N)$

Capacity = bit / second

Bandwidth (hertz)

S/N  * 5 to  double capacity given bandwidth

# Latency is Not Bandwidth

Size of the shovel vs. how fast you can shovel

Infinite shovel capacity(bandwidth) is limited by how fast one can shovel (latency).

# Great Bandwidth, Poor Latency

Buy a two terabyte disk drive

Put it in a car and drive to New York

# Expensive to Move Data

Computational Power Gets Cheaper Faster than Network Bandwidth

Cheaper to compute where data is instead of moving it

*Distributed Computing Economics* Jim Gray

Want data to be close to where your customer is

# Connectivity is Not Always Available

Cell phone

Data Center Outages

Equipment Upgrades

Data redundancy to improve reliability

# Waiting for Data Slows Computation

Partition Your Data to Improve Performance

Partition Your Data to Achieve Internet Scale

Data Naturally Lives In Multiple Places

Distributed Transactions Impede Throughput

Human Interaction

# Relational Databases Scale Up Not Out

- Relational Databases scale well on a single node or cluster
  - Complexity of relations
  - Query plans with hundreds of options the query analyzer evaluates at runtime
  - Normalization
  - ACID Transactions
- Two Phase Commit guarantees consistency if you have infinite time
- Quick scale up difficult with hardware upgrade

# Economics Dictate Scale Out Not Up

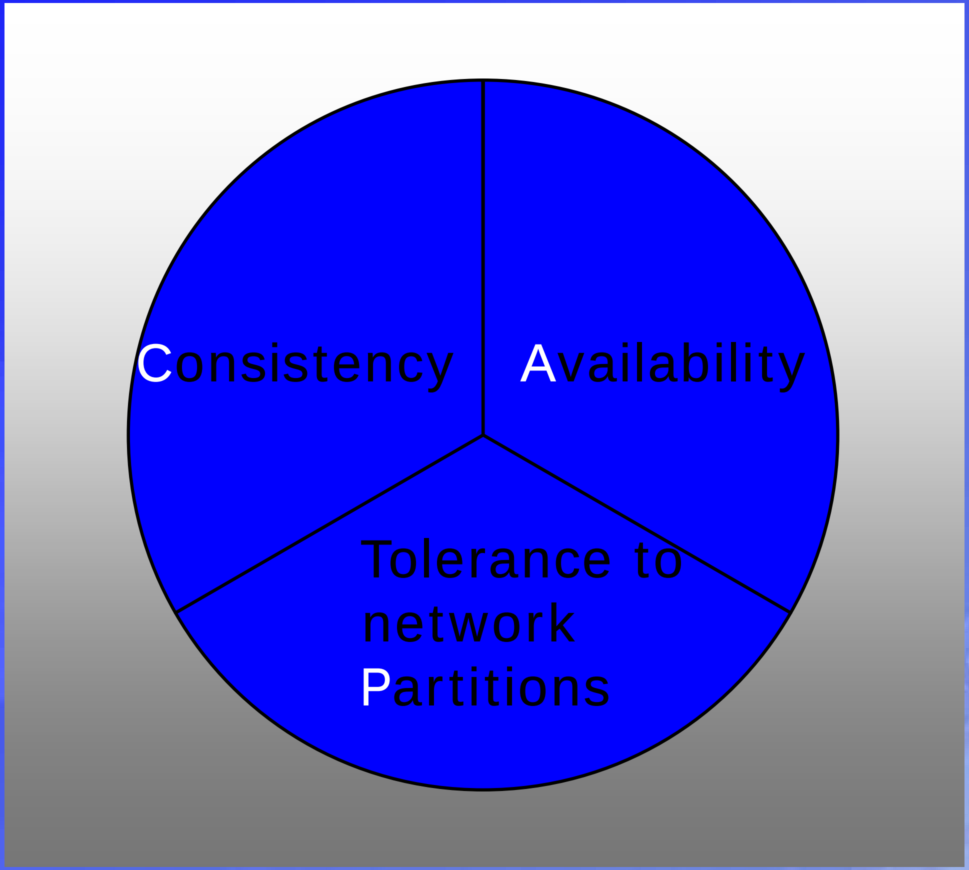
Cheap, commodity hardware argues for spreading load across multiple servers

How do you distribute data among several databases?

How do you achieve consistency?

How do you achieve throughput with distributed transactions?

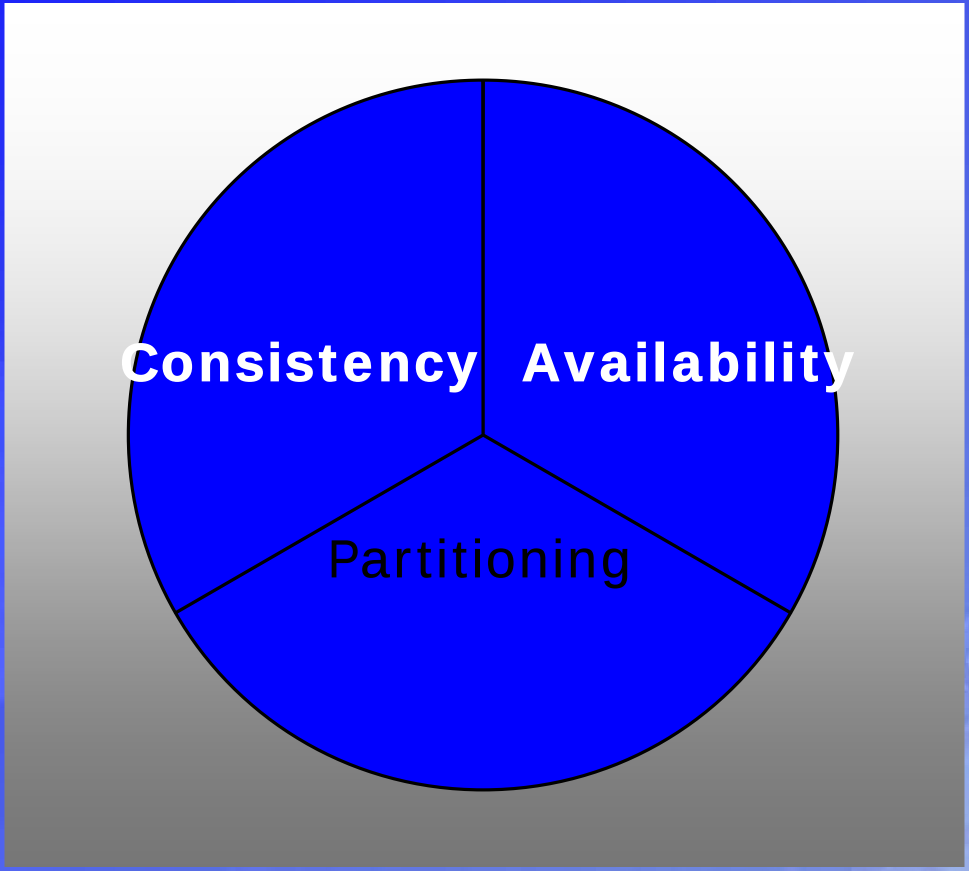
# CAP Theorem




Can Have Any Two

Eric Brewer, UC Berkeley, Founder Inktomi
http://www.cs.berkeley.edu/~brewer/cs262b-2004/PODC-keynote.pdf

# Consistency and Availability




Single site Database

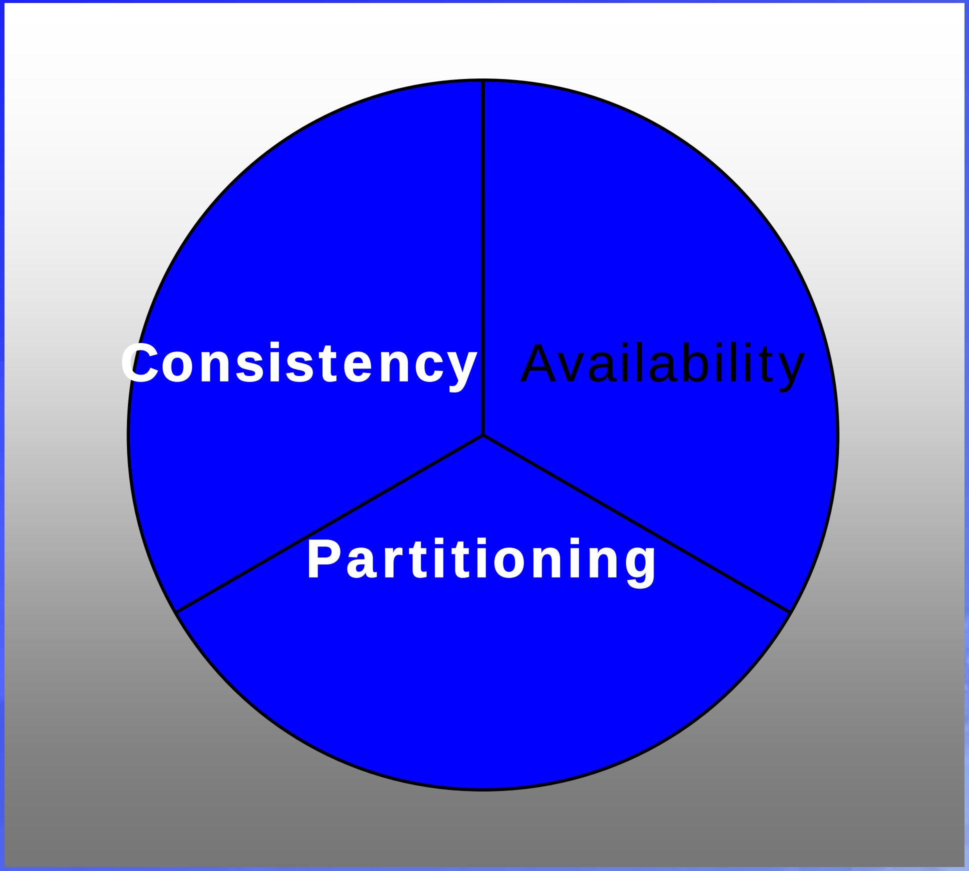
Database Cluster

LDAP

Two phase commit

Validate Cache

# Consistency and Partitioning



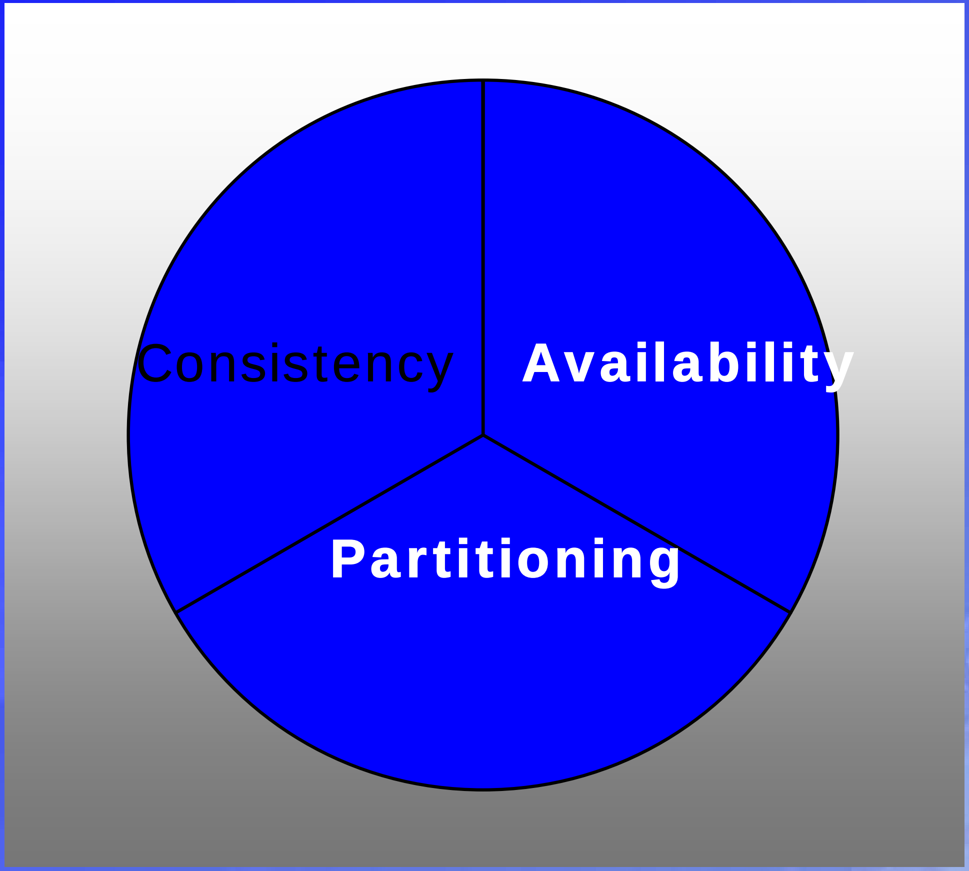

Distributed Database

Distributed Locking

Pessimistic Locking

Minority Partitions Invalid

# Availability and Partitioning




Forfeit Consistency

Google BigTable

Amazon Simple DB

Optimistic

Can Denormalize

No ACID transactions

Compensation

# Cloud Storage

- World of Consistency
  - Relational Database
- World of Internet Scale (Numbers or Geography)
  - Blobs, Tables, Queues

# Cloud Relational Databases

- SQL Azure
  - Revised to be SQL Server in the sky
    - Tables, Stored Procedures, Triggers, Constraints Views, Indices
    - Uses TDS (Tabular Data Stream) Protocol
  - Change connection string to get to another SQL Server
- MySQL, Sql Server, Oracle, etc. on Amazon VM

# Cloud Storage Services

Tables of key/value pairs for highly scalable structured storage

CRUD operations

No FK relations, Joins, Constraints, Schemas

Partition / Tables / Entities / Properties

Entity has Unique Row Key

# Cloud Storage Services

- Fit well with tens or hundreds of commodity servers
- Better mapping with objects than ORM
- No integrity constraints
- No joined queries
- No standards among vendors (lock in)
- Will Microsoft have query limits?
  - Amazon no query longer than 5 seconds
  - Google no more than 1000 items returned

# Car Table

| Key | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 | |
|---|---|---|---|---|---|
| 1 | Make: BMW | Color: Grey | Year 2003 | | |
| 2 | Make: Nissan | Color : Red<br>Yellow | Year: 2005 | Transmission: Easytronic | |
| 3 | Plane: Boeing | Color: Blue | | Engine: Rolls Royce | |

# Do You Need To Partition Your Data to Scale?

No Partitioning

Natural Partitioning

Partitioning for Availability

**If you have to partition to scale, how do you decide between availability and consistency ?**

# What is the Cost of an Apology?

Amazon

Airline reservations

Stock Trades

Deposit of a Bank Check

Deleting a photo from Flickr or Facebook

# Sometimes the cost is too high

Authentication

- SAML tokens expire

Launching a nuclear weapon

# Businesses Apologize Anyway

- Vendor drops the last crystal vase
- Check bounces
- Double-entry bookkeeping requires compensation
  - at least $13^{th}$ century
- Eventually make consistent

# State of the Software != State of the World

Software approximates the state of the world

It makes the best guess possible

Sometimes that is wrong

Other computers might have other opinions

Overturn software myths of the past 25 years.

# How consistent?

Business Decision

How much does it cost to get it absolutely right?

Computers can remember their guesses

Can replicate to share guesses

It may be cheaper to forget, and reconcile later

# Design For Eventual Consistency

- Identify objects by unique key (partition key / row key)
- Objects can move when repartitioning
- Cannot assume two objects remain on the same machine
- Data might go offline
- Transactions can only apply on per object basis
- Different computations might come to different conclusions
- Define message based workflows for ultimate reconciliation and replication of results

# Security in the Cloud

Identify Users and Applications

HIPAA, PCI, etc, compliance

Physical Security of Data

Access to Data

# Conclusions

Understanding Cloud Computing is about understanding

- Economics of cost and availability
- Need for Scalability

Architectural Implications

- Design for Eventual Consistency

Remember the 2 / 10 rule